Modelling Affect Regulation Dynamics (MARDy): A Computational Simulation of Affect Change

David Stuart Cameron

Department of Psychology
The University of Sheffield

Thesis submitted to the University of Sheffield in partial fulfilment of
The requirements of the degree of Doctor of Philosophy

January 2013

Abstract

This thesis explores the process of controlled affect regulation – the deliberate control of feelings and expressions – in terms of its dynamics. The thesis takes the perspective that affect is a dynamic and controllable process, regulated towards held goals, which themselves are controllable and dynamic. It is argued that affect regulation dynamics are underexplored, as are the dynamics of the related concepts of self-regulatory capacity and affect goal adjustment.

A model of affect regulation dynamics (MARDy) is presented, which integrates affect regulation, self-regulatory capacity, and affect goal adjustment, within a control theory framework. A computational simulation of the MARDy model is constructed and known trends in affect are simulated. The model further offers predictions of affect dynamics and understanding of underlying mechanisms involved.

Two studies are conducted to collect data for model representation. In Study 1, affect diary data are collected from five university staff and students. Parameter values for the model are derived from determining best fitting correlations of model results with the diary data across dimensions of felt-affect, self-regulatory capacity, felt-affect goals and affect-expression goals. In Study 2, affect diary data are collected from six teaching staff at a local primary school. This study extends beyond the first, to also incorporate data for affect-expressions. The capacity for the model to represent this second data set is assessed, using the protocol from Study 1.

In a third, simulated, study, the model is extended to represent a network of two individuals. Propositions regarding affect dynamics across the dyad are made and tested in simulation. Considerations are offered for dyad representation in the affect regulation literature.

The proposed dynamics of affect regulation, arising from model development and the three studies described, are discussed in terms of current literature; theoretical and practical implications of model results and propositions are discussed.

Acknowledgements

First, I would like to thank my primary supervisor, Peter Totterdell, who has given me invaluable guidance and support throughout the whole course of this thesis. In addition, I thank Karen Niven for taking on the role of second supervisor part way through the second year. Her friendship, enthusiasm, and advice are greatly appreciated. I thank them both for their continual encouragement, vital feedback, and ceaseless prompting for chapters; without which, I would not have completed this thesis.

I also thank David Holman for his support and supervision in the earlier stages of the project and thank Stuart Bennett for sharing his simulation designs and knowledge of control theory with me. I am grateful to have been part of the EROS research group and have always enjoyed the spirited discussions, the diverse research interests shared, and EROS gang drinks.

My thanks go to all participants in both diary studies, especially given the work required to keep diaries completed. Thanks as well to Sarah for help in recruiting participants for the second study.

I have been lucky enough to work within two great departments during my Ph.D. and my thanks go to all those at the Institute of Work Psychology and the Department of Psychology who have made this a memorable experience. In particular, thanks go to my past and present officemates and Jen, Mike, and Donny who have been available since CCN year to help take my mind off things.

Thanks to my family, who have unconditionally supported my decisions, helped me throughout my time as a student and have always been patient in listening to me talk about my work. Last, I thank Sarah again, for always being there, for listening, and for keeping me on track.

Publications and presentations arising from this thesis

Cameron, D. & Webb, T. (in press) Self-Regulatory capacity. In M. D. Gellman, & J. R. Turner (Eds.), *The Encyclopedia of behavioral medicine*. Springer.

Cameron, D. & Webb, T. (in press) Self-Regulatory fatigue. In M. D. Gellman, & J. R. Turner (Eds.), *The Encyclopedia of behavioral medicine*. Springer.

Cameron, D., Totterdell, P., Holman, D., & Bennett, S. (2009, October). Control Theory Model of Emotion Regulation: A Dynamic Model of Emotion. *In CD proceedings of 10th IFIP Working Conference on Virtual Enterprises*, Thessaloniki, Greece.

Cameron, D., Totterdell, P., Niven. K. (2012, May). *Changing what we want to feel: predictions arising from a model of affect regulation dynamics*. Paper presented at Consortium of European Research on Emotion, Canterbury, UK.

Contents

Chapter 1: Introduction **1**

1.1 Research Area 1

1.1.1 Affect as a Dynamic Process 3

1.1.2 Affect as a Controllable Process 4

1.1.3 Self-Regulation 5

1.2 Research Aims and Approach 7

1.3 Thesis Structure 8

Part 1 **12**

Chapter 2: Literature Review **12**

2.1 Felt-Affect and Felt-Affect Regulation 12

2.1.1 Felt-Affect Regulation 13

2.1.2 Automatic and Deliberate Felt-Affect Regulation 14

2.1.3 Affect Regulation as a Continual and Dynamic Process 16

2.2 Affect-Expression and Affect-Expression Regulation 17

2.2.1 From Feelings to Expression 18

2.2.2 From Expression to Feelings 18

2.2.3 Emotion Contagion 20

2.2.4 Controlled Expression Regulation 21

2.3 Effortful Self-Regulation 22

2.3.1 Limited Physical Resources 25

2.3.2 Self-Regulatory Capacity Restoration Dynamics 26

2.4 Goals and Affect Regulation 28

2.4.1 Affect Goals 29

2.4.2 Goal Adjustment 34

2.4.3 Affect Goal Dynamics 35

2.5 Summary 36

Chapter 3: Investigative Framework **39**

3.1 Introduction 39

3.2 Control Theory 39

3.2.1 Control Theory in Psychology 45

3.2.2 Application of Control Theory in Affect regulation 49

3.3 Computational Models 55
    3.3.1 Advantages of Computational Modelling 55
    3.3.2 Computational Models of Affect Regulation 59
3.4 A Control Theory Model of Affect Regulation Dynamics 64

Chapter 4: Model Design and Specification 67

4.1 Introduction 67
4.2 Felt-Affect Regulation 68
    4.2.1 Felt-Affect 68
    4.2.2 Felt-Affect Regulation 70
    4.2.3 Representing Felt-Affect 71
    4.2.4 Representing Felt-Affect Regulation 73
4.3 Affect-Expression Regulation 78
    4.3.1 Affect-Expression 78
    4.3.2 Affect-Expression Regulation 80
    4.3.3 Representing Affect-Expression 80
    4.3.4 Representing Affect-Expression Regulation 82
4.4 Self-Regulatory Resource Control 85
    4.4.1 Self-Regulatory Resources 85
    4.4.2 Representing Regulatory Resource 86
4.5 Regulation of Goal States 89
    4.5.1 Goal States 89
    4.5.2 Goal State Regulation 89
    4.5.3 Representing Goal States 90
    4.5.4 Representing Goal State Regulation 91
4.6 Noise and Parameter Variation in the Model 94
4.7 Summary 95

Chapter 5: Parameter Testing 96

5.1 Introduction 96
5.2 Theory for Model Testing 96
5.3 Model Testing 98
5.4 Component Testing 101
    5.4.1 Felt-Affect 102
    5.4.2 Felt-Affect Regulation 110
    5.4.3 Affect-Expression and Expressive-Feedback 117
    5.4.4 Affect-Expression Regulation 121

5.4.5 Regulatory Resource 126
5.4.6 Goal Adjustment 133
5.5 Summary 135

Part 2 **137**

Chapter 6: Validation Against Diary Data **137**

6.1 Introduction 137
6.2 Diary Data 137
6.3 Validation of the Model 143
6.3.1 Individual Specificity 148
6.3.2 Temporal Specificity 155
6.3.3 Relational Representation 159
6.4 Comparison with Human Predictions 161
6.5 Summary and Discussion 162

Chapter 7: Model Validation Against a Second Data Set **165**

7.1 Introduction 165
7.2 Diary Data 166
7.3 Validation of the Model 170
7.3.1 Individual Specificity 172
7.3.2 Temporal Specificity 182
7.3.3 Relational Representation 185
7.4 Summary and Discussion 187

Chapter 8: Modelling Affect Regulation in Dyads **190**

8.1 Affect in a Dyad 190
8.1.1 Agent-Target Designation 191
8.1.2 Back-and-Forth Exchange 192
8.2 Designing a MARDy Based Dyad 194
8.2.1 Overview 194
8.2.2 Implementing a MARDy Dyad 196
8.3 Simulating Dyadic Interaction 199
8.3.1 Scenario 1: Supportive Interaction 200
8.3.2 Scenario 2: Depressed Agent 202
8.3.3 Scenario 3: Surface Acting 203
8.4 Results 204
8.4.1 Results 1: Supportive Interaction 205

8.4.2 Results 2: Depressed Agent 208
8.4.3 Results 3: Surface Acting 212
8.5 Summary 215

Chapter 9: General Discussion 218

9.1 Thesis Overview 218
9.2 Summary of Model Predictions and Findings 222
9.2.1 Predictions Regarding Self-Regulatory Capacity 229
9.2.2 Predictions Regarding Affect Regulation Dynamics 232
9.2.3 Predictions Regarding Affect Regulation in a Dyad 236
9.3 Limitations 239
9.3.1 Limitations of the Model 239
9.3.2 Limitations of the Diary Studies 241
9.3.3 Limitations of Using the Diary Studies as a Validation Tool 242
9.4 Future Research Directions and Wider Implications 243
9.4.1 Further Parameter Testing 244
9.4.2 Further Developments of the Model 245
9.4.3 Wider Implications and Research Directions 249
9.5 Summary and Conclusions 254

References 255

List of Appendices

Appendix 1: Resource Model Formulae 280
Appendix 2: Glossary of Terms Used in Chapter 5 281
Appendix 3: Parameter Ranges used in Sleep Deprivation Simulation 282
Appendix 4: Example of Research Materials for Study 1 283
Appendix 5: Example of Research Materials for Study 2 292
Appendix 6: Parameter Ranges used in Dyad Simulation 299

List of Tables

Table 4.1	Parameters used in the model of felt-affect regulation	78
Table 4.2	Parameters used in the model of affect-expression regulation	84
Table 4.3	Parameters used in the model for resource depletion	89
Table 4.4	Parameters used in the model of affect goal regulation	93
Table 5.1	Outline of parameters to test and their colour coded location in the model	100
Table 5.2	Comparison of empirical data and modelled response to positive stimuli during manipulation of expression	120
Table 5.3	Comparison of empirical and model data for influence of sleep deprivation on felt-affect	133
Table 6.1	Periods for each diary recordings of feelings of being emotionally drained	142
Table 6.2	Parameter variation for data fitting of multiple diaries	145
Table 6.3	Parameters giving closest representation across multiple diaries	149
Table 6.4	Correlations for felt-affect between all diaries and models	150
Table 6.5	Correlations for felt-affect goals between all models and diaries	151
Table 6.6	Correlation of affect-expression goals between all diaries and models	153
Table 6.7	Correlation of perception of feeling drained between all diaries and models	154
Table 6.8	Average correlations for felt-affect within diaries and models	156
Table 6.9	Average correlations for felt-affect goals within diaries and models	157
Table 6.10	Average correlations for affect-expression goals within diaries and models	158
Table 6.11	Average correlations for perceptions of feeling drained within diaries and models	158
Table 6.12	Correlations of core concepts in each diary	160
Table 6.13	Correlations of core concepts in each model	160
Table 7.1	Periods for each diary recordings of feelings of being emotionally drained	170
Table 7.2	Parameters varied for data fitting of multiple diaries	171
Table 7.3	Parameters used as a best representation of diary data in study 1	172
Table 7.4	Parameters used as a best representation of diary data in study 2	173
Table 7.5	Parameters used as representation of diary data in study 2	173
Table 7.6	Correlations for felt-affect between all diaries and models	174
Table 7.7	Correlations for felt-affect goals between all diaries and models	176
Table 7.8	Correlations for feeling emotionally drained between all diaries and models	178

Table 7.9 Correlations for affect-expression between all diaries and models 179
Table 7.10 Correlations for affect-expression goals between all diaries and models 181
Table 7.11 Average correlations for felt-affect within diaries and models 182
Table 7.12 Average correlations for felt-affect goals within diaries and models 183
Table 7.13 Average correlations for feeling drained within diaries and models 183
Table 7.14 Average correlations for affect-expression within diaries and models 184
Table 7.15 Average correlations for affect-expression goals within diaries and models 184
Table 7.16 Correlations of core concepts in each diary 186
Table 7.17 Correlations of core concepts in each model 187
Table 9.1 Details of the final parameter ranges and the values specified in the model 225

List of Figures

Figure 2.1 Overview of affect regulation, self-regulatory capacity (resource) and affect goals 38

Figure 3.1 Complete control loop for a thermostat system 42

Figure 3.2 Complete control loop with a second loop for changes to the reference value 44

Figure 4.1 Schematic of MARDy 68

Figure 4.2 Model of felt-affect change in the Simulink environment 73

Figure 4.3 Model of felt-affect regulation change in the Simulink environment 77

Figure 4.4 Complete control circuit for felt-affect regulation 77

Figure 4.5 Model of affect-expression change in the Simulink environment 82

Figure 4.6. Complete control circuits for felt-affect and affect-expression regulation 84

Figure 4.7 Self-regulatory resource included in the control circuits for felt-affect and affect-expression regulation 88

Figure 4.8 Model of goal adjustment in the Simulink environment 91

Figure 4.9 Representation of the complete model 93

Figure 5.1 Representation of the complete model 102

Figure 5.2 Model of felt-affect change 103

Figure 5.3 Affect response and response variation to slides from the IAPS database 105

Figure 5.4 Modelled response to affective stimuli, using a saturation function 107

Figure 5.5 Modelled response to affective stimuli, using a hyperbolic tangent function 109

Figure 5.6 Felt-affect regulation control circuit with stimulus and results plotting 111

Figure 5.7 Variations in relative response time to reach a held felt-affect goal through felt-affect regulation 112

Figure 5.8 Relative resource depletion as a function of regulatory momentum and goal intensity 114

Figure 5.9 Felt-affect dynamics for affective event during felt-affect regulation 115

Figure 5.10 The standard pattern of affective dynamics 116

Figure 5.11 Felt-affect regulation control loop, affect-expression and expressive-feedback 118

Figure 5.12 Felt-affect dynamics with expressive-feedback 119

Figure 5.13 Complete circuit of affect-expression regulation added to existing model 122

Figure 5.14 Relative response times to reach a held affect-expression goal through affect-expression regulation. 123

Figure 5.15 Relative resource depletion as a function of regulatory momentum and affect-expression intensity 125

Figure 5.16 A) Relative persistence for felt-affect regulation B) Relative persistence for affect-expression regulation 129

Figure 5.17 Complete regulation of affect circuit with a central resource controlling regulation activity 131

Figure 5.18 The complete model in Simulink 134

Figure 6.1 Felt affect results for Model 1 and Diary 1 150

Figure 6.2 Felt affect goal results for Model 2 and Diary 2 152

Figure 6.3 Felt affect goals results for Model 3 and Diary 3 153

Figure 6.4 Perceived self-regulatory resource capacity results for Model 2 and Diary 2 155

Figure 6.5 Example provided to raters of a completed affect change rating sheet. 162

Figure 7.1 Felt affect results for Model 2 and Diary 2 175

Figure 7.2 Felt affect goal results for Model 2 and Diary 2 177

Figure 7.3 Perceived self-regulatory resource capacity results for Model 3 and Diary 3 178

Figure 7.4 Affect-Expression results for Model 3 and Diary 3 180

Figure 7.5 Affect-Expression goal results for Model 2 and Diary 2 181

Figure 8.1 Closed loop formed by each agent’s expressions influencing the other’s affective states 195

Figure 8.2 Schematic of two complete MARDy simulations connected through a model component that determines meeting times 197

Figure 8.3 Ranges of felt-affective states for Agents 1 (top) and 2 (bottom), both as isolated models (left) and together in a dyad design (right). 206

Figure 8.4 Ranges of self-regulatory capacity for Agents 1 (top) and 2 (bottom), both as isolated models (left) and together in a dyad design (right) 207

Figure 8.5 Ranges of felt-affective goal states for Agents 1 (top) and 2 (bottom), both as isolated models (left) and together in a dyad design (right) 208

Figure 8.6 Ranges of felt-affective states for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right) 209

Figure 8.7 Ranges of self-regulatory capacity for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right) 210

Figure 8.8 Ranges of felt-affect goal states for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right) 211

Figure 8.9 Ranges of affect-expression states for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right) 212

Figure 8.10 Ranges of affect-expression for the Employee as an isolated model (top), interaction with a positive affect Customer (bottom-left) and interaction with a negative affect Customer (bottom-right) 213

Figure 8.11 Ranges of felt-affect for the Employee as an isolated model (top), interaction with a positive affect Customer (bottom-left) and interaction with a negative affect Customer (bottom-right) 214

Figure 8.12 Ranges of perceived regulatory resource capacity for the Employee as an isolated model (top), interaction with a positive affect Customer (bottom-left) and interaction with a negative affect Customer (bottom-right) 215

Figure 9.1 Schematic of the complete model of affect regulation dynamics 224

Chapter 1: Introduction

This chapter outlines the general research area, the content, and structure of the thesis. This chapter is divided into three main sections. First, this chapter presents a broad outline of the developments of affect research and research directions within the field, particularly that of understanding affect in terms of being a controllable, social and dynamic process. Alongside this, the topic of self-regulation is introduced and the process of controlling affect is viewed in the context of the capacity for engaging in self-regulation. Second, this chapter presents an overview of the research approach and methods used in the thesis and the research aims for the project. Third, this chapter presents brief descriptions of the contents of the two parts to the thesis and each chapter within.

1.1 Research Area

Our everyday lives are shaped and characterised by how we feel. Our emotions and moods appear to both influence our actions and decisions in life and to be influenced by them. Yet, it is only recently that the cognitive revolution, of examining people as rational processing agents, has given way to an affective revolution, of examining people in terms of the influence of affective processes (e.g., Panksepp, 2003). Affect, as a term, encompasses both emotions and moods, which are differentiated by their duration, intensity, and specificity (e.g., Beedie, Terry, & Lane, 2005; Frijda, 1993; Scherer, 1984). Emotions are shorter-lasting, more intense feelings, occurring in response to events, while moods are longer-lasting, less intense, background feelings, occurring without specific cause. Often though, these distinctions can be muddied and many researchers prefer to use the more general term of affect for examining feelings (e.g., Gross & Thompson, 2007; Larsen & Prizmic, 2004; Russell, 2003).

Formal research in development of theories of affect can be dated back to James (1884), in which an argument is made for the existence of affect solely as a property of physiological changes. This theory is best characterised in James's own description, "*we feel sorry because we cry, angry because we strike, afraid because we tremble*" (p. 190). Around the same time, Carl Lange independently devised a similar perspective on affect (Lange, 1885/1922) and so the theory that physiological responses define the affective experience, with different responses forming different affective states, came to be termed the James-Lange theory (e.g., Cannon, 1927). Elements of this theory can still be seen in more recent developments in affect research, forming an integral part of the facial-feedback hypothesis, which argues that affective experiences are, in part, influenced by expressions (e.g., Adelmann & Zajonc, 1989; Laird, 1984).

The James-Lange theory has faced substantial challenges since its inception. Most notably, criticism highlights the relatively slow pace of physiological changes in comparison to the more immediate affective response and the wide range of affective experiences that are associated with broadly similar physiological responses (Cannon, 1927). An alternative theory, based on Cannon's arguments and Bard's animal lesion studies (e.g., Bard, 1939) termed the Cannon-Bard theory, posits that the physiological reaction and the affective experience coincide but the emotional experience is an independent construct. However, this perspective creates an ambiguity about affect's origin.

This uncertainty of affect's origin is resolved with the development of theories of appraisal, which specify that there is a cognitive component to the affective experience. Schachter and Singer's (1962) two-factor theory, which describes the process of attributing physiological changes to specific affect-relevant events or circumstances as the cognitive aspect of affect, supplants the Cannon-Bard theory through its provision of an origin for affect. Further emphasis on the cognitive aspect of emotional experience is seen in the theory put forward by Lazarus (1968, 1991), which argues that individuals' affective experiences arise from evaluations of events from the environment. In an initial appraisal, an individual assesses if an event supports or hinders his or her held goals and so determines whether the experience will be pleasant or unpleasant. Following this, a second appraisal is made regarding the capabilities for coping with this occurrence, which is argued to shape the actual affective state experienced.

The theory put forward by Lazarus (e.g., 1968) shows a lasting influence on affective research and can be seen to have shaped recent approaches to the investigation of affect discussed in this thesis. The principle of coping with an affect eliciting event underpins theories of affect regulation, although this field has broadened and developed the concept (see section 1.1.2). Also, the evaluation of events as affective in terms of their influence on goal pursuit is echoed in the modern control theory literature, particularly in Power's (1974, 2005) description of affect as an indicator that behaviour needs adjustment to reach goals (see section 1.1.3). A further contribution is the reference to affective experiences developing over time, namely that of an initial appraisal and then subsequent appraisal of affect eliciting stimuli, shaping the affective experience. However, how an affect experience unfolds in time and the course of affect change with time is, until recently, relatively under-examined (e.g., Kuppens, Oravecz, & Tuerlinckx, 2010; Scherer 2009).

1.1.1 Affect as a Dynamic Process

A fundamental development in modern affect research is the consideration of affect in terms of its dynamics (e.g., Eaton & Funder, 2001; Hemenover, 2003). It has been argued that although, in past affect research, emotions have been considered as brief, momentary responses, they should perhaps be considered as unfolding, longer-term processes (Frijda, Mesquita, Sonnemans, & Van Goozen, 1991). Further to this, it is put forward that, even throughout the course of a single affective experience, aspects such as intensity may dynamically unfold (Verduyn, Van Mechelen, Tuerlinckx, Meers, & Van Coillie, 2009). Similarly, evidence points towards moods not being homogenous, background states but feelings that vary with some degrees of regularity over the course of a week (e.g., Parkinson, Briner, Totterdell, & Reynolds, 1996) and a day (Murray, Allen, & Trinder, 2002; Owens et al., 2000).

Daily life is characterised by affective changes, which come with the day-to-day ups and downs of comforts and hassles. Affective changes are argued to exist so that individuals can be informed of an important change in the environment (e.g., Frijda, 2007) and the dynamic nature of affect is argued to be the very reason people experience affect at all (Kuppens et al., 2010). Individual differences in affective dynamics are considered an important factor influencing everyday experiences (Eaton & Funder, 2001). Moreover, atypical affective dynamics, such as emotional inertia (wherein a person’s emotions are slow to change) or heightened affective responses, are associated with affective disorders, such as depression (e.g., Rottenberg, 2005), or personality disorders, such as Borderline Personality Disorder (e.g., Trull et al., 2008).

Research into the underlying dynamics of affect is still a developing field, possibly because study designs traditionally used in psychological research are structured to investigate static variables (Larsen, Augustine, & Prizmic, 2009). Although study designs and methods used in affect research are diverse, including but not limited to: experiments (e.g., Richards & Gross, 2000), brain lesion studies (Bechara, 2004), observational methods (e.g., Locke, 1996), and cross-sectional self-reports (Zapf, 2002), these do not typically offer understanding of affect from a dynamic perspective. Diary studies (e.g., Totterdell, 2000; Totterdell & Kellet, 2008) offer insights into how affect changes across time and can act as a standpoint for developing simulations of underlying affect dynamics (e.g., Oravecz, Tuerlinckx, & Vandekerckhove, 2009, 2011).

Recent years have seen what has been termed an '*explosion of interest*' (Gratch, Marsella, & Petta, 2009, p. 1) in examining the dynamic process of affect through the use of computer simulation. While there has long been research investigating and describing affect change across time (e.g., Bolger, DeLongis, Kessler, & Schilling, 1989; Soloman & Corbit, 1974), the availability of computational modelling offers new means of representing and offering predictions regarding the dynamic courses of affect. These include describing the variability in affect associated with personality traits, (Oravecz et al., 2009, 2011), representing decisions made based on affective information in virtual agents (e.g., Gratch & Marsella, 2005), and modelling the dynamics of affect in individuals attempting to control their affect state (Bosse, Pontier, & Treur, 2010). The understanding of affect dynamics has been considered a challenge worthy of comprehensive investigation (e.g., Boker, 2002) and is anticipated to be a fundamental step in further understanding affect as a process (Scherer, 2000a). Computation modelling can offer a substantial contribution to understanding the dynamics of the process of affect regulation (Sloman, 2001).

1.1.2 Affect as a Controllable Process

As a parallel to the understanding that affect exists as phenomena changing over time, an important development in affect research is the recognition that affect can be actively changed (Thompson, 1994). Rather than simply being aspects of lives that just happen with people as passive recipients, affective experiences are now considered to be phenomena that people can seek out, engage with, and, in some ways, control (e.g., Parrot, 1993). In many circumstances, it may be important to control what is felt, such as trying to keep calm in the face of anger or fear eliciting events or stimuli.

Affect regulation is now considered to be an integral part of the affect experience; so much so, that very few, if any, affect experiences are thought to escape regulation (e.g., Frijda, 2007), It is argued that to experience affect is to have undergone affect regulation (Scherer, 2000b). Models of affect regulation, such as the widely regarded process theory (Gross, 1998a) pose that all affective situations, before developing as an affective experience, are in some way regulated. Gross's theory draws affect regulation into two broad categories: regulation of feelings, termed *antecedent focused regulation*, and regulation of expressions, termed *response focused regulation*.

The distinction between the regulation of affect as a felt process and regulation of affect as an expressed process is also made in the literature examining affect in more applied contexts. Hochschild (1983) poses that many employees in organisations, such as those in customer service, are expected in the course of their duties to present specific affect displays. This is considered to be achieved through two means: *surface acting*, which is the regulation and presentation of a target expression without influencing the felt state (thus, analogous to response focused regulation); and *deep acting*, which is the regulation of one's felt state so that one's affect-expression will, in turn, change (thus, analogous to antecedent focused regulation). The regulation of affect-expression serves as an important aspect of interpersonal communication; in this context, affect regulation of one's own affect state can ultimately influence how others feel.

One of the underlying assumptions within the process of affect regulation is that affect is regulated towards a specific, known goal state (e.g., Gross & Thompson, 2007). As such, affect regulation exists as a continuous loop: monitoring of affect, comparison against preferred, or necessary, affect, and seeking to change affect based on this comparison. This goal-directed process serves an adaptive function for affect regulation because it enables affect to be influenced so that people may work towards hedonistic or instrumental aims (e.g., Tamir, 2009a). This conceptualisation of affect and affect regulation places it within the broader field of self-regulation and goal-directed action.

1.1.3 Self-Regulation

Self-regulation, as a field of research, considers human action to be goal-driven (e.g., Austin & Vancouver, 1996); goals may be major or minor, short-term or long-term, and in the forefront of attention or more general background considerations. Actions and decisions are considered to be chosen, based on the pursuit of these held goals in life (e.g., Carver & Scheier, 2001; Powers, 1974). This concept of free decision of one choice over another and volition of action has arisen from the perspective of the existence of free-will. The existence of free-will in persons or a deterministic direction of action has long been debated in philosophy and considered in psychology under terms such as *will* (James, 1892) and *ego* (Freud, 1927), although is regarded by some to be too nebulous a debate to be resolved (e.g., Baumeister, 2008). Self-regulation, and particularly the sub-study of self-control, stems from the view that at least *some* action or cognition can *at times* arise from volition.

In recent years, the subject of self-control has seen a dramatic increase in interest and there exists an abundance of studies examining the influence of persistence in self-control engagement (for recent reviews see Gailliot, 2008; Hagger, Wood, Stiff, & Chatzisarantis, 2010; Heatherton & Wagner, 2011). A prominent assumption in research into self-control is that its use draws from a limited capacity to actively engage in the suppression of one predisposed action in favour of another (e.g., Muraven & Baumeister, 2000). This can lead to a temporary diminishment in the capacity to regulate actions, thoughts, or feelings, termed *ego-depletion*, echoing Freud's (1927) concept of the conscious self as an ego, rationalising and tempering the id, while striving to adhere to the super-ego's standards. Lapses in self-control are considered to occur when individuals know what action they ought to take, in order to work towards their goals, and yet choose alternative actions, such as eating unhealthy foods while dieting or overspending money while wanting to save for the future (e.g., Baumeister & Heatherton, 1996).

In terms of affect regulation, self-regulatory capacity and ego-depletion are seen to influence the capacity to manage feelings and expressions (e.g., Muraven, Tice, & Baumeister, 1998), further emphasising that affect regulation is a goal-directed process. Moreover, affect regulation is considered to exist as part of an integrated framework of multiple tiered goals (e.g., Diefendorff & Gosserand, 2003) in which regulation of affect and affect-expression serve to advance progress towards more distal goals. As part of a broader framework, known as control theory (e.g., Carver & Scheier, 2001; Powers, 1974), the goals themselves for affect experience or affect display may change over time (Kirshenbaum, Humphrey, & Malett, 1981) or with situations (e.g., Tamir, 2009a).

Self-regulation as a means for describing and explaining behaviour presupposes three key aspects: that current state of the system (such as affective state) is known, the difference between the current state and goal-state can be determined, and action is taken to change the current state based on this information. This process forms a feedback-loop, where information about the state of a system serves to influence the system's state. Control theory, has traditionally been a means of understanding physical systems of regulation that use feedback-loops (e.g., maintaining controlled, level flights, Ashby, 1961) and has since been adapted to become a primary means of representing psychological processes of self-regulation, including affect regulation (e.g., Carver, 2004; Diefendorff & Gosserand, 2003; Powers, 2005). Representing psychological processes as physical or mathematical systems requires specification of concepts, processes, and underlying assumptions made, which can then be investigated (e.g., Epstein 2008). Moreover, aspects of the psychological processes involved in affect regulation can be represented as parameters, of which variation in these could lead to predictions regarding their influence on affect dynamics.

1.2 Research Aims and Approach

This thesis has three main aims: i) to design and construct a computational model of affect regulation dynamics that can successfully represent known findings in the affect regulation literature, ii) to validate this model against two separate diary studies of affect change in individuals, and iii) to offer novel predictions of affect regulation dynamics in individuals and couples.

To meet the first aim, affect regulation is first examined and presented in terms of its dynamics, particularly the regulatory changes to affect made over time towards held affect goals. Based on this representation of affect regulation, a control theory framework for investigating affect dynamics is developed and a model of affect regulation is outlined. This model outline is then constructed as a computational model, which enables proposed dynamics of affect in the outlined model to be demonstrable in simulation. Relationships between phenomena represented in the model outline are specified as parameter values in the computational model and so can be subject to testing. At this stage the model can be tested against known findings in affect regulation literature.

To meet the second research aim, first, affect data is collected from a student sample using an intensive diary study conducted over a period of 6 days. The computational model built to meet the first aim is then fitted to the study data, using parameter adjustment, to capture the changes in affect recorded in the study, and quality of final fit is assessed. This process is repeated with a second study of affect change in teachers from a local school, again, using an intensive diary study over a period of 6 days. The computational model with parameters specified from the first study is fitted against the second data set and the model's validation is assessed in terms of quality of fit.

To meet the third research aim, the model's underlying dynamics are examined in terms of current theories and models of affect regulation; predictions are made relating to affect regulation dynamics in individuals. In addition to this, the computational model is copied to form a second model and connected to form a network of two agents, which can influence each other's affective states. Examples from the literature of affective interaction between two individuals (a dyadic network) are simulated in this new arrangement of the model and further predictions are made based on the simulation's operation.

Computational models offer new means to explore the hypothesised mechanisms and processes involved in dynamic systems such as affect regulation. Moreover, they require the specification of assumptions made in theories (e.g., Epstein, 2008) and offer a means for these assumptions to be explored and tested. By taking control theory as a framework for investigation, this computational model offers the potential to explore affect regulation in terms of its dynamics, alongside changes in affect goals, an aspect of affect dynamics under-explored in the literature. This model further offers an integration of the dynamics of felt-affect regulation, affect-expression regulation and self-regulatory capacity; the recurrent influence of these on each other over an extended period has not yet been investigated. Lastly, this model forms a foundation for further enquiry into affect regulation in networks and models of affect dynamics in groups. Practical applications may extend to the use of the model in affective forecasting and as a tool for affect and affect goal monitoring to determine typical and atypical changes in affect regulation dynamics in individuals.

1.3 Thesis Structure

This section details the division of chapters across the two parts and briefly outlines their structure and contents. The thesis is divided into two main parts. The first part comprises of a review of the literature, the construction of the model of affect regulation dynamics, and initial testing of the model against findings established in the literature. The second part comprises of the fitting of the model to two data sets collected from diary studies, and the development of the model in a simulation of dyadic interaction.

The final chapter integrates the findings, predictions and outcomes of the model and examines these in terms of current literature.

Part 1

The first part of this thesis details the theoretical background for the design of a model of affect regulation dynamics. The method of investigation through use of computer simulation is introduced and justified in terms of examining the dynamic nature of the phenomena described. The computer simulation is developed and its simulation of affect dynamics tested against known outcomes in the affect and affect regulation literature.

Chapter 2 outlines the issue of affect regulation in terms of its effortful and dynamic natures. In this chapter, affect regulation is divided into four interrelated areas: (i) felt-affect, (ii) affect-expression, (iii) limited capacity for affect regulation, and (iv) affect regulation goals. This approach builds upon established theories of affect regulation, in which specific held goals are regulated towards (e.g., Gross & Thompson, 2007), and self-control, in which individuals have a limited capacity for engaging in affect regulation (e.g., Baumeister 2002; Hagger et al., 2010).

Chapter 3 reports the approach taken for examining the questions raised and model of affect regulation dynamics outlined in Chapter 2. This chapter is divided into two parts: the first describes the perspective chosen for examining affect regulation dynamics, control theory; and the second describes the methodological approach taken, computational modelling. This framework and approach affords a means for developing, specifying, and testing models of affect regulation that incorporate dynamics in ways that other methods cannot achieve (e.g., Bosse et al., 2010; Carver, 2004).

Chapter 4 describes the design and structure of the model and the process of the model's construction as a computer simulation. The model is constructed in five component parts, in the order that each of the aspects of affect regulation dynamics are presented in Chapter 2, building up from the more concrete, lower levels of control to the more abstract, higher levels of control. The simulation is built so that the component parts are independent constructs and so each can be examined in detail against available known outcomes in Chapter 5. At the close of each section for component construction in

Chapter 4, a table of parameters is introduced and parameter boundaries, as specified by the model's design, are given.

Chapter 5 then aims to restrict the ranges of the parameter values specified in Chapter 4 to values that offer plausible representations of affect regulation. This is achieved through comparing the model's dynamics to that of known outcomes of studies and established theory, where available. Chapter 5 closes the first part of this thesis with a summary of the key parameters that influence the model's dynamics, ranges for these for further investigation against additional collected data, and an overview of observed model dynamics.

Part 2

The second part of this thesis covers the validation of the computational model against two diary studies of affect change. This section reports on the collection of diary data from both studies and the process of fitting the model to each of the data sets. Validation of the model is determined by its capacity to represent both of the data sets and the parameter values necessary to do so. This part of the thesis also covers the extension of the model to simulate affect sharing between two individuals in a network and the predictions made from these simulations.

Chapter 6 reports a diary study examining affect and affect goal adjustment over time in university students. These data are used as a set for the model to fit across four dimensions: felt-affect, felt-affect goals, affect-expression goals, and perceived self-regulatory capacity. Quality of fit is first assessed by correlating each diary and model. Fit quality is further assessed through examining correlations within each diary and model. Last, the model's performance in estimating affect change over the course of two days is compared against a series of human estimates of affect change.

Chapter 7 extends this approach of fitting the model to collected diary data by collecting further data – this time from staff in a local school. This environment was chosen because of the high likelihood for staff monitoring their affect-expressions and particular demands on affect goals. This study affords the opportunity to examine affect-expression dynamics alongside the aspects of affect regulation used in the prior study. This diary sample is used to validate the quality of fit of the simulation using the results and parameter values of the model determined by the previous diary study. Data fitting procedure and evaluations of fit are maintained from the last chapter.

Chapter 8 broadens the model and makes further predictions regarding affect regulation. This chapter is divided into two sections. The first examines the current understanding of dyadic interaction in theories of affect regulation and its relation to dynamic models of agents that both engage in affect regulation. Shortcomings in the representation of agents in traditional approaches are highlighted and argued to be a product of the use of informal, sketched, models instead of active, dynamic agents. The second section demonstrates a small series of simulated investigations in affect regulation in dyadic networks. The model is arranged as two agents sharing frequent contact, engaging in affect regulation processes that serve to influence both agents' affect states. Predictions for affect regulation dynamics in dyads are made and implications for understanding and representing affect in dyads and networks are considered.

General Discussion

The thesis closes with a chapter for general discussion. In Chapter 9, predictions made by the model and results from the prior chapters are summarised and considered in terms of established theories of affect regulation. In addition to this, limitations of the approach and the research conducted are examined and implications for future research and applied uses are discussed.

PART 1

Chapter 2: Literature Review

The previous chapter briefly overviewed landmark developments in affect research and the transition from understanding affect as an autonomous response of physiological states to an active process of appraisal. It further introduced affect as being dynamic and a process which is, to some extent, controllable by individuals through self-regulation (e.g., Bosse et al., 2010; Gross, 1998a) towards known, held affect goals (e.g., Diefendorff & Gosserand, 2003; Larsen, 2000; Tamir, 2009a). As with other controlled processes of self-regulation, the capacity to successfully regulate one's affect is considered to be limited by the depletion of mental 'resource', which facilitates regulation (Muraven & Baumeister, 2000). However, to date, there is no known model exploring the dynamics of affect regulation, self-regulatory capacity, and affect goals, within a unified framework.

This chapter therefore reviews the literature across these topics with the aim of developing a model of their interrelated influence on affect dynamics. The chapter is divided across four key distinctions concerning affect regulation. Firstly, affect regulation is considered in terms of regulating feelings (e.g., antecedent focused regulation, Gross, 1998a). Secondly, affect regulation is considered in terms of regulating expressions (e.g., response focused regulation, Gross, 1998a). Thirdly, affect regulation is considered as a process associated with the depletion of self-regulatory capacity. Finally, affect regulation is considered in terms of motivations to regulate affect and dynamic goals for regulation.

2.1 Felt-Affect and Felt-Affect Regulation

Historically, the folk concept representation of distinct emotions (e.g., joy, guilt, fear) has been used in research regarding feelings, stemming from the apparent universality of distinct affect-expressions across cultures (Ekman & Friesen, 1971). This approach has been used to suggest that there are multiple discrete, felt-affect states (e.g., Petersen, 2010), although this can lead to ambiguity about the nature of affect (Russell, 2009). For this thesis, affect (both as a felt state and as expression) is considered from the perspective of core dimensions (e.g., Russell, 1980, 2003, 2009); sensations of pleasantness or unpleasantness along with sensations of activation or sleepiness combined as one accessible state of *core affect* to form what is felt (Russell 2003). When attached to a specific cause and salient in awareness, these (most likely strong) affective states are generally considered as emotions. In contrast, when typically more moderate, less salient, and without clear cause, affective states are generally considered as moods. Affect as a term may be used to subsume both the specific and broader states to describe, quite simply, the felt state (Larsen & Prizmic, 2004; Russell, 2003).

A fundamental aspect of affect is its change over time. Affective states are characterised by changes in positive and negative feelings associated with the highs and lows in life (e.g., Kuppens et al., 2010). A change in affect can highlight the significance of changes to circumstances and guide individuals to make adjustments accordingly (Carver & Scheier, 2001; Larsen, 2000; Scherer, 2009) or reorganise behaviour (Powers, 1974). Affect is considered to show changes in response to events (e.g., Johnson, Husky, Grondin, Mazure, Doron, & Swendsen, 2008; Larsen, Diener, & Emmons, 1986; Sonnemans & Frijda, 1994; Stone & Neale, 1984) and these changes are thought to cumulatively shape affect across longer periods (Weiss & Cropanzano, 1996).

Feelings also subject to more general, cyclical changes (e.g., Totterdell, 1995; Whitton, 1978), showing variation in terms of mood changes due to interaction of sleep/wake patterns and circadian rhythms (Boivin et al., 1997), and also longer-term cycles such as that across a week (e.g., Parkinson et al., 1996). Variation in affect is prominently experienced in perceptions of alertness and fatigue in regular cycles, which are considered to be a combined function of circadian rhythm and time spent awake (Åkerstedt & Folkard, 1995, 1996; Åkerstedt, Folkard, & Portin, 2004). This understanding of affect changing in cyclical patterns is revisited in section 2.3, in which subjective fatigue is considered. Of particular interest to this section, though, is the process of actively changing affect through self-regulation.

2.1.1 Felt-Affect Regulation

Self-regulation can be considered the process of ensuring that the states of behaviours, thoughts, or feelings conform to corresponding held goal-states (Baumeister, Heatherton, & Tice, 1994; Carver & Scheier, 1982; Larsen 2000; Powers, 1974). At times, individuals may want to heighten or dampen the intensity of affective experience, such as increasing activation before competing in sports or reducing anxiety before taking an exam, or to prolong or shorten affect experience such as maintaining a positive mood or 'getting out of' a negative one (Gross, 1999; Parkinson & Totterdell, 1999). Again, for a practical use of terms, the regulation of emotion (e.g., Gross 1998a) and moods (e.g., Parkinson et al., 1996) can be subsumed by the universal term of *affect regulation* (Larsen & Prizmic, 2004).

Affect regulation may be divided into two broadly distinct categories, namely the regulation of felt-affect and affect-expression (e.g., Grandey, 2000; Gross 1998a, 1998b; Hochschild 1983). Gross (1998a) further draws the distinction between felt-affect regulation and affect-expression regulation by the relative timing of the regulation processes involved. Regulation influencing the felt-affect state is considered to occur earlier in an affective episode than regulation influencing the affect-expression state (e.g., Gross & Thompson 2007).

Specific experimental manipulation of different regulation strategy use also draws the distinction between felt-affect regulation and affect-expression regulation. Repeatedly, studies indicate that reappraisal of affective stimuli and suppression of expression show different outcomes (for a review see Koole, 2009) and regulation of affect-expression states can show little influence on the felt-affect states (e.g., Gross, 1998b; Richards & Gross, 2000). Moreover, habitual users of felt-affect regulation are reported to show better social, affective and wellbeing outcomes over habitual users of expression regulation (Gross & John, 2003). For the rest of this section, I focus on felt-affect regulation; in Gross's terminology this would be considered the processes of antecedent focused regulation. The process of affect-expression regulation is further examined in section 2.2.

2.1.2 Automatic and Deliberate Felt-Affect Regulation

In addition to the division of affect regulation into felt-affect regulation and affect-expression regulation, affect regulation can be further divided into automatic and deliberate processes (e.g., Mauss, Bunge, & Gross, 2007). Automatic regulation of felt-affect refers to the non-conscious, immediate and non-deliberate means of regulating how individuals feel. Automatic processing and regulation of affect may arise from over-learned behaviours; frequently-used affect regulation strategies may eventually be applied in response to affective situations without requiring the deliberate attention of the individual (Fitzsimons & Bargh, 2004). The study of automatic affect regulation is made difficult by the hidden nature of automatic processes, though (Bargh & Williams, 2004). Evidence for the existence of automatic regulation is thought to be seen in the tonic inhibition from the pre-frontal cortex, an area associated with self-regulation, on brain regions associated with affect (Jackson et al., 2003). Studies using priming (e.g., Mauss, Cook, & Gross, 2007; Williams, Bargh, Nocera, & Gray, 2009) indicate that affect regulation can be impacted by non-conscious processing.

In contrast, deliberate felt-affect regulation refers to the conscious and controlled regulation of what is felt. Active involvement is required to regulate affect towards a held goal (Larsen, 2000). Deliberate felt-affect regulation can, in some cases, be considered similar to coping (the deliberate improvement of one's affect or circumstances, Lazarus, 1966). However, felt-affect regulation is broader than coping, including the regulation of one's felt-affect towards either more positive or more negative states, along with efforts made at maintaining an affect state (Parkinson & Totterdell, 1999).

A number of physiological studies have indicated the brain regions associated with the deliberate control of affect. Ochsner, Bunge, Gross, and Gabrieli (2004) indicate that attempts made to regulate felt-affect through reappraisal are associated with an increase in pre-frontal activity. In a similar experiment, the conscious reappraisal of a stimulus was found to be associated with an increase in activation of the ventromedial areas of the prefrontal cortex and an inhibition of the amygdala (e.g., Quirk & Beer, 2006). Lesion studies indicate that damage to the ventromedial prefrontal cortex restricts the management of felt-affect and damage to the dorsolateral prefrontal cortex restricts the perception of affect (Krueger et al., 2009). There is a general agreement between physiological studies that deliberate affect regulation is associated with specific activation of pre-frontal regions.

For the remainder of this section, I focus on the more deliberate aspects of felt-affect regulation, although it is to be acknowledged that much of affect regulation may involve both processes together (Forgas & Ciarrochi, 2002). Deliberate affect regulation allows for the observation and monitoring of regulation strategies, which in turn allows for the change of, and improvement to, these regulation strategies (e.g., Smyth & Arigo, 2009). Automatic behaviours are much harder to observe and change as over-learning any behaviour often makes it invisible to attention (e.g., Bargh, 1994), impairing chances for change.

2.1.3 Affect Regulation as a Continual and Dynamic Process

Affective states are not just present during an affective event nor the immediate period afterwards, despite these being prominent times at which affect is consciously experienced (Russell 2003). Russell describes the experience of core affect as much like that of felt body temperature, it can be consciously accessed at any time but continues to exist when not consciously observed. When not at the forefront of attention, affect can still change over time (e.g., Oravecz et al., 2009), suggesting a continual, dynamic process.

Affect regulation is argued to coincide with felt-affect to such a degree that the two have been considered to be functionally the same (Campos, Frankel, & Carmas, 2004; Kappas, 2011). Gross (1999) argues that almost every affect experience is in some way regulated. Much of the same regions of activity for affect regulation are also seen to be associated with the experience of affect when individuals are apparently not attempting to engage in regulation (Jackson et al., 2003). However, there are likely grounds that they are closely related but to some degree distinct (Gross & Thompson, 2007). Executive control and self-regulatory capacity may temporarily be depleted, such that a person may no longer be able to successfully ‘control their emotions’ suggesting a failure to regulate affect (Baumeister et al., 1994) and therefore some dissociation between the two. Even so, several researchers have considered it functionally useful to regard affect regulation as a continual process acting on affect states (e.g., Kuppens et al., 2010; Larsen, 2000; Tamir, 2009a), which is the approach considered in this thesis.

The consideration of affect as a dynamic, unfolding process, rather than as series of isolated moments, is one of the remaining challenges for affect research (Eaton & Funder, 2001). It is only recently that the specific time courses of affects states are being examined (Verduyn et al., 2009). While the study of affect states across time has been long established in the literature (e.g., Bolger, Delongis, Kessler, & Schilling, 1989; Stone, Hedges, Neale, & Satin, 1985), it is only recently that more complete models of affect and affect regulation dynamics, which seek to examine the dynamic processes involved, have arisen (Bosse et al., 2010; Oravecz et al., 2009). The dynamics of affect regulation, in particular selection of regulation strategies in affective episodes and variation in capacity for affect regulation, remain an existing challenge for investigation in affect research.

The understanding of the importance of affect regulation dynamics has recently been shown by the adaptation of classic affect regulation experimental procedures. Traditionally instructions for participants (such as a request to reappraise a stimulus) are given before the stimulus is presented (e.g., Gross 1998b). However, Sheppes, Catran, and Mairan, (2009) show that delaying the instructions until the affect experience is well underway is a viable alternative and perhaps more ecologically sound method. In comparison, Sheppes and Gross (2011) indicate that earlier strategies in the process model (such as distraction) show effectiveness regardless of affect stimuli intensity; whereas, later strategies (such as reappraisal) show an effectiveness contingent on the current felt-affect intensity. The dynamics of affect regulation have always been a part of the understanding of the processes of affect regulation; however, up until recently, process dynamics have been largely in the background of understanding. It is through the development in understanding of, and empirical support for, the strategies implemented in deliberate felt-affect regulation that a more complete examination of its dynamics is possible.

2.2 Affect-Expression and Affect-Expression Regulation

Much like felt-affect, affect-expression can be considered in terms of its dynamics and the process of affect-expression regulation as being both automatic and controlled. Affect-expression can be regarded as social phenomena, occurring as part of the communication with others (e.g., Hareli & Rafaeli, 2008; Parkinson, 1996). Some experienced affect states may necessarily require the social presence (or at least implied or imagined presence of others), such as embarrassment (Miller & Leary, 1992). Expressive behaviour is seen more prominently in social situations than when alone; Kraut and Johnston (1979) observed ten-pin bowlers' expressions before and after turning back to their peers and noted that expressions were far more apparent when facing others, despite the affective component of the situation (the evaluation of bowling success) remaining unchanged.

Expression may be intertwined with felt-affect, rather than just an outlet for feelings. Parkinson (1996) argues that emotions exist as means for communicating evaluations and appraisals. Emotions are said to, "*make claims about the personal meaning of a topic of potential mutual interest in the context of an ongoing relationship*" (p. 676), essentially requesting others to acknowledge and respond to a person's concerns. This concept is developed by Parkinson (2005), suggesting that expressions may serve to communicate motives in order to shape a person's environment in the form of others' behaviour. This approach draws a neat parallel with the interpretation of felt-affect as a signal for individuals to make changes to their situation (e.g., Scherer, 2009); expression signals others to make such a change.

2.2.1 From Feelings to Expression

It is no secret that affective states influence expressions. Common experience of affect indicates a 'feed-forward' process from experience to expression and at particularly strong affect intensities it can be said that 'we are unable to contain ourselves' and felt-affect must be expressed (e.g., Rosenberg & Ekman, 1994). The association between felt-affect and expressions is apparent in a study by Colby, Lanzetta, and Kleck (1977); they reported a monotonically increasing relationship between experienced and expressed pain from administered electric shocks. More broadly, specific facial expressions are recognised as being associated with their experienced counterparts (e.g., smiling and happiness, Ekman & Friesen, 1971) and coherence of felt-affect and affect-expressions extends to include postures and movements too (e.g., Wallbott, 1998).

This concept of coherence of expression, experience and physiological change is supported by a range of researchers (for a review of positions, see Mauss & Robinson, 2009). Recordings indicate a moderate association between subjective experience, expression and physiology, but when just experience and expressions are considered the association is considerably higher (Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). Even attempts to restrict expressions, such as during impression management or lying, are not thought to be sufficient to prevent 'leaking' of felt-affect (e.g., Ekman, Friesen, & O'Sullivan, 1988), pointing towards a strong feed-forward relationship from experience to expression and the limitations of suppressing expression (e.g., Gross 2001).

2.2.2 From Expression to Feelings

In addition to the 'feed-forward' link from felt-affect to affect-expression, there is an abundance of evidence that affective expressions influence felt-affect. Despite the decline in popularity of the James-Lange theory, its principle of affect as an embodied experience has remained influential in understanding affect (Dalgleish, 2004). The proposed effect of expressions on felt-affect is termed the *facial-feedback hypothesis,* which argues that "*facial expressions provide feedback to the responder that is necessary or sufficient to affect significantly his or her emotional experience and behavior.*" (Buck, 1980, p. 812). However, Buck argued that there was little compelling evidence for such an effect because of methodological flaws in the studies, such as the potential for demand characteristics when asking participants to generate expressions. In a widely regarded paper in testing the facial-feedback hypothesis, Strack, Martin, and Stepper (1988) address many of Buck's concerns by implementing an unobtrusive means of manipulating expression, providing unambiguous evidence for facial-feedback. By inhibiting or facilitating smiling in participants, Strack et al. (1988) could respectively dampen or heighten participants' reported feelings of amusement, in response to cartoons presented.

Since Strack et al. (1988), there is now a wealth of evidence to suggest that one's affect-expression has a real, if somewhat small, effect on one's felt-affect (for reviews see McIntosh, 1996; Soussignan, 2004). The generation of expressions has a greater impact on affective states, if individuals are made more self-aware of their expressive states (Kleinke, Peterson, & Rutledge, 1998); the judgment of the affective content of sentences is facilitated, when engaging in congruent expression (Havas, Gelnberg, & Rinck, 2007); blocking expression impairs recognition of other's expressions (Olberman, Winkielman, & Ramachandran, 2007); and maintenance of neutral expressions through self-regulation diminishes felt-affective response to stimuli (Davis, Senghas, & Ochsner, 2009). In sum, studies repeatedly indicate that affect-expression plays a role in shaping felt-affect.

Recent neuropsychology studies indicate that the physical expression of affect is a contributing but not a necessary component for typical affect experience to occur. Keillor, Barrett, Crucian, Kortenkamp, and Heilman (2002) demonstrate in a single patient study that a sufferer of bilateral facial paralysis both reported a normal affective experience in her every-day life and responded to affect inducing pictures to the same degree as healthy controls. Temporarily induced deficits in expression manipulation, in the form of *Botox*™ injections appear to attenuate activation of the amygdala, an area associated with felt-affect (Hennenlotter et al., 2009). Using a similar experimental design, Davis, Senghas, Brandt, and Ochsner, (2010) find a decrease in reported positive felt-affect in individuals having undergone *Botox*™ injections in comparison to controls, leading them to conclude that expressions can influence felt-affect but are not necessary for the production of affect experiences.

Expanding upon the model of an embodied experience of affect, a number of studies have demonstrated that facial expressions are not the only means by which expressive states shape affective experiences (Niedenthal 2007; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). The effects of embodied changes are seen across a broad range of outcomes. For example, clenching muscles, such as closing a fist, may enhance a feeling of power in males (Schubert, 2004) and enhance self-regulatory capacity in both sexes (Hung & Labroo, 2010); participants required to sit in a slumped posture report worse mood in comparison with those sitting upright (Stepper & Strack, 1993); and vocalisation of affective tones is indicated to enhance associated emotions (Hatfield & Hsee, 1995). Affect-expression's influence on felt-affect may then be considered much wider than just a facial-feedback process, but rather expressive-feedback.

General conclusions that can be seen across these studies are first, the facilitation of congruent felt-affect with physical actions, and second, the diminishment of felt-affect with either incongruent physical actions or restrictions on physical expressions. Requirements of specific expressions at times may shape felt-affect through expressive-feedback processes and external influence on affect-expression may have indirect influence on felt-affect.

2.2.3 Emotion Contagion

Expressive-feedback is considered to play a wider role in shaping an individual's felt-affect state through the non-conscious, automatic mimicry of others' expressions and postures (Hatfield, Cacioppo, & Rapson, 1992). This proposal of *primitive emotional contagion* was later expanded upon in the book *Emotional Contagion* (Hatfield, Cacioppo, & Rapson, 1994), suggesting mechanisms of how emotions may be 'caught' through mimicry of expression and subsequent expressive-feedback processes. This suggests that social expression of affect has a unique influence on individuals in comparison to other affect events, potentially influencing felt-affect across direct (inferential) and indirect (contagion) channels (Hareli & Rafaeli, 2008).

Experimental studies indicate that, as Hatfield et al., (1994) argue, felt-affect is related to the intensity of the other's expression (Wild, Erb, & Bartels, 2001). Emotion contagion may occur through facial expression but it may also occur through other modalities such as hearing another's voice (Neumann & Strack, 2000) and even through written messages in computer-mediated interactions (Van Kleef, De Drew, & Manstead, 2004). Studies on the convergence of affect due to contagion processes indicate evidence for mechanisms of automatically reducing dissonance in affective states between individuals (Bartel & Saavedra, 2000; Friedman & Riggio, 1981; Sullins, 1991). The process of affect contagion may be considered to be in part a process of automatic affect-expression regulation. Further to the automatic process of regulation through contagion, affect-expression regulation can also be achieved through controlled, deliberate means.

2.2.4 Controlled Expression Regulation

In many situations, it may be important for a person to ensure an appropriate expression of affect. Affect can be considered a social phenomenon, particularly that of affect-expression (Parkinson, 2005) and across a broad range of circumstances, affect-expression may be regulated. A polite, positive, and often enthusiastic display of affect is expected in many customer service roles, regardless of one's genuinely held feelings towards a dissatisfied or angry customer, suggesting the need for replacing one affect-expression with another (e.g., surface acting, Hochschild, 1983). Grandey (2003) offers an example of a hotel clerk who displays sympathy, while still feeling irritation towards a customer. In this case, the process model of affect regulation (Gross, 1998a) would identify these affective regulation behaviours as response focused regulation actions, also termed *expressive suppression* (e.g., Gross, 2001); although, the desired outcome of regulation can include response exaggeration (Côté, 2005; Schmeichel, Demaree, & Robinson, 2006).

Despite the influence of affect-expression on felt-affect seen in expressive-feedback or embodied cognition studies, the response-focused strategy of regulating one's expression is not considered to have a substantial effect on felt-affect (Gross, 1998a; 2001; Richards & Gross, 2000). This finding is supported in literature on emotional labour (Hülsheger & Schewe, 2011). Repeatedly, studies indicate that surface acting, which is a strategy of expression regulation rather than felt-affect regulation, results in poorer felt-affect (Grandey, 2003; Judge, Fluegge Woolf, & Hurst, 2009; Liu, Prati, Perrewé, & Ferris, 2008), alongside a host of other negative outcomes. These outcomes include: negative ratings of authenticity of expression (Grandey, 2003); an increase in job tension or decrease in satisfaction associated with the job (Judge et al., 2009; Liu et al., 2008; Martínez-Iñigo, Totterdell, Alcover, & Holman, 2007) and elevated levels of emotional exhaustion or fatigue (Goldberg & Grandey, 2007; Grandey, 2003; Toterdell & Holman, 2003).

Many of the negative effects associated with regulation of expression are thought to lie with the formation of a dissonance between the expression and experience of affect (Abraham, 1998; Morris & Feldman, 1997). As described earlier, an authenticity of expression and a close relation between experience and expression is considered a desirable outcome (e.g., Diefendorff & Gosserand, 2003) and the creation of a perceived dissonance is aversive (Gross & John, 2003; Morris & Feldman, 1996) resulting in negative outcomes. However, these effects may be specific to Western cultures (Butler, Lee, & Gross, 2007; Koole, 2009). Despite the apparent negative effects associated with response-focused regulation, surface acting, or affective dissonance in general, expression regulation is a commonly used strategy for the regulation of affect (Hülsheger & Schewe, 2011).

Given the distinctions between regulation of felt-affect and affect-expression in terms of quality of interaction with others, onset in an affective episode, and development of dissonance and fatigue, it plausible that affect-expression regulation dynamics differ from felt-affect regulation dynamics. Affect-expression's rooting in the social aspects of affect could further influence its dynamics given the dynamic nature of affect cycles between individuals (e.g., Hareli & Rafaeli, 2008). If a limited resource model (section 2.3) is considered, it may be anticipated that the potential for persistence will be more limited for affect-expression regulation than for felt-affect regulation because expression regulation appears to be more demanding. Although individuals may typically favour one regulation strategy over another (e.g., Eftekhari, Zoellner, & Vigil, 2009) the selection of strategy use across an extended period could vary, potentially seeing individuals switch regulation styles in line with physiological changes, such as fatigue. Factors which may influence affect-expression regulation strategy use are examined in sections 2.3 and 2.4.

2.3 Effortful Self-Regulation

So far in this chapter, affect regulation has primarily been considered in terms of being a conscious and deliberate process. In this section, I review the literature pertaining to the effortful nature of conscious and deliberate regulation. In particular, I examine research pointing towards a limited capacity for self-regulation, consider its relation to subjective fatigue, and explore indications of the dynamics of self-regulatory capacity.

As described earlier, self-regulation may be represented as the process of discrepancy reduction between one's current states of behaviour, thought, or affect and one's goal states for these (e.g., Carver & Scheier, 2001; Powers, 1974). A distinction is made in the literature between automatic and deliberate regulation; automatic regulation is considered to be habitual and non-conscious, whereas deliberate regulation is a controlled and conscious process (Karoly & Kanfer, 1982).

Numerous researchers have argued that individuals may engage in automatic self-regulation (e.g., Carver & Scheier, 2001; Fitzsimons & Bargh, 2004; Mauss et al., 2007; Norman & Shallice, 1986) and evidence points towards the existence of automatic self-regulation (e.g., Gross 1999; Govorun & Payne, 2006). However, issues arise in examining automatic self-regulation because it is less consciously accessible, more elusive to wilful engagement, and as a result, challenging to study through tools such as self-reports. In contrast to automatic self-regulation, conscious efforts at self-regulation can be recorded through self-reports, as can progress towards consciously held goals and potentially pitfalls for self-regulation efforts identified. Moreover, the results from the study of conscious behaviours in regards to self-regulation can be implemented in training or interventions for the improvement of self-regulatory behaviours in the wider population (e.g., Larson, 2005; Muraven, 2010; Totterdell & Parkinson, 1999).

In parallel to the literature on automatic self-regulation, there is substantial evidence for the use of deliberate self-regulation (Gross, 1998a; Latham & Locke, 1991; Mischel 1974; Parrot, 1993). Within this area, there is an abundance of literature indicating that deliberate self-regulation is an effortful process (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Vohs, & Tice, 2007; Hagger et al., 2010; Muraven & Baumeister, 2000; Schmidt, Neubach, & Heuer, 2007). In integrating this understanding of an effortful process of regulation with ample evidence that indicates individuals can often fail to engage in successful self-regulation (e.g., Baumeister et al., 1994; Muraven & Baumeister, 2000; Tangney, Baumeister, & Boone, 2004; Tice & Bratslavsky, 2000), the *strength-model* of self-control has grown to be the prevailing theory for understanding effortful self-regulation (Baumeister, 2002, 2003; Baumeister & Heatherton, 1996; Baumeister et al., 2007; Muraven & Baumeister, 2000; Muraven et al., 1998).

The strength-model offers explanation for why individuals can fail to successfully engage in regulation of behaviour, thoughts, or feelings by means of analogy to muscular fatigue. The capacity to persist in deliberate self-regulation is considered to be dependent on a limited 'resource' for self-regulation, which, when depleted, limits the capacity for persisting in effortful self-regulation (e.g., Muraven et al., 1998). Self-regulatory exertion can be considered analogous to muscular exertion, which requires strength and energy to be performed and depletion of physical resource impairs persistence. In addition to these similarities, rest and recuperation is thought to restore the capacity to further engage in self-control, much like physical rest restores a muscles capacity to exert force (e.g., Muraven & Baumeister, 2000; Oaten, Williams, Jones, & Zadro, 2008; Tyler & Burns, 2008).

Much of the evidence for the strength-model comes from two-task design experiments, in which participants either undergo a self-regulation task or a control task and then a second-task in which self-regulation performance is recorded (e.g., Muraven et al., 1998). Exertion of self-regulation in the first task is anticipated to limit capacity for further self-regulation. Differences between experimental and control participants' performances is argued to demonstrate a depletion in self-regulatory capacity (a state of *ego-depletion*). Ego-depletion affects a broad range of self-regulatory behaviours (e.g., Cameron & Webb, in press a), including: persistence at aversive (e.g., drinking something unpleasant) or impossible (e.g., working on unsolvable anagrams) tasks; errors made and response times in inhibition tasks (e.g., the Stroop task); and resisting temptation (e.g., restricting alcohol consumption). Depletion is not domain-specific so exertion of self-control for one task can impair subsequent exertion of regulation in unrelated tasks.

A recent meta-analysis demonstrates that there is a structured relationship between the effects of ego-depletion and the experimental conditions designed to evoke it (Hagger et al., 2010). More complex tasks promote higher levels of self-regulatory fatigue. Longer breaks between the induction of and measurement of ego-depletion result in a larger restoration of the capacity for self-regulation. A subset of the studies investigating self-regulation involves the effortful self-regulation of affect, which has been associated with the depletion of self-regulatory capacity and appears to be affected by the capacity for regulation (Baumeister et al., 1998; Muraven et al., 1998; Tice & Bratslavsky, 2000; Baumeister et al., 2007). In the wider context of emotional labour, the self-regulatory behaviours of managing one's felt and expressed emotions have been associated with feelings of exhaustion, possibly indicating a state of depletion (e.g., Grandey, 2003; Goldberg & Grandey, 2007; Martínez-Iñigo et al., 2007). In sum, in order to better understand the process of affect regulation and its dynamics it would be advantageous to examine the associated process of resource depletion.

2.3.1 Limited Physical Resources

A wide array of studies point towards a limited resource model for self-regulatory capacity, yet the specific nature of this resource is not well determined by a standard two-task design. The hypothetical resource for self-control is argued to deplete with self-regulation but exactly what is being depleted cannot be determined by the performance outcomes outlined above (e.g., Cameron & Webb, in press b). Resources are regarded as things of value to individuals that aid in reaching goals, such as close attachments and health, or means to obtain these, such as social networks and money (Hobfoll, 2002). Building close attachments through positive interactions can be considered as an investment of one's resources in others (Brotheridge & Lee, 2002). These broader resources may have influence on the hypothetical resource for self-regulatory capacity (e.g., Fitzsimons & Finkel, 2011) but are not thought to *be* the hypothetical self-regulatory resource.

Several studies point towards an increase in self-regulatory persistence through a variety of means, including: experiencing positive affect (Tice, Baumeister, Shmueli, & Muraven, 2007), self-affirmation (Schmeichel & Vohs, 2009) and incentives to persist (Muraven & Slessareva, 2003). However, these studies do not further elaborate upon what resource *is* nor do they necessarily indicate that resource is restored by these means. Further studies indicate that these interventions may just encourage persistence at self-regulation and a greater state of ego-depletion (Muraven, Shmueli, & Berkley, 2006; Tyler & Burns, 2009). To offer an account for the material nature of resource, Gailliot and Baumeister (2007) proposed that a physical depletion of energy, such as that seen when one is fatigued, occurs during self-regulation.

A physiological analogue has been sought for self-regulatory resource so that understanding it in physical terms and direct measurement is possible. A cluster of studies indicate that depletion of self-regulatory resource is associated with a depletion of blood glucose (DeWall, Baumeister, Gailliot, & Maner, 2008; Dvorak & Simons, 2009; Gailliot et al., 2007; Gailliot, Peruche, Plant, & Baumeister, 2009; Masicampo &

Baumeister, 2008). Moreover, they indicate that an infusion of glucose to the blood stream (via a sugary drink) can restore self-regulatory capacity of ego-depleted individuals to that of their capacity prior to depletion. This experimental design has been adopted for an animal study and shown similar results (Miller, Pattison, DeWall, Rayburn-Reeves, & Zental, 2010). Further to this, blood glucose levels have been associated with perception of task difficulty (Schnall, Zadra, & Proffitt, 2010), and executive function (Benton, Owens, & Parker, 1994; Masicampo & Baumeister, 2008), developing the assumed relationship between executive function and self-regulation (e.g., Baddeley, 2007).

Limitations of the blood glucose hypothesis have been identified, with competing theories suggesting that effects seen are associated with glucose allocation rather than depletion (Beedie & Lane, 2012), or identifying more a suitable physiological candidate for resource (Gailliot, 2008). Gailliot (2008) reviewed a series of studies that point to the limitations of the 'glucose model' for resource, brain glycogen's role as an energy store, and, critically, evidence of executive function's association with brain glycogen use. The nature of glycogen stores, depletion, and replenishment offers the integration of the resource-based strength-model with fatigue and rest in individual's daily lives (Gailliot, 2008), expanding beyond examining short-term depletion in experimental designs (e.g., Gailliot et al., 2007; Muraven et al., 1998). Glycogen's proposed role as an available energy store for executive control and its depletion with use serves as a strong candidate for the physical analogue of resource.

2.3.2 Self-Regulatory Capacity Restoration Dynamics

The strength-model places emphasis on the necessity of sufficient rest to restore depleted self-regulatory capacity (e.g., Muraven & Baumeister, 2000) and a meta-analysis indicated longer rest periods in-between experimental self-control tasks are related to greater self-regulatory capacity restoration (Hagger et al., 2010). Glycogen as a proposed physical basis for self-regulatory resource offers account for dynamics of self-regulatory capacity, integrating experimental results (e.g., Hagger et al., 2010), observations of time-of-day effects on ego-depletion (e.g., Baumeister et al., 1994), and the association of sleep with both executive function (e.g., Harrison & Horne, 2000) and affect (e.g., Zohar, Tzischinsky, Epstein, & Laive, 2005).

The advent of glycogen as a candidate for self-regulatory resource has been preceded by several suggestions that sleep and self-regulatory capacity are associated. Baumeister et al. (1994) suggest that self-regulation may be impaired when people are tired, such as late in the evening, a suggestion echoed by Baumeister and Heatherton (1996). Baumeister, Faber, and Wallace (1999) make explicit that assumption of a link between sleep and self-regulatory resource, stating, "*We think sleep is probably the major way to replenish the ego after the depleting effects of everyday decision, making self-control and other volition*" (p. 59). However, Vohs, Glass, Maddox, and Markman (2011), do not report any effects of sleep deprivation on ego-depletion across a short-term experimental study. Rather than 'acute' effects of fatigue typically measured in an experimental environment, sleep may serve as a long term restorative function of depleted resource. Barber, Munz, Bagsby, & Powell (2010) argue that sufficient sleep could be a means of restoring the chronic effects of continual resource depletion seen across a day and demonstrate that consistent and sufficient sleep together predict improved self-regulatory capacity.

Gailliot's (2008) review of glycogen and executive function points towards a potentially observable cycle of resource depletion and restoration across a waking/sleeping period. Self-regulatory capacity may be observed to change in a study where repeated measures of self-regulation or even subjective fatigue are made. Hagger (2010) highlights the current paucity of research into self-regulatory capacity and sleep, reporting on a *"clear consensus… for more systematic and extended experimental research"* (p. 184) on the matter. While he specifically refers to the need for more 'objective' measures for recording sleep, it is evident from the scarcity of studies linking sleep and self-regulatory capacity at present that valuable contributions can still be made from a range of approaches.

Experienced sleepiness has consistently been associated with impairments in sustaining attention, memory, and general decrements in cognitive executive function (e.g., Harrison & Horne, 2000; Nilsson et al., 2005; Killgore, Balkin, & Wesensten, 2006). Although fatigue does not appear to be the sole determinant of an individual's self-regulatory capacity (Clarkson, Hirt, Jia, & Alexander, 2010; Job, Dweck, & Walton, 2010; Vohs et al., 2011), subjective fatigue is associated with limiting self-regulatory capacity (Finkel et al., 2006; Sergerstrom & Nes, 2007; Stewart, Wright, Hui, & Simmons, 2009). Further to this, sufficient sleep is indicated to promote improvements to self-regulatory capacity (Barber & Munz, 2011), again pointing towards an association of self-regulatory capacity with fatigue.

Sleep deprivation studies indicate a significantly adverse effect on individuals' affect and affect regulation, most commonly an increase in negative affect (e.g., Moore et al., 2009) and a decrease in positive affect (e.g., Franzen, Siegle, & Buysse, 2008). Baumeister et al. (1999) put forward that people who are sleep deprived have "*difficulty controlling their emotion*" (p. 59), which Walker and van der Helm (2009) ascribe to successful emotional processing as having a dependence on sleep. The effects of sleep on affect have been examined from both the perspective of sleep deprivation, in which an increase in negative affect or detriments to positive affect and alertness due to tiredness are normally measured (e.g., Scott, McNaughton, & Polman, 2006; Franzen Siegle, & Buysse, 2008; Tempesta et al., 2010), and sleep sufficiency, in which associations between 'healthy' sleep and the mitigation of strain, enhancement of well-being, or intensity of affect states are recorded (e.g., Barber et al. 2010; Birchler-Pedross et al., 2009; Moore et al., 2009). As a general theme throughout the literature, sleep is considered a contributing factor for successful regulation of affect and the maintenance of a positive affect state.

It still remains to consider the potential of regular dynamics in self-regulatory capacity and its possible association with dynamics of affect regulation and affect. As described earlier, executive function is regarded to drop at the end of the day (Baumeister et al., 1994), has been linked to brain glycogen stores (Gailliot, 2008), and associated with a dependency on sleep for its restoration (Barber & Munz, 2011). Beyond this though, there has been little examination of the dynamics of self-regulatory capacity over the course a day. Given these associations, it appears surprising that there has not been a formal investigation to understand if regular cycles of self-regulatory capacity exist.

2.4 Goals and Affect Regulation

The final aspect of affect regulation dynamics to be considered is that of goals. Goals are desired states that individuals work towards achieving (e.g., Geen, 1995) and form an integral part of the process of deliberate self-regulation (Carver & Scheier, 1982, 2001; Powers, 1974; Powers, Clark, & McFarland, 1960a, 1960b). Simply engaging in a 'blind' process of change without self-monitoring whether the change is towards a desired state prevents recognition of whether progress is occurring or if the change is even in the right direction (Powers, 1974; Powers et al., 1960a, 1960b). Insufficient monitoring of one’s current state or desired state therefore leads to failures in self-regulation (e.g., Kirschenbaum, 1987).

Goal setting and goal striving occur across a wide range circumstances and are often viewed alongside motivation. Goals can serve as a strong motivation for change to behaviour; for example, Bargh, Gollwitzer, Chai, Barndollar, and Trötschel (2001) indicate that individuals primed with achievement goals show better performance than controls on subsequent tasks. Motivations for goal striving can be increased if achieving the goals is made more desirable; this could be through priming (Custers & Aarts, 2005), through overt incentives such as money (Baumeister, DeWall, Ciarocco, & Twenge, 2005), through highlighting the importance of persistence, or through suggesting self-development benefits (Muraven & Slessareva, 2003). More broadly, Locke and Latham (1990) reviewed the necessity for specificity for goals and feedback on goal progress in work-related environments. Studies on student goal-setting for working indicate that flexibility in goals encourages perseverance because overly rigid goals can become restrictive if circumstances or working behaviour changes (Kirshenbaum, Humphrey, & Malett, 1981; Kirshenbaum, Tomarken, & Ordman, 1982). The achievement of short-term goals can maintain motivation in working towards longer-term goals due to the regular sense of achievement (Baumeister et al., 1994).

Self-regulation, as a whole, is considered to be largely dependent on the process of setting and monitoring goal progress (e.g., Schmeichel & Baumeister 2007), described as a test-operate-test-exit system (Miller, Galanter, & Pribram, 1960). In such as system, the discrepancy between a current state (such as an affective state) and a desired state are compared and regulation efforts are made to reduce discrepancy until none is detected. This representation of self-regulation highlights its grounding in control theory as a framework for understanding goal-directed action (e.g., Carver & Scheier, 2001).

2.4.1 Affect Goals

Affect regulation goals are a vital part of the process of affect regulation in that individuals desire to reach them and work towards doing so (e.g., Diefendorff & Gosserand, 2003; Gross & Thompson, 2007; Morris & Reilly, 1987). When individuals engage in regulation, such as the reappraisal of a situation, it is considered to be done with an aim of regulating towards a specific state (e.g., Gross & Thompson, 2007). It should also be acknowledged that goals can influence individuals non-consciously; priming for non-conscious goals in affective regulation has been indicated to help change individual's responses to affective stimuli (Williams, Bargh, Nocera, & Gray, 2009). In this section, I examine held motivations for deliberately regulating affect in terms of two contrasting motivations for both felt-affect regulation and affect-expression regulation.

Felt-Affect

Hedonistic View of Felt-Affect Regulation

For the most part, affect regulation research has been based on the assumption that, as a general rule, people want to feel good (Khrone, Pieper, Knoll, & Breimer, 2002; Larsen, 2000). It seems self-evident that positive affect is favourable over negative affect and people's goals would be aligned with the maximising of pleasure and the minimisation of displeasure (e.g., Larsen 2000; Morris, 2000; Tice & Bratslavsky, 2000). Much of the literature on affect regulation and associated areas is focused on the reduction of negative affect, such as coping (e.g., Lazarus, 1966; Lazarus & Folkman, 1984), helping behaviour as a means of reducing sadness, (Cialdini, Darby, & Vincent, 1973) or experimental research involving the reappraisal of negative stimuli (e.g., Gross 1998b, 2002; Urry, 2009). Alternatively research tends to focus on the development of positive affect (e.g., Parkinson & Totterdell, 1999; Thayer, Newman, & McClain, 1994; Totterdell & Parkinson, 1999).

While the literature shows evidence for the processes of increasing positive affect as a favourable outcome, there are limits to this: positive affect is not *necessarily* always beneficial. Positive affect can be considered as a signal that things are going well, that progress towards goals is greater than expected and that it may be appropriate to slow down goal pursuit (Carver, 2004; Carver & Scheier, 1990, 2001). Failure to limit positive affect in light of this has been argued to be a maladaptive affect regulation strategy and has been associated with diminished goal pursuit slowing, as seen during manic states in Bipolar Disorder (Fulford, Johnson, Llabre, & Carver, 2010).

Instrumental View of Felt-Affect Regulation

An alternative consideration of the motivations for regulating felt-affect is to regard individuals as wanting to experience affective states that serve a useful function (e.g., Tsai, Miao, Seppala, Fung, & Yeung, 2007). This instrumental approach could be characterised by individuals actively attempting to regulate their affect, regardless of whether the goal felt-affect state is positive or not (e.g., Erber & Erber, 2000a, 2000b). In contrast to the hedonistic view of affect regulation, affective states traditionally considered aversive are not seen as states to be avoided or regulated away but rather as being beneficial in some circumstances (for a review see Tamir, 2009a).

The research available on instrumental felt-affect regulation is somewhat restricted in size, in comparison to the hedonic literature. Riediger, Schiedek, Wagner, and Lindenberger (2009) state, "*Little attention has been paid to the fact that such self-regulatory behaviours are preceded, and fundamentally shaped by, motivational processes*" (p. 1529). They suggest that the paucity of investigation in the area has arisen from the assumption that the only driving motivation for affect regulation is an increase in well-being. Nevertheless, despite the limited range of the area, there is compelling evidence to suggest that felt-affective states are better examined from a perspective, which forwards the view that affect goals can flexible and vary to suit an individual's wider goals.

One of the earlier examples of instrumental affect regulation is seen in a study by Erber, Wegner, and Therriault (1996), in which individuals down-regulated their positive affect states when expecting to meet a stranger. More recent studies demonstrate that instrumental affect regulation may occur not just as a process of down-regulating positive affect, but also a process of increasing negative affect. This includes the increase of anger, (Tamir, Mitchell, & Gross, 2008), fear, (Tamir & Ford, 2009), sadness, (Hackenbracht & Tamir, 2010) and worry (Tamir, 2005). Reidiger et al. (2009) highlight the existence of contra-hedonic motivations for increasing or maintaining negative affect in teenagers, and Wood, Hiempel, Manwell, and Whittington, (2009) highlight that individuals with lower self-esteem are less likely to be motivated to improve affect. Collectively, this research indicates that felt-affect goals can extend greatly beyond just wanting to feel positive.

This instrumental approach to affect regulation is considered in models of affect within the control theory literature. Powers (1974) argues that feeling bad prompts individuals to reorganise behaviour until goals are better pursued. Carver and Scheier (2001) suggest that experienced negative affect may act as a signal that progress towards goals (or away from aversive goals) is too slow. These negative affect states act as an indication that more effort is needed and goal striving is expected to increase. Tamir (2005) indicates that individuals scoring high in neuroticism prefer to increase their level of worry before a task, suggesting a preference for trait-consistent affect. Moreover, those that did so showed an increase in task performance. While, Carver and Scheier (2001) suggest that increased striving comes with the goal of reduction of experienced negative affect, it is plausible that negative affect needs to be amplified before it is considered a salient experience for task motivation. The control theory perspective and Powers (1974, 2005) and Carver and Scheier's (2001) models of affect are further considered in Chapter 3

Affect-Expression

In section 2.2, affective expression was described as serving a social purpose. Expression of affect (and in some views affect as a whole) exists to serve as a communication tool to shape the feelings, thoughts or behaviours of other individuals (e.g., Parkinson 1996, 2005). This view can be seen to be related to the process of shaping the environment to fit a desired outcome (e.g., Carver and Scheier, 2001; Powers, 1974). For example, one individual may feel anxious about a deadline at work and a co-worker may seek to calm this individual by encouraging him or her to focus on what can be done. In contrast, a leader of a group may attempt to increase anxiety in what they perceive to be a complacent co-worker, in an attempt to encourage motivation to complete a task before a looming deadline.

Having established that affect-expression may serve as communication to others as part of the process of shaping the environment, it still remains to examine the motives behind communication of affect and the regulation efforts necessary. In this section, I examine the motives and practices involved in deliberate affect-expression regulation. Automatic regulation of affect through processes, such as contagion (Hatfield et al., 1994) or the automatic production of complimentary affective states (Hareli & Rafaeli, 2008), are acknowledged to be a part of social affect regulation but are not the focus of this section. As described in section 2.1.2, narrowing the focus on deliberate regulation actions allows for both the more straightforward understanding of processes (given that automatic processes are often hidden from attention) and the room for changes to actions to be made.

Impression Management View of Affect-Expression Regulation

Contrasting with the external focus of social affect regulation, impression management can be seen to be serving more immediately personal goals. Impression management can be regarded as the active shaping of the 'self' that is presented when interacting with others; the process has been likened to performing in front of an audience (Goffman, 1990). Individuals' actions in social situations may be different to that when individuals are alone and this effect of others is strong enough to shape actions, even if their presence is only implied or imagined (e.g., Leary, 1995). Controlled affective expressions can play a significant part in impression management as a means of shaping others' attitudes, fitting in with groups or gaining some rewards from the current social situation (e.g., Kelly & Barsade, 2001). Impression management as a topic is broad enough to include the act of a deliberate creation of a social self, in the form of deception. This process evidently requires the deliberate management of affective expression as self-regulatory efforts are necessary to prevent affective expressions that may betray a person's attempts to successfully deceive (e.g., Ekman et al., 1988).

Although there is evidence to suggest that individuals shape expressive states to manage presented 'selves', there appear to be restrictions on the degree to which this is done. For example, Snyder and Gangestad (1982) indicate that people prefer social situations that allow for impression management which is closer to their held self-concept. A motivation for regulating expressive affect may lie in the preference for aligning affect-expression and perceived felt-affect states, creating a sense of authenticity (e.g., Diefendorff & Gosserand, 2003). Tice (2002) highlights that if this coherency is challenged by requiring acting 'out of character' in front of an audience, individuals' reports of their self-concept change to accommodate this. The process of aiming to align affect-expression with held self-concept bears a strong resemblance to that of the regulation of felt-affect to be congruent with personality traits (Tamir, 2009b), suggesting a preference for perceived authenticity in feelings and expressions.

Instrumental View of Affect-Expression Regulation

In some circumstances, though, authentic affective expression is not considered appropriate. As mentioned in section 2.2.4, affective expressions within a workplace environment have been extensively studied because often the desire to express something and the requirements of the workplace environment come into conflict (e.g., Grandey, 2000, 2003; Hochschild, 1983). In terms of emotional labour, motivations for expression regulation may then be focused on external sources such as complying with workplace norms, or *display rules*. The expected aims for actually engaging in affective regulation may again be seen to be the shaping of other's felt-affect or shaping their behaviour. For example a flight attendant may seek to calm down and reassure an anxious passenger or a worker at a call-centre may be expected to sound positive, bright and cheerful when handling queries or complaints.

Diefendorff and Gosserand (2003) highlight that motivations for engaging in expression regulation may come from distinct and possibly even conflicting goals with that of wanting to authentically express affect. In addition to this, they posit a number of effects display rules would have upon expression. If expressive goals are restricted, in that only a narrow, fixed range of expressions are considered suitable to meet display rules, then this limits the range of expressions that individuals can regulate towards, possibly promoting greater self-monitoring and exhaustion. In contrast, broader ranges of permissible expression should allow for greater variation in individual's expression, which would presumably increase the chances of expressive goals and felt-affect aligning and limiting the potential for exhaustion. Experimental evidence (e.g., Goldberg & Grandey, 2007) points towards a restriction placed on the range of expression, in the form of an adhered to positive display rule as opposed to the emphasis on authentic expression, is associated with both an increase in performance errors and exhaustion.

2.4.2 Goal Adjustment

An important part of the process of goal-setting is the monitoring of the goal state itself; the ability to adjust goals is an integral part of self-regulation (Hollenbeck & Williams, 1987; Lord & Hanges, 1987; Powers, 1974; Wrosch, Scheier, Carver, & Schulz, 2003). Children as young as five and six demonstrate the understanding that in order to alleviate negative feelings it may be necessary to adjust goals in order to reduce discrepancies between desired and current outcomes (Davis, Levine, Lench, & Quas, 2010). Goal adjustment may also become necessary if goals are too difficult and cannot be met with available resource (Baumeister et al., 1994; Heatherton & Ambady, 1993) or there not sufficient incentive to continue goal pursuit (Alberts, Martijn, & de Vries, 2011). Flexibility in goals is also useful if circumstances or behaviour patterns change (Brandtstädter & Rothermund, 2002; Kirshenbaum et al., 1982) or if the goal needs to be corrected to accommodate for progress (Williams, Donovan, & Dodge, 2000). Adjustment to goals may also be seen in response to changes in self-efficacy (Vancouver & Kendall, 2006). Although, one apparent shortcoming in the literature is the lack of research on changes in affect regulation goals because affect appears to only be examined in terms of experienced response to achieving or failing to reach goals (Cron, Slocum, VandeWalle, & Fu, 2005; Ilies & Judge, 2005; Morling & Evered, 2006).

2.4.3 Affect Goal Dynamics

The literature on instrumental affect regulation suggests that there is a situational component for the current state of held affect goals. The purpose of felt-affect as a guidance for behaviour implies that as behaviour needs to change across differing situations, goal affect also needs to change. The expectation of an upcoming avoidance goal prompts a change in affect goals and the increase in individual's self-regulation of fear (Tamir & Ford, 2009) as fear would be a congruent experience for the situation (Carver, 2001). Oravecz et al. (2009) recorded individuals' changing felt-affect states in terms of valence and arousal in an intensive diary study. They then modelled the felt-affect trajectories, best representing felt-affect intensity as randomly moving but overall tending towards a specified focal point (termed the '*home-base*') for each individual (i.e., an affect goal). Critically, the home-base varies across time, showing a positive linear trend in terms of valence and an inverted U for arousal across a day, suggesting felt-affect goals vary in cyclical patterns.

Affect regulation goals may then, like any other held goal, be subject to change over time. This may be apparent when regulation efforts to meet goals are not successful and discrepancy reduction can only come from a change in the goal affective state (e.g., Carver & Scheier, 2001; Lord & Hanges, 1987; Powers et al., 1960a, 1960b). The process of goal adjustment may then potentially be related to the self-regulatory capacity for guiding affect towards these held goals; depletion of self-regulatory capacity may encourage the shifting of affect goals towards current affect states, although this remains to be investigated. While the view that affect regulation simply serves a hedonic purpose is a popular one, there is evidence to suggest that affect goals may change in terms of meeting short-term requirements to aid in broader goal pursuit (e.g., Tamir, 2009a). Felt-affect regulation goals may also change in a regular cycle throughout the day (Oravecz et al., 2009), although this is still a tentative suggestion in an area of limited current research.

2.5 Summary

Throughout the literature associated with deliberate affect regulation, a common theme emerges of change in affect across time. This may be in the form of Gross's (1998a) affect episodes in self-regulation, Hareli and Rafaeli's (2008) affect cycles in dyads, longer-term, slower trends in affect change highlighted in Parkinson et al. (1996), simulations of changes of both affect and goal affect (Oravez et al., 2009), and even hypothesised dynamics of self-regulatory capacity to achieve these changes (Gailliot, 2008). One of the fundamental properties of affect is its change; change in affect alerts individuals to events or situations as well as the apparent importance of these events (Kuppens et al., 2010). Yet, even though it is considered a vital aspect of affective research, understanding the dynamics of affect still remains limited and a current challenge to be met (e.g., Eaton & Funder, 2001).

With regards to affect being a dynamic process, it is also useful to consider affect as a continuous process. While the process model (Gross 1998a) for affect highlights well the processes of regulation of both experienced and affect-expression, its linear nature may limit ways in which affect regulation is considered. If affect is considered as a dynamic and unfolding experience (e.g., Oravecz et al., 2009; Verduyn et al., 2009) it may be useful to assume that multiple processes can overlap or operate together. For example, individuals may attempt to suppress their physical reaction to a stimulus, while still attempting to regulate their experienced state through reappraisal. Similarly, the strategy chosen to engage in for regulation may be subject to dynamic changes – one strategy may supplant another.

Following on from this, deliberate affect regulation is thought to be both costly in terms of self-regulatory resource and impacted by self-regulatory resource depletion (e.g., Hagger et al., 2010; Muraven et al., 1998). Resulting dynamic changes to self-regulatory capacity may result in the abandonment of regulatory efforts towards a goal during a period of regulation (e.g., Baumeister, 2002). Dynamic changes to self-regulatory capacity could even potentially steer individuals' regulatory strategy choice; less resource intensive strategies could be favoured during periods of depletion. Given sufficient demands on self-regulatory resource, a narrow band of appropriate affective expressions could, instead of limiting expression variability, as suggested by Diefendorff and Gosserand (2003), create a greater variability of expression, once display standards are not adhered to.

Affect regulation is frequently characterised as a process of reducing the difference between what individuals currently feel with goal states for feelings, or the difference between expressions and expected expressions (Carver & Scheier, 1998; Diefendorff & Gosserand, 2003; Larsen, 2000). This reflects the broader trend of examining self-regulatory behaviour as a whole as the process of discrepancy reduction, through means of self-monitoring progress towards a held goal (Baumeister et al., 1994; Carver & Scheier, 1982; Powers, 1973, 1974). It may even be considered that social sharing of affect and affective expressions serve such a purpose; affective expressions communicate to others and can shape their affect, thoughts or behaviours. This approach of viewing affect regulation as progress towards held affect goals allows for a broadening of the examination of the processes of regulation. These held goals of what individuals want to feel do not by any means have to remain stationary; individuals can shape what they want to feel according to the perceived utility of a particular affect state at that time (e.g., Tamir, 2003). More generally, if a discrepancy is prolonged between a perceived state (such as what is felt or expressed), and a reference point (such as a goal state for feeling or expression) efforts are made to reduce this discrepancy by bringing the reference closer to the perceived state, implying goal adjustment (Carver & Scheier 2001; Powers, 1974).

Moreover, these processes are not implied to be distinct and separate from one another. While felt-affect and affective expression are examined separately in this chapter, it must be stressed that there are evident shared links between them (e.g., Mauss et al., 2005; Soussignan, 2004), forming a cyclical influence. A cyclical influence is not just restricted to the aforementioned example; affect-expression can shape the social environment and the affect or actions of others. This change in turn shapes the environment experienced, impacting on affective states and moderating any need for regulatory efforts to be made. Further changes to what may be considered a complex system in the form of competing pressures from non-aligned felt-affect and affect-expression goals may shape affect dynamics; again, these may be subject to continuous and cyclical influences from changes in self-regulatory capacity and environmental changes. Figure 2.1 overviews the interrelated nature of the different aspects of affect regulation reviewed in this chapter.

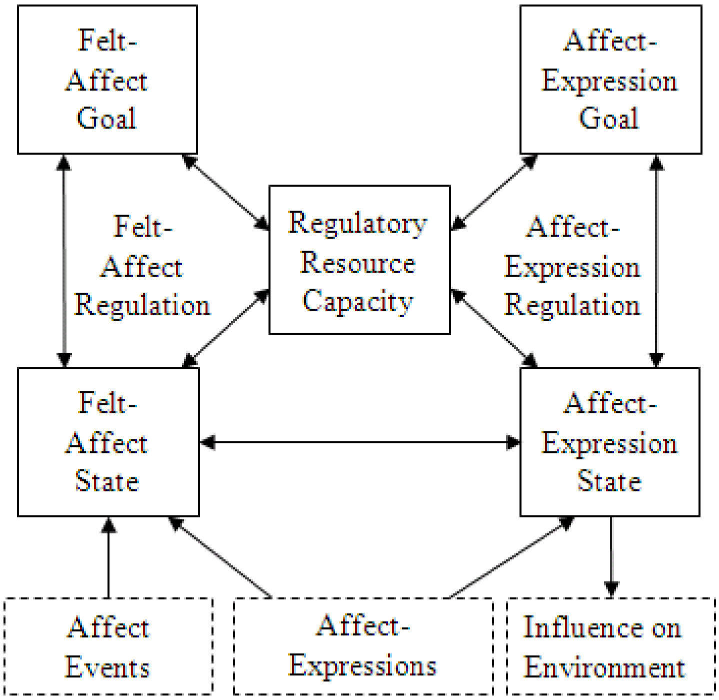

Figure 2.1 Overview of affect regulation, self-regulatory capacity (resource) and affect goals

Solid boxes denote intra-individual processes; dashed boxes denote environmental or inter-individual processes; arrows denote proposed existence of relationships between processes.

Given the prevalence of recurrent and cyclical relationships described in the literature and represented in Figure 2.1, traditional investigatory methods may be restricted in their capacity for exploring continuous, dynamic phenomenon such as affect and affect regulation. Chapter 3 offers a framework for exploring the relationships between affect, self-regulatory capacity, and affect goals based on control theory and offers computational simulation as a method for representing complex dynamics.

Chapter 3: Investigative Framework

3.1 Introduction

Chapter 2 highlighted several issues arising in the current literature that are yet to be integrated within a unifying explanatory framework. These issues include but are not limited to: the dynamics of affect regulation and dynamics of affect regulation strategy selection, the capacity for affect regulation across time, resource competition between alternative affect regulation strategies, and change in affect regulation goals across time and in terms of self-regulatory capacity. In the current chapter, I outline a means of investigating these issues within a coherent framework to show how the outstanding issues and any overlap between them can be investigated in a single model.

The first section of this chapter outlines how the framework of control theory (e.g., Powers, 1974) has been regarded as a useful means of describing goal-directed, self-regulatory processes. Using this framework, I outline how affect regulation processes, described in Chapter 2, can be considered in terms of a control theory model. Existing descriptions of affect regulation that are based on a control theory approach are examined and the model proposed in this thesis is compared with these.

The second section of this chapter overviews the use of computer simulation as an investigative tool in psychology. Computational modelling of affect regulation is a relatively new and growing means of investigating the processes involved in affect regulation (e.g., Bosse et al., 2010). The benefits of using computational models and simulated experiments, in terms of specifying hypotheses and generating new lines of inquiry in the dynamics of affect, that are beyond the reach of traditional methods of investigation, are described. Existing simulations of affect regulation are discussed and the requirement for a further model examining affect regulation dynamics is outlined.

3.2 Control Theory

This section overviews the use of, and further potential for, control theory as an investigative framework for affect regulation. Affect regulation, like other forms of self-regulation, can be considered in control theory terms as a dynamic, goal-directed process, of changing states and goals. Control theory presupposes that information gained from comparing a present state (such as a person's current status in a weight-loss diet) and a goal state (such as a target weight) is fed back to effect changes to the present state accordingly. Through examining affect regulation as the change of affect towards a specific state or goal, control theory can be used to demonstrate how the dynamic processes involved in affect regulation can influence one's current affect states. Affect regulation in control theory terms is examined in section 3.2.2.; however, first, I outline some key principles of control.

Control theory provides a structured framework for examining dynamic systems. As part of the field of cybernetics, it examines the process of feedback of information from a system's output to typically ensure stability in an observed state (Wiener, 1948). Its modern origins lie in the need for creation of stability in mechanical systems, such as that of controlled flight (e.g., Ashby, 1961). Disturbances or deviations in a system's behaviour, such as a sudden gust of wind affecting an early aeroplane's stability, needed to be overcome, if a stable flight was to be maintained. A control loop, which feeds back corrections in a closed system, offers a means for real-time changes to be made in response to, or even in anticipation of, disturbances, to ensure that a system remains stable in a dynamic environment (e.g., Clark 1996).

A commonly-used example of a control loop, perhaps because it is an everyday, simple, working system, is the thermostat in a central heating system (e.g., Barone, Maddux, & Snyder, 1997; Carver & Scheier, 2001). A functioning thermostat compares measurements of room temperature against a specified reference temperature. If the measured room temperature is lower than the reference temperature, the thermostat sends a signal to heating systems to turn on and increase room temperature. This signal is maintained until the discrepancy between measured temperature and reference temperature is sufficiently reduced, at which point no further discrepancy is detected and the system does not need to act. The system here is termed a *negative feedback loop* because the system serves to reduce discrepancy between the measured temperature state and reference state.

This simple example above reflects just a small part of the dynamics involved in maintaining a steady room temperature. Events (e.g., a person opening or closing a window) may also impact on the state (in this case room temperature) that the feedback loop operates on. The thermostat responds to environmental changes by modifying its impact on the current temperature state: an opened window might cool the room, and be likely to create a discrepancy between measured temperature and reference temperature.

The heating system must resume working to reduce the discrepancy, even if its previous rate of work when the window was closed used to be sufficient to keep the room at the reference temperature.

The thermostat model may be further embellished by considering room temperature as a continuously changing value. Heat in a room dissipates over time to the outside environment; unless a continuous heat source is applied, the room temperature will fall back towards the cooler state of the wider environment (assuming that outside is cooler than inside). This wider environment's temperature state can be considered the room temperature's natural resting point. Disturbances to the recorded temperature, such as a large number of people gathering in a room, may drive recorded temperature upwards, beyond that of the reference point. At temperatures exceeding the reference point, the thermostat turning off the heating system could result in passive temperature control occurring, through the natural dissipation of heat. Alternatively, a combined heating and air-conditioning system, operated by the thermostat, could still actively regulate room temperature towards the reference temperature by cooling a hot room. This consideration of a dynamic variable that is controlled, in both positive and negative directions, is directly applied in representing affect regulation in section 3.2.2.

The complete system for a closed negative feedback loop of temperature regulation is shown in Figure 3.1. This basic example outlines how each moment in the system is dependent on preceding action and will shape forthcoming action. It is not a linear system in which instructions for procedure flow from left to right, in a simple, causal chain, where the output of a system could be considered the end result. Instead, causal relationships become harder to define as single, isolated entities, particularly as system complexity increases.

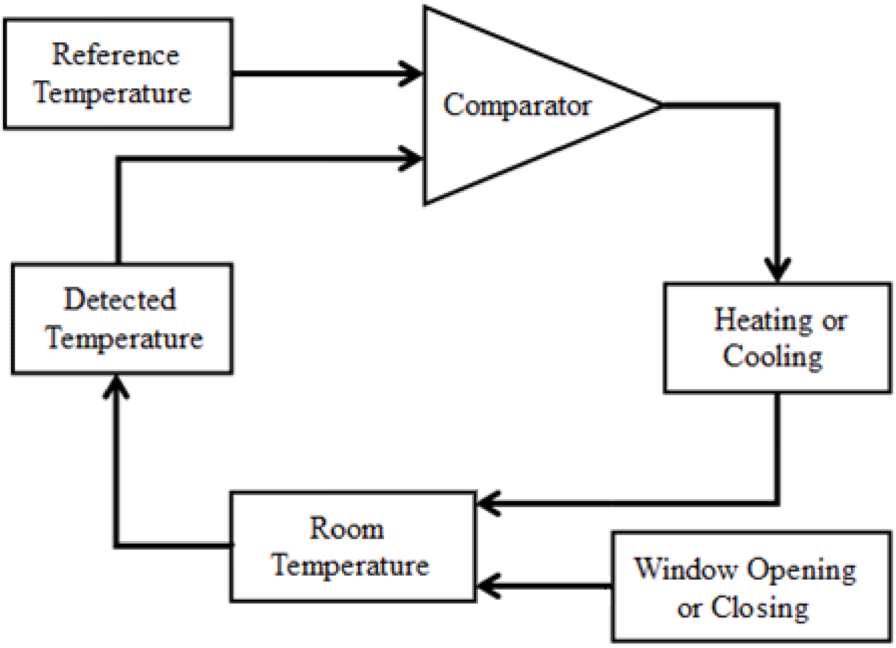

Figure 3.1 Complete control loop for a thermostat system

A discrepancy between the reference temperature and the detected temperature at the comparator drives changes (by heating or cooling) to account for external disturbances and maintain temperature at the reference state.

One means by which a temperature control system may become more complex is the existence of a second, competing feedback loop that also serves to influence the room temperature (e.g., Schmidt, 1988). For example, if, instead of the above model in which both heating and cooling are determined by a single system, two systems exist, one for heating and one for cooling, each with their own thermostats. The two systems' reference points could be specified at different temperature levels and so the effect of reducing discrepancy between room temperature and reference temperature in one system would act as a disturbance to the other system, creating a discrepancy in the second. Depending on the dynamics of the systems, room temperature might oscillate between approaching the two reference temperatures, or settle at an artificial point between the two incongruent reference temperatures (e.g., Powers, 1974).

A balanced system, where two control loops do not come into conflict can be achieved through further modifications. In the above example, the two systems reference temperatures differ, causing conflict in the overall system. Reference values, such as the thermostat's reference temperature, themselves can be changed in a control system, allowing for control to be achieved, even with the moving target of a changing reference value (e.g., Clarke, 1996). An elaboration of the control system to include multiple levels of control is offered by Powers (1974), in which the reference value for a lower level control loop is specified as being the current state of a higher level control loop. Using the thermostat example, a higher level of control in this system could be a person changing the temperature dial (i.e., reference temperature) on the thermostat to meet his or her goal of feeling comfortably warm. This concept of cascading changes to reference values in a complex control model, ultimately shaping the system's outputs at lower levels, is revisited in section 3.2.1.

Further to the process of cascading changes to reference values as a means of influencing a system's outputs, reference values may also be changed through changes ascending in a complex control system (e.g., Powers, 1974; Powers et al., 1960a, 1960b). A perceived discrepancy in a control loop is ordinarily reduced by changing the current state towards the reference value; however, if this is no longer possible, an enduring discrepancy may be reduced by moving the reference value towards the static current state (Figure 3.2.). This process of reference value change is argued to occur much more slowly than that of behavioural change, accumulating gradually (e.g., Powers, 1974). This could be conceived as an energy saving 'smart' thermostat, which gradually lowers energy consumption by reducing the reference temperature to levels closer to the room's natural resting point temperature. Again, this concept of changes to reference values is examined in section 3.2.1, in terms of self-regulatory capacity and goal pursuit.

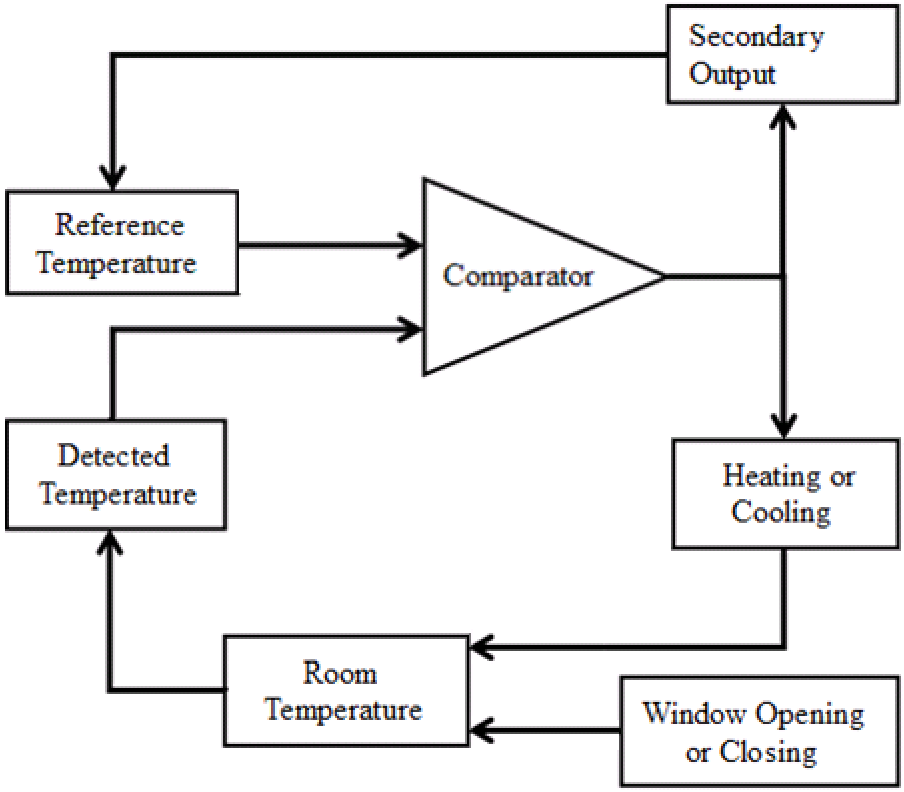

Figure 3.2 Complete control loop with a second loop for changes to the reference value As with Figure 3.1, detected temperature is regulated towards the reference temperature through adjustment of heating or cooling. Over time, a prolonged discrepancy between detected and reference temperature is reduced by regulating the reference temperature state towards the detected temeperature.

The representations of control shown in Figure 3.1 and 3.2 can be abstracted beyond that of a simple thermostat model. In general terms, the reference temperature would be considered a *reference value*, the output to heat or cool termed as an *actuator*, external factors such as a window opening or closing termed *disturbances*, the room temperature labelled as the *current state*, and the detected temperature would be labelled the *perceived state* or *input*. In terms of the generic control loop, a disturbance to the stable system is detected as a discrepancy between the current state and reference value, a correction in the form of a change to the output is necessary in order to generate a desired input. The principle of a negative feedback loop outlined above may be expanded to any number of systems that rely on correcting for changes introduced so that a perceived state is maintained at a reference value.

The adaptation of the control loop to suit wider contexts than just corrections to mechanical systems, alongside many other developments, can be seen in the broad field of cybernetics. Cybernetics encompasses systems that use feedback to achieve goals in recurrent patterns of sensing current states, comparing against goals, making actions to change progress, and then again sensing new states (e.g., Ashby, 1961; Wiener, 1948). Cybernetics as an interdisciplinary approach affords the study and development of feedback and control in many fields including robotics, computational neuroscience and psychology.

3.2.1 Control Theory in Psychology

Control theory, as described in the preceding section, allows for an understanding of systems in which processes are not just simple linear chains of action. Human behaviour, particularly goal-directed self-regulatory behaviour, can be considered to follow iterative steps of actions and self-monitoring of the changes made as a result of these actions (e.g., Miller et al., 1960). Regulation towards meeting held goals can be considered in terms of the closed feedback loops seen in control theory (Powers, 1974). In this section, I overview self-regulation, in terms of a control theory perspective, and look at two prominent control theory frameworks, which have influenced the study of self-regulation.

The processes of self-regulation can be seen across many aspects of psychology and physiology. For example, in a brain physiology analogue of the thermostat model offered in section 3.2, the anterior hypothalamus serves to contribute to body temperature regulation, appearing to act as the comparator, instructing physiological or behavioural changes in order to warm or cool the body (e.g., Magoun, Harrison, Brobeck, & Ranson, 1938). Other automatically regulated physiological processes include (but are not limited to): blood-glucose regulation (e.g., Jarrett, 1979), caloric intake (e.g., Adolph, 1947) and body-weight (e.g., Keesey & Powley, 1986). Regulatory processes extend beyond the automatic processes offered here, and include deliberate control towards held goals such as the intended modification of body weight through changing diet. It is in terms of controlled and effortful processes of self-control that this thesis examines self-regulation.

Control theory offers a template to examine both automatic regulatory processes and controlled, goal-directed self-regulation. Self-regulatory behaviours, such as dieting in order to lose weight require the formation of a goal and the monitoring of progress towards that goal. If behaviour is not monitored and appropriate changes to behaviour not enacted to move towards a goal, the whole process becomes little more than a vague intention to diet (e.g., Gollwitzer & Oettingen, 2011). In experimental designs, such as the Stroop task, the self-monitoring and control of behaviour is necessary to overcome over-learned impulses of word reading in order to meet the goal of colour naming (e.g., Macleod, 1991). Control theory concepts are also present in models within social psychology, such as Festinger's (1954) Social Comparison Theory. Festinger (1954) argued that individuals facing unclear situations with no explicit guide for behaviour, such as being part of a large crowd, compare their own behaviours to similar others and using these cues attempt to correct for perceived differences. Across a broad spectrum, goal-directed or self-monitoring behaviour can be examined within the framework of control theory.

Powers's Model

Perceptual Control Theory (PCT, Powers, 1974) is a framework for describing human behaviour, cognition and emotion in terms of control loops, such as those outlined in section 3.2 and variants thereof. Behaviour is regarded as the self-regulation of one's outputs from the actuator in order to experience the correct inputs perceived at the comparator. For example, the general model posed in Figure 3.1 may even represent physiological systems such as muscle tension. An individual carrying a stack of books in the library must maintain a certain degree of muscle tension in the arms to counter the constant downward pull of gravity. If another book is added to the stack (a disturbance to the system's equilibrium), the perceived change must be met with extra effort from the arms to continue meeting the goal of carrying the books (e.g., Powers, 1974). I now outline the framework of PCT, some of its key concepts, and highlight its use as a means of investigating goals in self-regulation and self-regulation processes.

PCT is built upon the foundation that there exists a hierarchy of control loops, in which reference values at the lower levels exist as perceived states which in turn are subject to self-regulation at higher levels (e.g., Powers, 1974). Changes made through self-regulation at higher levels result in a cascade down the system, enacting changes to reference values at lower levels. This structure enables a rich variety of possible goals to be held at many different levels of abstraction. In accordance with having multiple control loops at each level, lower level goals serve the purpose of making corrections to meet multiple higher level goals. For example, choosing to walk to the shops may serve both the higher level goals of taking some exercise and completing the week's shopping. Each of these may serve a higher level goal still, such as maintaining a healthy lifestyle. At the lower levels, goals are regarded as more concrete, rapidly changing and immediate, such as motor commands or simple procedural tasks. In contrast, higher level goals are viewed as being more abstract, more rigid and longer term, such as perceptions of held principles or generalised plans for behaviour. Powers (1974) offers nine levels in total for control, including system concepts (such as an idealised self-image), programs (chained sequences of action, analogous to Schank & Abelson's, 1977, scripts), and first order perceptions (sensory perceptions such as luminance detection).

One of the key concepts in PCT is the existence of conflicting goals. While people may have many differing goals, there are restrictions in the ability to pursue them all at any one time, due to the physical or cognitive limitations. This topic of resolving conflict has received extensive attention in recent years and is regarded as a fundamental question on human and animal behaviour that needs to be answered (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Conflict may be seen when one response is favoured, perhaps because it is over-learned or just an influential impulse, and yet another response is required. PCT argues that conflict detected at one level can be resolved by the adjustment of reference values at higher levels. The motivations for each response need to be assessed and readjusted to fit required behaviours. Powers (1974) argues that the experience of affect (or more specifically emotions) arises from internal conflict limiting capability to reach held references.

In control theory terms, conflict can be described as a product of the influence of one control loop on another. More specifically, conflict arises if regulating one perceived state towards its reference value causes another perceived state to shift away from its own reference value. Across the long term, it may become necessary to reprioritise control in the hierarchy so that the pursuit of different higher level references may alter the reference values at levels of experienced conflict to ensure greater coherence. Alternatively, the control hierarchy may need reorganisation to alleviate conflict. Reorganisation is the process of changing connections across the hierarchy to achieve higher level control through alternative means to that currently undertaken. For example, an injured athlete might continue his or her pursuit of excelling at a sport by coaching the next generation of athletes. Initial conflict between wanting to compete and yet being unable to is resolved by finding an alternate pathway in the control hierarchy that enables control at the higher level.

Carver and Scheier's Model

Carver and Scheier (1982) take elements of the framework offered by Powers (1974) to develop applicable models of control within social and health psychology. As before, illustrations of hierarchical control highlight how even simple motor commands could ultimately contribute progress towards higher level, abstract goals. In contrast with Powers (1974), Carver and Scheier's (1982; 2001) model is not built up from lowest level perceptual control to higher order control as a biophysical model of the brain. Instead, Carver and Scheier largely use the control theory framework of a hierarchy of competing control systems as models of cognitive processes (and affective processes, discussed in section 3.2.2) with varying tiers as different abstractions of the cognitive action examined. Carver and Scheier (2001) primarily consider regulation in terms of changes to the current state and goal state, offering a suitable template for examining the model of affect regulation dynamics put forward at the close of Chapter 2.

One key representation of regulation in Carver and Scheier's (2001) model is the use of information from the comparator to influence both the current measured state (via the primary actuator) and the goal state (via a secondary actuator). This model offers a means to reduce discrepancies between the current state and goal state through two means and is an adaptation of the model proposed by Powers et al. (1960a). Carver and Scheier (2001) focus on two controlled states 'behaviour' and 'cognition', with behaviour being at a level lower than cognition. They argue that should regulatory efforts in changing behaviour be insufficient to reach its goal (that of the cognition's current state) and an enduring discrepancy is created, cognition will be regulated to reduce the discrepancy and shift towards the current behaviour state. This is considered by Carver and Scheier (2001) to be the process by which higher-level control is temporarily diminished and behaviour becomes more poorly regulated (p. 239); lower level control is considered to be functionally super-ordinate during periods of higher-tier change towards lower-tier references.

Carver and Scheier (2001) do not specify the timeframe for a change in a higher-tier loop relative to changes at lower-tier loops; they simply say that higher change takes longer. They suggest that whenever a discrepancy is detected between the current state and the reference value, a small change is made bringing the reference closer (as shown in the extra loop at the top of Figure 3.2). The expectation in this model is that there may be many discrepancies between the state and the reference, some of which show the state to be greater than the reference and some lower. Over time, the small changes both in a positive and negative direction would not greatly affect the reference's position, providing progress towards the reference runs relatively smoothly. If a longer term discrepancy is present, then reference may be adjusted in one continual direction, slowly creating a changed reference to reduce discrepancy. Static inputs and prolonged periods of detected errors may arise from insufficient control, potentially as a result of fatigue, or from two conflicting references.

The representation of a higher tier of control becoming subordinate to a lower tier is considered by Carver and Scheier (2001) to be similar to that of self-regulatory failure offered by Baumeister and Heatherton (1996). While there are substantial similarities, Carver and Scheier (2001) represent self-control failure as disengagement with higher-tier control so that an individual would no longer be attending to the ideal goal for the self. The strength-model of self-control is broad enough to accommodate this as a model for self-regulatory failure but can also include an individual still being aware of the higher-tier goals and yet not engaging any regulatory efforts towards them (e.g., Baumeister et al., 1994). The proposed model of goal adjustment contrasts with Carver and Scheier's (2001) suggestion of diminished attention paid to inconvenient higher goals, suggesting that Carver and Scheier's (2001) model might be improved through a closer integration with the strength-model of control.

3.2.2 Application of Control Theory in Affect regulation

Control theory offers, as Carver and Scheier (1982, p. 111) describe, *"a useful conceptual framework"* for examining psychological processes. While the previous section examined control theory in terms of the general contribution to psychology, this section focuses on control theory representations of affect regulation. Control theory has proven to be highly influential, albeit indirectly, in shaping affect regulation research with Gross's (1998a) landmark model being based upon Miller et al.'s (1960) work depicting control loops (Gross & Thompson, 2007). In this section, I discuss an important divergence in representing affect between Powers's (1974) control framework and Carver and Scheier's framework (1982; 2001; 2004) and further examine a third control theory based model dedicated to representing of affect regulation.

Powers's Model

In models of control, a difference between the perceived state and reference is compared and the error corrected for; however, there appears limited academic attention paid to the nature of this intrinsic error signal itself. Powers (1974) addresses emotions, describing the feeling sensation as being the intrinsic error signal: existence of error is felt as being bad (i.e. negative valence affect). Powers (2005) goes on to describe that the pursuit of maintaining a perception at the reference is to, "*make the feeling go away*" (p. 257), suggesting that people seek to reduce emotional experiences because presence of emotion points toward prolonged errors. In an example offered regarding a person's chronic experience of anger, Powers (2005) offers means of regulating the affect state, which are strikingly similar to strategies listed in Gross's (1998a) process model: situation selection, situation modification and reappraisal.

The experience of emotion in the PCT framework is closely related to the experience of conflict within the hierarchy of control. Conflict arising due to the pursuit of two incompatible goals can result with neither goal state being reached, resulting in perceptions coming to rest at stable points away from that of references (Powers, 1974). Greater errors or errors regarded as most important to correct are considered to be associated with more intense emotional experiences (Powers, 2005). At times of conflicting states existing in the hierarchy, regulation of enduring error signal may be blocked for long enough for an abstracted feeling (such as muscle tension, elevated heart rate) to be perceived as emotions (Powers, 2005). Reorganisation of the control network may serve to reduce these experiences of conflict, although the process may invoke temporary error signals at levels of perception more core to the self. Research points towards this influence of goal conflict upon individuals' felt state (e.g., Emmons & King, 1988) suggesting that enduring conflict, particularly at higher levels (e.g., King & Emmons, 1991; Kelly, Mansell, & Wood, 2011), is detrimental to well-being.

Carver and Scheier's Model

While Carver and Scheier (2001) also look to the intrinsic error signal as the seat of affective experience, unlike Powers (1974; 2005), they suggest that felt-affect reflects the *progress* of error reduction. Their model of goal-directed behaviour broadens out the simple 'first order' control loop structure (the hierarchy outlined in section 3.2.1) to include a 'second order' control loop, which monitors the progress of the first control loop against a held goal of ideal progress rate. This second order control loop is regarded as affective information, meaning that, in their model, affect arises from perceived progress towards a goal. Faster progress than expected towards a goal elicits more positive feelings; slower progress than expected towards a goal elicits more negative feelings.

Affect experienced is then used as instruction to change progress rates towards a specific goal (e.g., Carver 2004; Carver & Scheier, 2011). Individuals wishing to reduce negative feelings would want to expend more effort while working towards a goal, whereas positive feelings allow for, and may even encourage, coasting and reducing effort expended while working towards a goal. In this instance, it is worth noting that there is a meaningful difference in positive (attractive) goals and negative (aversive) goals and that progress towards, or away, from these different types of goal is argued to be associated with different affect states. Faster progress than expected towards a positive goal or away from a negative goal respectively is argued to elicit elation and relief, while slower progress than expected towards a positive goal or away from a negative goal respectively elicits depression and anxiety (Carver & Scheier, 2011).

In this model of dual control hierarchies (a hierarchy of behaviour and of affect regulation), information is fed back on progress towards goals and an individual may then use this information to change effort expended towards goals or even to change the goals themselves (e.g., Carver & Scheier, 2001). Carver (2004) expands on this understanding to explain why people seek to limit affect experiences: people slow down and coast towards goals specifically to reduce positive affect so other important goals are not neglected. Failure to suitably temper goal progress when approaching a goal too quickly may be associated with maladaptive behaviour in individuals, such as that seen in bipolar disorder. Fulford, Johnson, Llabre and Carver (2010) report that individuals with bipolar disorder do not coast when exceeding expectations for goal progress to the same degree as control subjects, partially supporting the control model of affect. Unrestrained positive affect and the continual pursuit thereof may indeed result in the neglecting of other important goals, highlighting the maladaptive nature of a manic episode.

Limitations of Both Models

There are two main issues with the representation of affect regulation presented by these hierarchies of control. Firstly, affect is presented as an experience that needs to be limited, or restricted. Powers (2005) argues that emotions arise from conflict and the presence of persistent error, and exclusively focuses on negative emotion. Positive emotion is not associated with an absence of error because Powers (2005) describes this as an absence of conscious affective state. Carver and Scheier (2001, 2011), while approaching the topic of intrinsic error reduction by a different means, still point towards affect as a state that is restricted through regulation. Goal striving is argued to be increased or decreased so that affect states are regulated away, rather than affect being something that is regulated for its own sake. Moreover, empirical evidence (Holman, Totterdell, & Rogelberg, 2005) is not wholly supportive of Carver and Scheier's (2001, 2011) model as rate of progress towards goals shows some independence with felt-affect.

Hedonic models of affect (e.g., Larsen, 2000; Westen, 1994) argue that affect regulation directs affect towards more positive states rather than regulating them away. The frameworks offered do not appear to account for the active process of seeking out affective experience. Typically, hedonic views approach positive affect as the focus for people's regulation efforts: it can be assumed intuitively that people want to be happy (e.g., Larsen, 2000). Larsen (2000) outlines that certain affect states, such as feeling happy, are desired by individuals and that people may specifically regulate towards these states for their hedonic value alone. More broadly, individuals may want to experience a range of affect states (Labouvie-Vief & Medler, 2002), including regulation specifically towards negative states (Tamir, Chiu, & Gross, 2007), or not wanting to improve a negative state (Wood, Heimpel, Manwell, & Whittington, 2009). While the regulation of affect can serve a utilitarian purpose, such as individuals' increase of worry before a challenging task to improve task performance (Tamir, 2005), it still demonstrates that individuals are actively seeking affect states for their own perceived value rather than just seeking to diminish affect experience.

Secondly, in Carver and Scheier's (2001; 2011) conception, affect's purpose is solely expressed as means to guide progress towards held goals. The reaching of an affect state (other than the stable, limited affect experience) is not regarded as a goal within the vertical structure of the primary control hierarchy. Affect in Carver and Scheier's (2001; 2011) model appears to be considered a by-product of approaching goals, which is then used to inform progress. As described earlier, affect regulation may be explicitly sought out and there are numerous instances where affect regulation can be considered essential to the control hierarchy as it is necessary in meeting higher-tier goals (e.g., Hoschild 2003; Grandey 2000; Totterdell & Holman 2003). Carver and Scheier's (2001; 2011) model offers no account for such deliberate regulation of felt-affect or affect-expression as part of an integrated hierarchy of goal directed behaviour. An alternative method of describing emotional experience and expression within the control theory framework through the integration of these into the primary vertical hierarchy of control loops has been described by Diefendorff and Gosserand (2003).

Diefendorff and Gosserand's Model

The model of emotional labour offered by Diefendorff and Gosserand (2003) addresses one of the limitations outlined above: affect regulation can be purposeful as a goal in itself in order to work towards higher goals. Their model presents potential conflict between one's goal felt state and one's goal expressed state, a situation commonly faced by service industry workers, where genuinely felt-affect may not be appropriate for customer interaction (Hochschild, 1983). Diefendorff and Gosserand (2003) construct a sketch of a hierarchical model of four levels to represent potential points of conflict during affect regulation to meet affect goals required by the work environment. In the construction of this model they offer a series of propositions regarding the nature of affect regulation; many of these have evidently been derived as a result of the control theory approach used.

Some of the propositions posed by Diefendorff and Gosserand (2003) are specified forms of more generalised rules found in control theory. For example, "*Specific display rules lead to less variance in emotional displays… than general display rules*" (p.956) is an applied understanding of the more general rule that a fixed reference value should result in less variability in input than a reference value subject to change. Ascending changes to reference values in the face of an unsuccessful attempt to reduce perceived error through change at lower levels are also included. The model claims to offer, through the dynamic nature of control theory models, a more comprehensive account of affect regulation than that of more traditional, static models. The authors further suggest that their model offers a deeper level of understanding of observable results. They use, by way of example, Grandey's (2000) model, which argues there is a positive relationship between customer interaction and use of affect regulation. In comparison, Diefendorff and Gosserand (2003) model's offers to explain *why* this is the case, based on the greater occurrence of perceived errors in control and the subsequent requirement for more frequent error reduction efforts through affect regulation.

Limitations of Diefendorff and Gosserand's Model

Although Diefendorff and Gosserand (2003) offer a control theory framework model that places affect regulation at the forefront, there are still limitations to its use as an investigative tool in understanding affect regulation dynamics. Carver and Scheier (1982) describe the control theory framework as being the only means that they know of to successfully relate the micro actions of movements (such as expressions) with the macro aspects of abstracted goal pursuit (such as maintaining a positive self-identity). Where this is typically considered across nine levels of control (e.g., Powers, 1974), Diefendorff and Gosserand (2003) reduce this to just four, yet still appear to seek a similar scope of representation of behaviour.

Appropriate timescales are not considered in Diefendorff and Gosserand's (2003) model. As mentioned, their model, as a tool for making predictions regarding emotional labour, covers actions on the order of seconds or shorter, such as maintaining eye contact, and concepts that may endure across a lifetime, such as maintaining a desired self-concept (Diefendorff & Gosserand, 2003, p. 949). The practicalities of examining both short and enduring changes within the control model could serve to prove prohibitively complex. This may be reflected in the propositions made arising from the model's design, which largely focus on the middle tiers of the model and conflict between meeting personal emotional goals and work related emotional goals.

Further to this, Diefendorff and Gosserand's (2003) model is limited in its capacity to examine and make predictions regarding affect across time. Control models, by their design, reflect change across time (Miller et al., 1960; Powers, 1974) and their value comes from being able to represent complex dynamics that cannot be achieved otherwise. Diefendorff and Gosserand (2003) offer some predictions regarding affect dynamics; however these are lacking in specificity and consideration of how some aspects of the model may influence aspects across an extended period. Examples of influence of one aspect of the model on another over time are further considered in section 3.3. This representation of an active process of affect regulation and the associated unfolding conflicts between affect regulation for personal or for work related goals as a static, sketched model limits the model's utility as a predictive and investigative tool.

A New Approach in Examining Affect Dynamics

In summary, control theory can be used to describe complex recurrent relationships between multiple factors, such as those between affect, affect regulation efforts and the environment. A simple control loop can demonstrate that a linear causal relationship is not always sufficient to explain the behaviour of systems (Powers, 1973). Introduction of multiple control loops arranged as layers of competing systems may be able to generate complex, dynamic behaviour (Powers, 1974). In terms of control theory, affect is traditionally considered a secondary outcome, useful for monitoring the progress of goals and serving as indications to alter efforts towards reaching goals (e.g., Carver & Scheier, 2001). However, more recent concepts of affect within a control framework (e.g., Diefendorff & Gosserand, 2003) allow for affect regulation to be integrated into a hierarchy of control.

In recent years, it has been argued that understanding the dynamics of affect is an essential aspect of affect itself (Oravecz et al., 2009; Verduyn et al., 2009). While control theory offers an excellent framework for representing and understanding the dynamics of complex processes, such as affect and affect regulation, current control models (e.g., Diefendorff & Gosserand, 2003) do not extend beyond drawn sketches of static models. As a result of this, there are many questions and propositions left unaddressed regarding the dynamic nature of affect. In the next section, I overview a method of representing such models that addresses the dynamic aspects of affect regulation: computational simulation.

3.3 Computational Models

Computational models are a relatively underused approach for exploring questions about affect regulation. In this section, I outline some of the benefits that computational models offer over more traditional means of investigating affect regulation, the development of current computational models of affect and propose a further model of affect regulation dynamics built within a control theory framework

3.3.1 Advantages of Computational Modelling

Traditional means of examining affect regulation, such as correlational (e.g., Grandey 2003) or experimental (e.g., Gross, 1998b) studies have their limitations in understanding the processes involved. Some of these limitations will be described. Moreover, models constructed as pen-and-paper diagrams (e.g., Diefendorff & Gosserand, 2003; Larsen, 2000) designed to examine or explain affect regulation processes are limited by their reliance on implicit assumptions due to a lack of specificity or formalisation of constructs described. Unlike these informal models, computational modelling offers a means to create specific, testable predictions and explanations about the underlying processes for observed phenomena (e.g., Epstein 2008) such as affect regulation.

Limitations of Traditional Approaches

Correlational studies have proven to be an enduring means of examining affect regulation, particularly in workplace environments in which affect regulation is an everyday facet of occupations (e.g., Diefendorff, Croyle, & Gosserand, 2005; Grandey, 2003; Pugliesi, 1999). However, correlational studies have a significant limitation in that they only show that a relationship between variables exists. Correlations do not establish causality between variables or go so far as to explain underlying mechanisms by which variables relate. As a result, they are unable to answer such questions as: If one strategy for managing affect is more effective than others, why do individuals use a range of strategies of varying effectiveness, and how does the decision to do so arise? How do recurrent relationships between concepts, such as the need for and depletion of self-regulatory resource by affect regulation, impact on how affect regulation occurs over time?

Experimental studies offer a means to establish causality and so can be used to approach questions about affect regulation in different ways to that in correlational research. However, often in the pursuit of creating a controlled environment for experimental investigation of affect regulation, participants are exposed to situations which may influence the processes of affect regulation. For example, experimental studies indicate that antecedent focused regulation strategies, such as reappraisal of a stimulus, are an effective means of regulating affect both in terms of efficacy of affect change (Gross, 1998b) and cost of resource depletion (Baumeister et al., 2007). However, in laboratory settings, participants are often instructed in advance how to regulate their feelings, allowing individuals to anticipate affective stimuli and prepare regulation strategies (Sheppes et al., 2009). The cost of reappraising a stimulus might therefore be underestimated as a product of experimental design. The dynamics of unfolding affect, the efforts to regulate them and the interaction between them represent further challenges for experiments that either focus on affect as a static phenomena or as a linear system. Larsen (2005) catalogues a variety of means and methods to reflect the dynamics of affect, to which repeated data collection methods, such as diary studies, prove invaluable in better understanding affect.

Verduyn et al. (2009) argue that a full understanding of affect can only be achieved when dynamics are considered. As described by Diefendorff and Gosserand (2003), developing an account for the dynamics of affect change is a fundamental issue in affect regulation, as is searching for the deeper relations between affect regulation concepts. They argue that some of these relations may be predicted through the construction of informal models like their own. However, there are still many more assumptions within their model that are not stated, and several assertions that require testing across time. For example, their assertion that a narrow range of permissible expressions would result in less variation of expression than a broad permissible range would (p. 950); however, they also assert that a narrow range of expressions may require greater regulatory efforts than a broad range (p. 951). In turn, the greater expended effort may impede the ability to subsequently manage one's own expressions (e.g., Muraven et al., 1998), resulting in greater variability overall. The influences of each proposition in the model on the others are not considered by Diefendorff and Gosserand (2003) because propositions are not fully specified and assumptions in the model are left unstated.

Advantages of Computation

A computational model offers the opportunity to formally test hypotheses put forward by informal models. Within each informal model, there may lie a series of unstated assumptions about the nature of the relationships between concepts. By constructing a computational model and formally describing these assumptions, the researcher makes assumptions explicit and effectively creates specific, testable hypotheses (Epstein, 2008). Beyond this, computer models serve many other useful purposes, such as identifying new research questions and areas for data collection (Carley, 1999), testing plausibility of explanations (Stafford, 2009), and escaping limitations of intuitive or pre-conceived theories (Farrel & Lewandowsky, 2010a).

To focus on just one of the functions of a computational model, formalising predictions, I shall briefly revisit the informal model by Diefendorff and Gosserand, (2003). They propose a "*dynamic, process-oriented approach to understanding emotional labor*" (p.

945), and while their expansive model does successfully outline the problem of affect regulation dynamics, the underlying rules in the model for achieving this are left unstated. Simply put, their dynamic model of affect does not include mention of fundamental properties such as rates of affect change or timescales of affect and so faces issues outlined earlier in this section. A computational model introduces these rules and can address these issues by consideration of what Marr (1982) terms the *algorithmic level* of analysis.

Marr's (1982) proposal of the computational modelling approach itemises three levels of understanding a problem. First is the *computational level*: the problem undertaken and solved by the system (for example, engaging in affect-improving intrapersonal regulation). Second is the *algorithmic level*: the processes and representations necessary to function and achieve the aims outlined at the computational level (for example, detection of the current affect state and the comparison with the desired affect state). Third is the *implementation level*: the physical realisation of the model as both a plausible design and a functionally appropriate one for the task (for example, a negative feedback control loop that monitors errors and enacts change to the affective state). Diefendorff and Gosserand's (2003) model only exists as a top level of Marr's (1982) framework and so does not adequately specify *how* these operations occur, leading to propositions which may prove incompatible with each other. It is only through examination of such models at all of Marr's (1982) levels that such propositions of computation can be adequately examined.

Expanding on the use of computer models for informing data collection, computer models have potential for raising new research questions. Carley (1999) argues that computational models have a vital role to play in the continuing investigation of complex systems, such as group behaviour, and aid in understanding non-linear systems, where dynamic processes may interact. The generation of new hypotheses, which may not be immediately available via traditional studies, can occur through the running of virtual experiments in computer simulations. By specifying key parameter values in complex models, the outcomes of subsequent simulations based on these parameters can be used to inform further questions. Virtual experiments allow for testing systems that have high complexity, multiple interacting elements, impractically large sample sizes or even investigating dynamic behaviour. Carley (1999) demonstrates such a process in a large simulation of individuals' learning within an organisation, providing clear and testable hypothesis and predictions derived from simulated experiments.

A further benefit of simulated experiments and, more broadly, computational modelling, is the capacity to represent phenomena that may be too complex to examine in sum through more traditional approaches. Sun, Coward, and ZenZen (2005) regard computational models as being *"necessary to explicate the intricacies of the mind"* (p. 615), further arguing that research without the guidance of computational models representing complex processes is just the accumulation of data without a purpose. Lewis (2005) highlights affect in particular as being a domain that would benefit greatly from the representation in terms of computational, dynamic systems and that an integration of affective science and computational modelling would further help understand the complex process of affect. In the following section, I outline some of the computational models of affect to date that have shaped understanding of complex affect dynamics.

3.3.2 Computational Models of Affect Regulation

This section outlines some established computational models of affect dynamics and affect regulation. They vary in both approach and specific focus of investigation but share commonalties in their specification of affect in formal, mathematical terms and offer predictions or descriptions of complex affect dynamics. These computational models include connectionist models of affect transition (Thagard & Nerb, 2002), Bayesian networks of probabilistic affect states (Conati & Maclaren, 2009), complete agents in which affect supports behavioural choices (Maria & Zitar, 2006; Velazquez, 1997), fully embodied robotic representations of expression, such as Kismet (e.g., Breazeal, 2003), and even commercial attempts at simulating affect change seen in some computer games (e.g., Chaplin & Rhalibi, 2004). Outlined below are just three of the many models available, chosen because elements of each have influenced aspects of this thesis' proposed model.

Gratch and Marsella's Model

Gratch and Marsella (2001; 2004) aimed to integrate a model of emotion into a model of cognition, with the focus on designing human-like agents. Their model focuses on the appraisal of events to inform felt-affect, based on appraisal theories of emotion (e.g., Smith & Lazarus, 1990). An event that impairs progress or undoes the achievement of a held goal may be appraised by the model as a fear inducing event (Gratch & Marsella. 2004). This affect state is used as information to drive coping strategies based on the model's beliefs about the environment and its intentions for action. Affect, as well as being the modelled response to environmental change, is used to inform the model's plans and beliefs about the environment, ultimately shaping how it responds to environmental change in the future.

Gratch and Marsella (2004) structure their model to highlight the interaction between the environment and emotion through affective events and appraisals of these events. Affect events shape emotional responses through appraisals and affect responses are used to shape the experienced environment; this forms a complex relationship in the model between affect and the environment because a closed loop is formed. A strength of the model is rooted in this complexity because it enables the capture of dynamic responses to affective events that are contextual, based on prior experiences. Examples of this complexity between the influence of circumstances and affect on each other are addressed in Chapter 8, where multiple instances of this thesis' developed model are cast as agents in a network of two individuals.

One of the limitations of Gratch and Marsella's (2004) model comes from its wide remit of development. While this model illustrates appraisal of affective events and subsequent regulation of affect, these aspects are but a part of the model's operation, which extends to include: belief formation, planning, action, dialogue, and intentions (p. 278). As a result, this model serves to represent affect within the context of all these surrounding cognitive and behavioural processes and so exists as an extensive model, with many free parameters. This presents issues with the capacity for the model to make specific and scientifically useful predictions for affect regulation because the range of possible outcomes within the model is vast (e.g., Roberts & Pashler, 2000). Further to this, the model represents affect in terms of goal pursuit and, like the control models described in section 3.2.2, Gratch and Marsella (2004) do not consider affect as a goal state in itself. A further limitation to the use of this model as an investigative tool for examining affect regulation is that Gratch and Marsella (2004) focus on coping, which is considered to be less well defined in comparison with affect regulation (Parkinson & Totterdell, 1999) and too narrow to cover processes such as affect worsening (e.g., Parrott, 1993; Tamir, 2005).

Oravecz et al.'s Model

Oravecz et al. (2009) present a diffusion model of affect dynamics (DynAffect). This model differs substantially from the one presented by Gratch and Marsella (2001; 2004) in that it represents affect as a stochastic process rather than the outcome of a production system of structured rules towards held goals. Oravecz et al. (2009) represent affect as a random walk on the Russell Grid (e.g., Russell, 2003) about a focal point of the home-base. At any given moment in the model, the trajectory of affect is determined by the continuous decay towards the home-base and by the next step in the random walk. Parameter values in the model pertaining to the location of this home-base and the 'spread' of recorded steps around it are regarded as representing an individual's extraversion and neuroticism, respectively. Individual differences in these personality traits are said to shape the profile of the random walk created by the model: higher extraversion leads to a higher valence home-base and higher neuroticism leads to greater distance in the random walk from the home-base.

A strength of Oravecz et al.'s (2009) model is its foundation in affect data and the use of this data in the model to describe hidden trends in affect change. Higher intensity affect states are considered to more rapidly decay towards the home-base than that of low intensity affect states. This model further outlines that while affect might continually shift about the home-base of felt-affect intensity, the home-base itself shifts over time. A stronger fit of the collected data is seen to be achieved by the model if this shift in the home-base takes place. The affect home-base is modelled to drift over the course of a day, increasing slightly in valence as a day progresses and following an inverted U for activation. With just a few parameters, the model successfully offers a representation of affect changing across time.

However, the model offered by Oravecz et al. (2009) has several limitations from an affect regulation perspective. Firstly, the authors argue that influencing factors on one's current affect state, such as affect events and intentional, goal-directed affect regulation, are too numerous to adequately capture in a model. As a result, affect's trajectory across the day is arranged to be largely determined by random values. While perhaps not the intention of the authors, their design does imply that people are substantially limited in ability to shape their own emotional experience or even adequately change what they may want to feel. Building on from this, there is only one point in the model that affect tends towards, implied as a unique typical felt state each person ordinarily experiences.

However, individuals can drive their affect states to specific held states (e.g., Gross, 1998a; Tamir, 2005) and potentially away from this home-base. In this sense, the model offered by Oravecz et al. (2009) is limited in its capacity to represent affect regulation dynamics. At a more fundamental level, the probabilistic model of affect outlined by Oravecz et al. (2009) does not offer accounts of the processes behind affect regulation and how they may relate to outcomes of the model; it just describes affect change.

Bosse et al.'s Model

Bosse et al. (2010) have formalised a model for emotion regulation that was originally informally described by Gross (1998a). The model conceptualises emotion regulation as a dynamical system based on feedback loops correcting the current level of emotion towards an optimal level of emotion. The sensitivity of the feedback loops are argued to necessarily require an adaptation mechanism to allow for change during an emotional episode, a departure from Gross's model. Unlike Oravecz et al. (2009) but like Gratch and Marsella's (2004) model, this model accounts for changes in emotional states as a result of emotional events. Bosse et al.'s (2010) model is used to demonstrate several hypothetical scenarios through parameter adjustment, including: over- and under-regulation, adaptive change in regulation to reach an affect goal, and a response to training in improving a personal tendency to regulate behaviour (a model of anger-management therapy). Their model as a formalisation of Gross's informal model shows consistent agreement with predictions made by Gross (1998a).

Bosse et al. (2010) highlight the need for inclusion of costs to a model of affect change. This does not reflect the limited self-regulatory capacity (e.g., Muraven & Baumeister, 2000) or motivation (e.g., Alberts et al., 2011) models of regulation but is a step towards forming integrated models of affect. Bosse et al.'s (2010) representation of cost is associated with the model's changes to the 'willingness' to change an emotional state and so is removed somewhat from that actual process of regulating affect. Like the model by Oravecz et al. (2009), Bosse et al. (2010) present the affect state as tending towards a singular state over time, although in this model, the tendency for affect to change is regarded as wholly due to regulation. Because of this specificity offered, Bosse et al. (2010) also include affective events in their model, allowing for the representation of regulation of affect overcoming momentary disturbances in affect.

A limitation seen in Bosse et al. (2010) is the general lack of specificity regarding current model dynamics. While affect responses during regulation are seen to change, the timescale behind these changes is not clear. In one instance, a scenario is created for the model: a simulated response to an anger management therapy session. Angry affect in the model is seen to decrease once a parameter value for the capacity to change affect is altered to reflect this simulated 'therapy session'. However, without appropriate timescales represented in the model it cannot be determined if this is a rapid change or one across many days. This issue extends to the remaining tests conducted on the model and the regulatory processes during the models operation.

Bosse et al. (2010) also offer an open-ended suggestion for an extension to their model: an inclusion of dynamics to their static goal affect state. They acknowledge that a goal affect state can depend on specific circumstances and that people search for *emotional variation*. As with the Oravecz et al. (2009) model, there just exists one state that affect tends towards over time, which limits the model's capacity for representing affect regulation dynamics.

Affect Models Summary

Each of the models described above offers means to better understand affect regulation or affect dynamics. Gratch and Marsella (2004) and Bosse et al. (2010) share commonalities in examining changes in affect as a complex process and in terms of regulating the experience of affective events. Though they approach affect change from different theoretical backgrounds (coping and affect regulation, respectively), the most substantive difference is that Gratch and Marsella's (2004) model shapes future affective events through interaction with the modelled environment. In contrast, Bosse et al.'s (2010) model does not interact with the affect inducing environments, leaving the model as a more passive recipient of affect events. Gratch and Marsella's (2004) model offers a means to understand affect dynamics as part of a complex unfolding relationship between a modelled agent and the affective environment.

Both Bosse et al. (2010) and Oravecz et al. (2009) represent affect change as a stand-alone concept for investigation. Unlike affect as a response to, or indicator for, goal progress, as represented by Gratch and Marsella (2004), affect change or affect regulation are considered on their own terms. From this standpoint of examining affect irrespective of wider cognitive processes, Bosse et al. (2010) and Oravecz et al. (2010) diverge in focus. Bosse et al. (2010) examine affect regulation, in part, in terms of the cost of changing feelings; whereas Oravecz et al. (2009) examine affect change, in part, in terms of changing goal states, something that Bosse et al. (2010) consider valuable further direction for affect models. It still remains for an integrated model to examine affect regulation across: changing affect goals, a limited capacity for enacting affect change, and a complex interaction with the affective environment.

In summary, computational models, and particularly computational models of affect (e.g., Lewis, 2005), allow specifications to be made that turn underlying assumptions of a generally understood but not well examined aspect of a phenomenon into specific hypotheses (e.g., Epstein, 2008). In this instance, the dynamics of affect and affect regulation are yet to be appropriately examined as even computational models designed for the task do not yet achieve this. However, because specification is fundamental to a computational model, the approach at least makes clear the questions that remain unanswered. In the next section, I outline the necessity for a further model of affect regulation dynamics.

3.4 A Control Theory Model of Affect Regulation Dynamics

As previously described, affect regulation is a complex, dynamic process, which can be suitably understood through the framework of control theory (e.g., Carver, 2004; Carver & Scheier, 2001; 2011; Diefendorff & Gosserand, 2003; Powers, 1974; 2005). Control theory as a framework lends itself well to the study of phenomena through the development of computational models, given its origins in cybernetic theory (e.g., Wiener, 1948). Computational modelling offers a means for formal specification of assumptions in theories (e.g., Epstein, 2008) and avenues for greater explanatory power of the underlying processes involved (e.g., Lewis, 2005; Sun et al., 2005).

At present, there are many attempts made to represent and understand the dynamics of affect and affect regulation through computational models. In a sense, Bosse et al. (2010) have developed a computational model of affect regulation with origins based in control theory, given that Gross's process model (1998a) builds upon the test-operate-test-exit control system outlined by Miller et al. (1960). However, this approach sought to model one self-contained theory of affect regulation (i.e., Gross, 1998a) with ad-hoc expansion suggested in order to accommodate further development.

In section 3.3.2, elements of three existing models were outlined and identified as useful avenues for better understanding affect regulation dynamics. Here I describe how these, and further elements not yet addressed by current computational models of affect, are incorporated into a single control theory framework computational model.

Of primary interest to this thesis are the changes in affect regulation over time. In the strength-model of self-regulation, affect regulation is repeatedly demonstrated to both deplete self-regulatory resource and be impacted by a depletion of this resource (e.g., Hagger et al., 2010). Like Bosse et al. (2010), an effective model of affect regulation would include a 'cost' to controlled change in affect. However, unlike the approach proposed by Bosse et al. (2010), this cost may be better suited to a direct relation with the degree of control enacted (i.e., the extent and duration of regulation towards a held goal of a particular affect intensity) rather than associated with making changes to a 'willingness' to regulate affect.

This proposal for inclusion of a limited resource for affect regulation dovetails with that of the regulation of affect goals. Oravecz et al. (2009) propose that the goal state for affect drifts in regular patterns across days, although they do not consider the active process of deliberately changing affect goals. In a control hierarchy, the process of affect goal regulation would be considered a higher tier level of control and particularly useful as a means to limit resource depletion when standard regulatory efforts do not reduce discrepancy between experienced and goal states (e.g., Lord & Hanges, 1987, Powers, 1974). Individuals are known to seek a variety of affect experiences (e.g., Tamir 2005) and affect goals may appropriately be included within a structured hierarchy of actively pursued goals (Diefendorff & Gosserand, 2003). These held goals may in turn be incorporated into a wider understanding of goal-directed behaviour; however, at this stage, a model of affect change is considered a complex enough problem, particularly if active, changing goals are considered.

Further to the inclusion of self-regulatory resource and goal adjustment, an important aspect of understanding affect regulation dynamics is examining affect as both its felt and expressive components. As outlined in section 3.2., changes to the states of control loops can influence the current states in other loops (Powers, 1974), a process which has direct application in understanding the reciprocal influences of felt-affect and affect-expression. Moreover, felt-affect and affect-expression may be independently regulated to distinct held goals (e.g., Diefendorff & Gosserand, 2003; Hochschild, 1983) and these regulation processes have influence on the capacity to further engage in regulation (e.g., Muraven et al., 2000).

The development and investigation of affect regulation dynamics to include affect-expression regulation broadens substantially the scope for which affect regulation can be examined. While there is much to be examined in terms of the potential conflict arising between felt-affect and affect-expression drawing from the same, limited resource, further understanding comes from the model as an interacting agent with the emotional environment. A computational model including affect-expression makes room for examining the complete model as a social agent, alongside the individual processes within the model, leading to understanding affect regulation processes on what Sun et al. (2005) term multiple levels of analysis. As with Gratch and Marsella's (2004) model, an expressive agent allows for the shaping of the affective information that an agent receives. This is further explored in Chapter 8.

In this thesis, I present a new computational Model of Affect Regulation Dynamics (MARDy) that uses a control theory framework. Having identified the requirements for a computational model of affect regulation dynamics, the next chapter outlines the structure and development of a modular model of control that meets criteria for examining affect regulation dynamics, within the context of changing affect goals and a limited capacity for affect regulation.

Chapter 4: Model Design and Specification

4.1 Introduction

This chapter outlines the process of designing a computer simulation of affect regulation dynamics using a control theory framework. In Chapter 2, four aspects of affect regulation were examined: (i) the regulation of felt-affect, (ii) regulation of affect-expression, (iii) self-regulatory capacity, and (iv) affect goal regulation. In this section, I outline a visual representation of a computational model connecting these related aspects of affect regulation dynamics and the parameters used in the model.

This chapter has been arranged so that the requirements for each model section are presented first, such as the aspects of affect and affect regulation to be modelled, and then the approach for modelling the outlined aspects is described. The intention is to present each separate part of the whole model as a self-contained unit, which can be tested as an independent construct and then tested as part of the wider model. At the end of each section, the parameters used are listed alongside range limits imposed on them by the structure of the model. In Chapter 5, plausible ranges for these parameters are established, based on existing studies where appropriate.

The environment chosen to be used to simulate affect regulation dynamics is Simulink (Version No. 7.1) in the Matlab (Version No. 7.6.0.324) software. Simulink is an ideal environment for the design and running of control systems because of its graphical representation of systems. The visual modelling offered by Simulink allows for a clear and accessible means of representing recurrent relationships in systems, enabling a more direct comparison between the form of a computer simulation model and an informal 'box-and-arrow' model used in papers outlining affect regulation theory.

Across the literature, there exist a number of informal models of affect regulation, ranging from the small (e.g., Gross, 1998a; Larsen 2000) to the more comprehensive (e.g., Carver & Scheier, 2001; Diefendorff & Gosserand, 2003). The current model aims to outline the related nature of felt-affect regulation, affect-expression regulation, self-regulatory capacity and the adjustment of affect goals over time. Each of the substructures of the model is related to all others through a shared dependency on self-regulatory resource. This chapter outlines the development of a model from a sketched representation of affect regulation dynamics (Figure 2.1) towards a functioning computational model (MARDy schematic in Figure 4.1), which aims to capture the connected and related nature of self-regulatory systems in affect regulation.

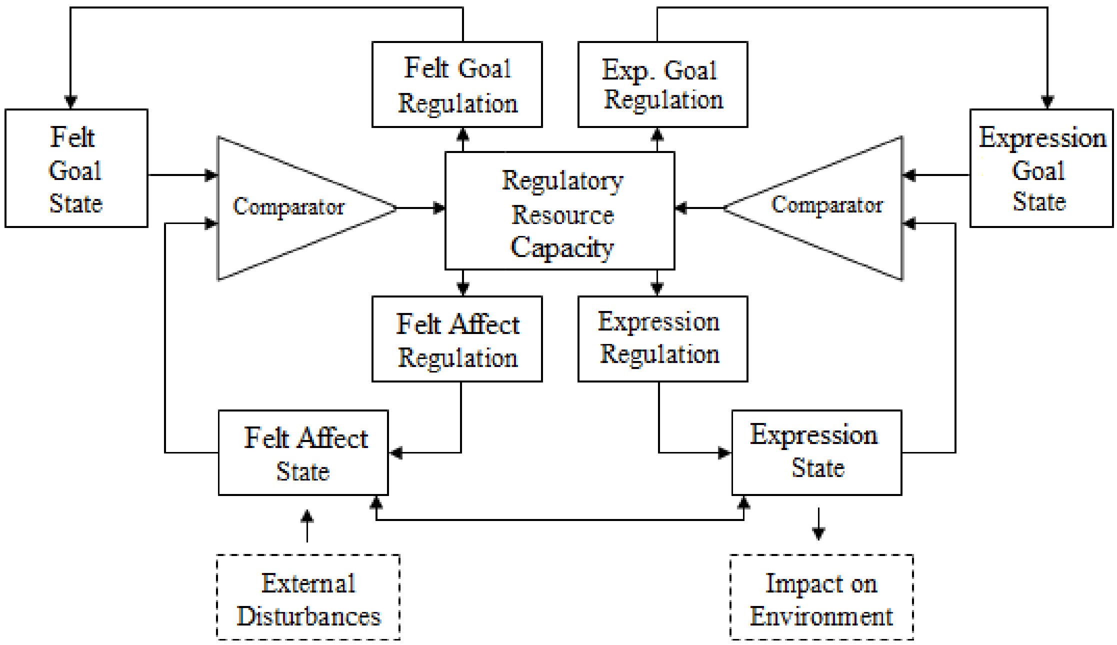

Figure 4.1 Schematic of MARDy

Representations of felt-affect regulation, affect-expression regulation, self-regulatory capacity (resource), felt goal regulation, and expression goal regulation are shown as two competing primary and secondary control loops. Solid boxes denote intra-individual processes; dashed boxes denote environmental or inter-individual processes; arrows denote proposed direct effects from one process to another.

4.2 Felt-Affect Regulation

4.2.1 Felt-Affect

This part of the model refers to the process of felt-affect change across time. Felt-affect dynamics are considered in terms of change due to affective events or expressions from others and the regulation of felt-affect towards a held goal state. For this part of the model, it is first necessary to consider how felt-affect can be represented in a simulation and how changes across time may unfold. After this, affect regulation, in the form of a feedback loop, can then be constructed to direct felt-affect towards particular held goal states. Characteristics of affect dynamics are highlighted in this section and representations of these are compared on their suitability for simulating affect dynamics in this model.

In this thesis affect is considered in terms of core dimensions (e.g., Russell, 1980, 2003, 2009) and within the proposed model, as varying valence intensities. Indeed, affective intensity is regarded as one of the most noticeable aspects of the experience of affect (Sonnemans & Frijda, 1994). Felt-affect intensity may be shaped by things such as the strength of a stimulus (Larsen, et al., 1986) and responses to affective stimulus have been mapped out creating intensity profiles over time (Sonnemans & Frijda, 1994; Verduyn et al., 2009). When considering the intensity of felt-affect, changes to intensity over time are considered a significantly important factor (e.g., Kuppens et al., 2010). Affective events play an important part in the model because they shall serve as disturbances to the current state, ultimately contributing to felt-affect dynamics (see also, affective events theory, e.g., Weiss & Cropanzano, 1996). Further aspects of affective events, such as the dynamics offered by the opponent-process theory (Soloman & Corbit, 1964), are examined in the testing stage of the model in Chapter 5.

Across studies examining affect intensity, an argument is made that, over time, felt-affect returns to a baseline level (e.g., Oravecz et al., 2009; Sonnemans & Frijda, 1994). Affective events may be considered to destabilise the felt-affect state about this base This is mirrored in the more general literature on well-being in which it is argued that individuals have a (mostly static) set-point for life satisfaction and that life events may cause deviations from this (e.g., Lucas, 2007). In terms of overall well-being, it is argued that people generally feel somewhat positive (Diener & Diener, 1996), whereas in terms of examining affect on a momentary basis, the general resting point for affective states appears to vary according to personality traits (e.g., Oravecz et al., 2009).

Requirements for a model of affect change in a control framework are straightforward. Aspects of felt-affect, such as valence can be represented as a bipolar scale from more positive to more negative, felt-affect intensity can be shaped by affective events and, over time, affect will return towards a baseline level. Processes such as these can be represented with a single formula, described in Section 4.2.3. However, before moving on to formally represent felt-affect, felt-affect's place in the felt-affect regulation control loop is examined.

4.2.2 Felt-Affect Regulation

As described in Chapter 3, self-regulation can be viewed from a control theory perspective as a means of reducing discrepancy between an observed current state of a system (such as felt-affect) and a goal state for the system (such as desired felt-affect). Across several different approaches felt-affect regulation is conceived of as just this (e.g., Diefendorff & Gosserand, 2003; Gross & Thompson, 2007; Muraven et al., 1998). Informal models also make this distinction, suggesting a distinct goal state as a plausible focus for regulation towards (e.g., Larsen, 2000). In order for successful regulation towards this held goal state, regulation efforts must be sufficient to overcome any influence pushing felt-affect away from the held goal state.

Given the decision in section 4.2.1 to consider current felt-affect as a point ranging from more positive to more negative valence, as argued in Russell's (2003) model of affect, a goal affect state can also be considered by a point on the same range. The distance between these two points can then be considered the discrepancy between the current felt-affect and goal affect. The process of reducing this discrepancy between current and goal affect can therefore represent the regulation of felt-affect. It would be anticipated that a greater distance on the scale from the current felt-affect state to the goal affect state would be associated with more regulation effort expended (as will be explained in section 4.4).

As described in section 4.2.1, felt-affect may exhibit a general trend of decay of affect intensity towards a base state, as time passes (e.g., Oravecz et al., 2009; Verduyn et al., 2009). An existing model of affect regulation (Oravecz et al., 2009) subsumes self-regulation into the singular process of returning to a fixed home-base. This assumption removes the possibility of regulating towards a specific held goal state *away* from the point that felt-affect intensity decays towards. Unlike Oravecz et al.'s (2009) model, the current model offers two points for felt-affect to move towards: the home-base (through a passive decay of felt-affect intensity) and the goal state (through the active process of regulation). As a result, the current model offers predictions that the model by Oravecz et al. (2009) cannot; affective events of the same intensity will have differing influences depending on whether these events steer felt-affect towards the home-base, towards the goal state or away from both.

4.2.3 Representing Felt-Affect

The process of affect change during affective events and a gradual continual return to a specific base level may be represented mathematically in a recurrent formula in which the state of a single variable (in this case felt-affect intensity) and its derivative (change in felt-affect intensity) are represented. Three differential equations, as used in the literature, are examined below for their suitability for modelling affect in this current simulation.

In a simulation of affect dynamics, Oravecz et al. (2009) use a stochastic differential equation to model affects changes across time. Specifically, they represent affect as a randomly moving value about the home-base using an Ornstein-Uhlenbeck model; the process of constructing the model is outlined in Oravecz et al. (2009). This approach captures the general trend of felt-affect intensity returning to an approximate baseline from any given point, with higher intensities decaying at faster rates than more moderate affect intensities. The two parameters used in the differential equation represent the location of the home-base and the extent to which one's affect varies from this point, represented on an affect grid (e.g., Russell, 2003). For the purpose of their simulations, all affect events and processes such as self-regulation of felt-affect are subsumed into the stochastic movement and continual 'pull' of the home-base. Limitations of Orvacez et al.'s (2009) model are seen by introducing affect events in the form of a stimulus signal; using parameters specified for typical model operation, the introduction of even a low intensity persistent stimulus (i.e. an enduring affect event) can result in ever increasing affect response by the model. This outcome is not suitable for models required to represent every day affect dynamics, including response to affect events.

A second and alternative means of representing affect change using a differential equation may be achieved through use of a leaky integrator model. While retaining much of the same functionality as the above approach, such as a continual return to a home-base and rates of return dependent on felt-affect intensity, the approach also has the benefit of limiting the intensity of response to stimuli. Rather than having a parameter for the variation in felt-affect used in the prior approach, the leaky integrator has a parameter that represents the rate at which felt-affect changes so that regardless of the value of this parameter, response and input to the integrator remain comparable. This creates a transparent relationship between simulated affective events and simulated felt-affect intensity. One limitation of the approach is that the rate of affect change is the same for both affect response and decay back to a home-base, restricting this approach to either a model of rapid felt-affect change with affect events or a slower change in affect across a longer period of time.

A third means examined for representing affect is through a second order differential equation: a damped oscillator. Bennett (n.d.) outlines an approach for representing felt-affect intensity dynamics as a vibration of a damped spring; energy in the system, as indicated by oscillation amplitude, represents current felt-affect intensity. This method has advantages over ordinary differential equations because it allows for a richer means of modelling affect, capturing both felt-affect's rapid onset and gradual decay, and has been used in models covering an extended period of time (e.g., Chow, Ram, Boker, Fujita, & Clore, 2005). A limitation of this approach is the complexity necessary for modelling affect over time. In Bennett's (n.d.) model, the energy of the oscillations at their peak is needed to model gradual trends in affect change, rather than a rapid switching back and forth from one state to another if amplitude itself is recorded. Further to this, affective stimuli are required to be presented to the model as matching the natural frequency of the system or else the end of an affective event results in dramatic changes in felt-affect. Rounding errors in Simulink over time invariably result in the modelled affect becoming desynchronised with stimuli representing affect, resulting in diminished or even inverse responses by the model to affective events.

Across the range of possible means of representing affect, the leaky integrator model stands out as the most practical approach because of the necessity of a close relationship between response and affective input. Affect change is described by Formula 1, in which affect intensity (R) at time t is dependent on both the affect intensity at time t-1 and affective events (S) at time t; these values are weighted by a single parameter k, which determines the rate of change of affect. The home state, to which affect returns towards, is determined at a point in the model beyond this loop, which over time would return affect to a base state of zero.

$$R^{t} = k\,(S^{t} - R^{t-1}) + R^{t-1} \qquad (1)$$

Figure 4.2 shows a visual representation of the leaky integrator circuit in the Simulink environment. Formula 1 is represented by the feedback loop created from linking the centre of the figure back to the left side. The home state (H) is added to the perceived affect state outside of the differential equation loop, giving a perceived affect state dependent on both the differential equation (1) and the home-base (*H*). The saturation component of the circuit limits the model's maximum and minimum response to affective events at an upper limit of 1 (feeling most positive) and a lower limit of -1 (feeling most negative). Because the complete model is large, covering several different aspects of affect regulation, only a single dimension of affect, valence, is modelled here.

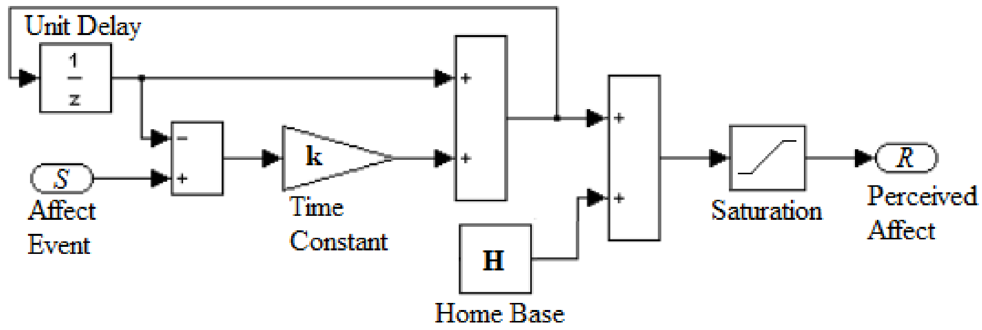

Figure 4.2 Model of felt-affect change in the Simulink environment
Information regarding affect intensity flows from left to right in the diagram, through pathways marked with arrows. Current affect (*R*) is determined by ongoing affect events (*S*), past affect intensity (held in the loop passing through the block labelled unit delay), and the home-base (*H*). The rate at which affect changes is determined by the time constant block (*k*), which acts as a gain on affect intensity passing through it.

4.2.4 Representing Felt-Affect Regulation

There are four parts to the control loop necessary for a model of self-regulation (e.g., Powers et al. 1960a). The first, perceived felt-affect state, has been introduced in section 4.2.3. The second, the goal felt-affect state, is examined more closely in section 4.5 and in this section can just be considered a constant value. The third and fourth parts to the control loop, the comparator and actuator, are described in this section.

Comparator

The comparator's role in the control circuit is the detection of a discrepancy between the current state and goal state (e.g., Miller et al., 1960; Powers et al. 1960a). This information regarding the existence of a discrepancy (or not) is then sent to the actuator so a change can be enacted. How the comparison between the current state and the goal is made is not considered important (Carver & Scheier, 2001, p. 11) in terms of the modelled implementation or the physical process to do so. The important aspect is that the comparator provides sufficient information to the actuator and that the control loop as a whole is recognised as a purposive system (p. 12).

I examine two means of describing a discrepancy between perceived and goal states. First, a discrepancy can be described as a simple detection of whether a discrepancy exists or not; the output of the comparator describes if the current affect intensity is higher or lower than the goal state. Second, a discrepancy can be described in terms of how dissimilar the two states are; the output of the comparator is equal to the difference between the two states. The choice between these two approaches may be considered as a choice between an analogue and a digital signal. Caver and Scheier (2001) discuss the distinction between analogue and digital means of control, although in terms of goal pursuit rather than individual components of the control loop. They come to the open conclusion that pursuit of higher levels goals could be analogue and programs (sequences of action) could be digital, endorsing Powers's (1974) propositions.

For the purpose of this thesis, a digital comparator is considered, given the special case of the actuator used to enable resource depletion effects, which is further explored in section 4.4. This also offers a straightforward means of testing Diefendorff and Gosserand's (2003) proposition regarding the different influences of a broad versus a narrow range of acceptable affective states on affect, by varying the sensitivity of the comparator. The alternative approach of using an analogue comparator would require the addition of further parameter values in order to broaden model testing to include tests of such propositions.

The logic used by the digital comparator to describe the current detected discrepancy is shown in Formula 2. A positive discrepancy, where the goal state (G) is greater in intensity than the current perceived felt-affect state (R) results in a positive comparator output (C), whereas a negative discrepancy results in a negative output.

$$G - R > 0 \Rightarrow C = 1, \qquad G - R < 0 \Rightarrow C = -1 \tag{2}$$

Actuator

Typically, the actuator's role in a negative feedback control loop is the input of stimulus to the current state to reduce the comparator's detected discrepancy between state and goal (i.e., reference state, Miller et al., 1960; Powers, 1974). Likewise, actuator outputs are dynamically adjusted to maintain the current state at goal level. This section describes a special-case actuator that, looking ahead to section 4.4 and representation of limited capacity for regulation, will not always have the capacity to maintain felt-affect at the goal level.

In control systems, the input from an actuator to the current state is a transformation of the discrepancy detected; typically, this transformation is *proportional* (input based on current discrepancy), *integral* (input based on past cumulative discrepancy), *derivative* (input based on current change in discrepancy), or a combination of any of these (e.g., Bennett, 1993). In a standard, analogue control loop, systems just using proportional control may exhibit a phenomenon known as *droop*, which is persistent-under regulation of the perceived state. As error is reduced towards zero, control influence is also reduced because the comparator signal decreases and subsequently, the held state does not ever reach the goal. An actuator with an additional integrator component corrects for this by increasing control based on all previous error and not just current error. With a digital comparator, proportional control can result in oscillations about the goal state; integral control, even without a proportional component, reduces oscillatory behaviour. Derivative control can reduce errors ahead of predicted disturbances but in both cases of analogue and digital comparators, can cause substantial control errors in presence of noise.

One type of controller is used in this current model: an integral actuator, modified from its more traditional use in control systems to form another leaky integrator system. This adjustment allows for representation of variation in the capacity to regulate affect as a function of self-regulatory capacity (further considered in section 4.4). Use of a standard integrator actuator indicates that once control reduces discrepancy and the felt-affect state reaches the affect goal, actuator input to the felt-affect state is stable, even if the actuator's capacity for regulation is altered. In contrast, use of a leaky integrator actuator indicates maintenance of the felt-affect state at the affect goal *does* depend on current capacity for regulation: insufficient capacity results in insufficient control and felt-affect drifting away from the goal state and towards its home-base.

Use of a leaky integrator actuator determines the choice for comparator. An analogue comparator results in persistent droop with the leaky integrator actuator design due to the decrease in signal intensity to the actuator when discrepancy decreases. In contrast, the digital comparator enables control of the felt-state to reach the affect goal (actuator capacity for regulation notwithstanding) because its signal to the actuator is not influence by the degree of discrepancy.

The described regulatory behaviour of the actuator is determined by a single parameter, *k2,* which, like the leaky integrator from section 4.2.3, determines rate of change in the leaky integrator. In the case of use in the actuator, this refers to the degree of change that the model makes in its regulation efforts, given a detected discrepancy. A low *k2* value represents a sluggish change in the model's regulatory action, leaving the model prone to under-regulation, whereas a high *k2* value results in a high level of oscillation in both the regulatory system and the felt-affect state during control; in the current model, this parameter is therefore termed *regulatory momentum*.

At this stage in model development, the output of affect regulation is determined by Formula 3. Affect regulation (*R2*) at time *t* is dependent on both the regulation intensity at time *t-1* and comparator signal (*C*) at time *t*, and these values are weighted by the single parameter *k2*, regulatory momentum. The output of the system is increased by a factor of two at a point in the model after the differential equation loop to enable regulation from the lowest affect point in the model to the highest.

$$R2^{t} = k2\,(\,C^{t} - R2^{t-1}\,) + R2^{t-1} \qquad (3)$$

Figure 4.3 shows a visual representation of Formula 3. In comparison with Figure 4.2, the model shows a differential equation with rate of change determined by a single parameter. In contrast with Figure 4.2, the system here does not have a parameter for home-base value to return to, so the system would return to a state of zero output (no regulation) if an absence of signal from the comparator persisted (no discrepancy). Further to this, the outcome of the differential equation is doubled to increase the range to which the model can regulate towards, covering the whole range of affect states from -1 to 1.

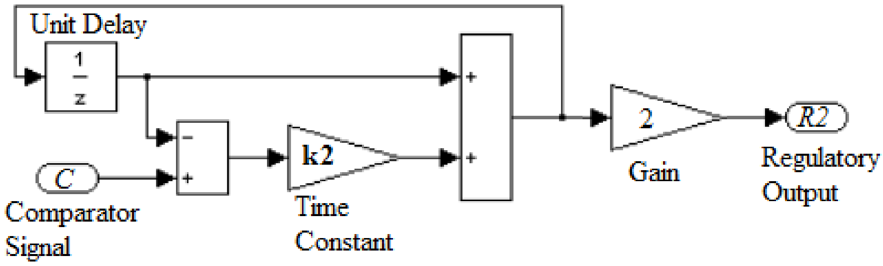

Figure 4.3 Model of felt-affect regulation change in the Simulink environment
Information regarding affect intensity flows from left to right in the diagram, through pathways marked with arrows. Current regulation (*R2*) is determined by the current signal of discrepancy from the comparator (C) and past regulation output (held in the loop passing through the block labelled unit delay). The rate at which regulation changes is determined by the time constant block (*k2*), which acts as a gain on affect intensity passing through it.

The complete system can then be represented in a single, simple figure, if the Figures 4.2 and 4.3 are represented as simple boxes that contain the two leaky integrator systems. The resulting system (Figure 4.4) is a control loop, such as that seen in the control literature (e.g., Powers et al. 1960a, p.76).

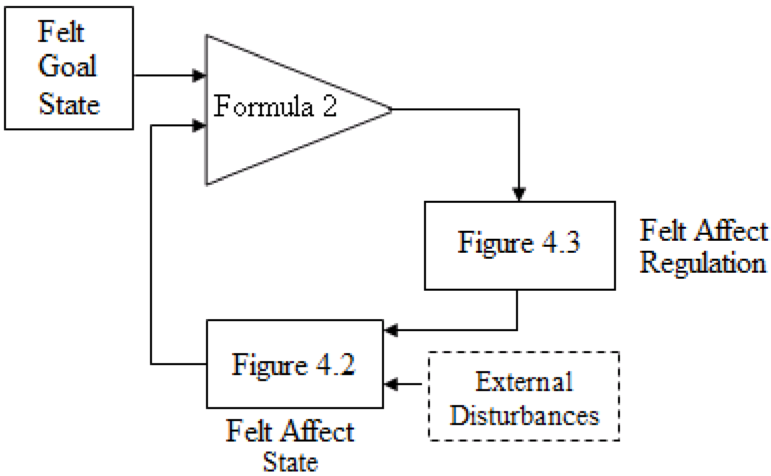

Figure 4.4 Complete control circuit for felt-affect regulation
Schematic representation of the felt-affect control loop. Felt affect state is determined by external disturbances, the current felt goal state and dynamics as a product of Simulink models described in Figures 4.2 and 4.3 and Formula 2.

As a conclusion of this section on the affect regulation loop, Table 4.1 details the parameters used by the current section of the model, their function and the limits imposed on their range by the structure and design of the model.

Table 4.1 Parameters used in the model of felt-affect regulation

Parameter Name	Parameter Symbol	Parameter Function	Parameter Limits
Felt-Affect Change Rate	*k*	Determines the rate of change of felt-affect.	Maximum < 1 Minimum > 0
Home-Base	*H*	Felt-affect resting point in absence of affect events or regulation	Maximum = 1 Minimum = -1
Regulatory Momentum	*k2*	Determines the rate of change of felt-affect regulation.	Maximum < 1 Minimum > 0

4.3 Affect-Expression Regulation

4.3.1 Affect-Expression

This section refers to the process of affect-expression change across time in terms of the current felt-affect and regulation of affect-expression towards a held goal. For this section, the relationship between felt-affect and affect-expression is reviewed and change in affect-expression through the process of emotional contagion considered. After this, the process of affect-expression regulation is then applied in the model to the affect-expression state. Decisions made in Section 4.2 in part determine the representation of affect-expression.

Affect-expression, like felt-affect could be represented as a number of differing discrete states based on facial musculature movement (e.g., Ekman & Freisen, 1971). Specific muscle movements have long been associated with unique expressive states; for example, the Duchenne smile, an apparent expression of authentic happiness, is characterised by the non-conscious movement of orbicularis oculi muscles (e.g., Frank & Ekman, 1993). This process was thought to be unique to the expression of genuine happiness, although recent evidence suggests that individuals can fake this expression on demand and that the authenticity of a smile can be determined even when the upper half of a face is obscured (Krumhuber & Manstead, 2009). Representing an exhaustively accurate model of authentic expression could require a multitude of controlled processes representing each of the facial muscles. Given the constraints of the output of the single dimension of affect valence from the represented felt-affect model, this was not a practical solution in the model.

As an alternative to the representation of affect-expression as discrete states, affect-expression, like felt-affect in section 4.2.1, can be represented as a single dimension of valence. While this restricts the scope and intricacies of expression and its dynamics at a micro-level (that of short-term or subtle changes of expression such as those described by Ekman, 1985), it still affords a general representation of expression over time in relation to that of felt-affect. From this, affect-expression and felt-affect are regarded in terms of their *relation* to one another, rather than considering the specific measuring of affect-expression in terms of its physical properties. This can be thought of as a degree of coherence with the felt-affect state. Expression intensity values on the measure of valence, which closely correspond with values of felt-affect indicate a high coherency between the two states and an authentic expression of affect; whereas, a mismatch between the two states indicates that there is a dissonance experienced and the presence of inauthentic expression (e.g., Grandey, 2000; Hochschild, 1983; Totterdell & Holman, 2001). This section therefore considers expression in a broad, general term of potential or probable expression. More advanced or complex adaptations of the model could allow for the outcome of this affect-expression state to operate as a goal for lower level control loops regulating the physical aspects of expression, such as that described by Diefendorff and Gosserand (2003).

There are two additional considerations for affect-expression in the model: first, the process of emotional contagion and second, a feedback mechanism from expression to felt-affect. Firstly, emotional contagion automatically shapes expressive states through processes such as expressive mimicry (e.g., Hatfield et al., 1994). This creates a distinction between the two external environment disturbances to the model: affect events, which only directly impact on felt-affect, and other's affect-expressions, which directly impact on both felt-affect (e.g., through cognitive appraisal of the expression, Hareli & Rafaeli, 2008) and affect-expression (e.g., through contagion, Hatfield et al., 1994). Secondly, the expressive state also shapes felt-affect through expressive-feedback (e.g., Buck, 1980; Strack et al., 1988). A link back from expression to felt-affect, as well as the existing feed-forward link from felt-affect to expression is therefore necessary to represent this established phenomenon.

4.3.2 Affect-Expression Regulation

Like the representation of felt-affect regulation in section 4.2.2, affect-expression regulation can be represented as a process of discrepancy reduction between a current state of expression and a goal state of expression (e.g., Diefendorff & Gosserand, 2003; Gross & Thompson, 2007). A goal state for expression is by no means restricted to matching that of the goal state for felt-affect; there are many situations that require the regulation of affect-expression while not necessarily requiring the regulation of felt-affect, such as that of emotional labour (e.g., Hochschild, 1983).

The process of expression regulation is often regarded as the creation of a discrepancy between affect-expression and felt-affect (e.g., Gross & John, 2003), often resulting in aversive outcomes (e.g., Grandey, 2003; Totterdell & Holman, 2003). This has been particularly well examined in terms of surface acting in the emotional labour literature (Goldberg & Grandey, 2007; Martínez-Iñigo et al., 2007). Aversive outcomes will be more thoroughly examined in terms of fatigue and emotional exhaustion in section 4.4 but in this section the discrepancy created is considered in terms of a hypothesised preference for authentic expression in individuals. Diefendorff and Gosserand (2003) describe, in their model of emotional labour, a held goal for "*Being true to one's feelings*" (p. 949), which is analogous to authentically expressing a felt state. Also, Grandey (2003) highlights that use of surface acting correlates with negative ratings of authenticity of expression. In this regard, affect-expression regulation can be considered as a process of regulating expression without substantially changing the felt-affect state. This process may include creating a discrepancy between felt-affect and affect-expression in order to reduce a discrepancy between current affect-expression and goal affect-expression.

4.3.3 Representing Affect-Expression

The main process of affect-expression that this model seeks to capture is the preference for congruence between felt-affect and affect-expression. This process is achieved by taking the concept of Diefendorff and Gosserand's (2003) description of a control loop for maintaining authenticity as a goal for expression and reshaping this to become a hardwired, unchanging element of the model. Affect-expression is therefore assumed to continually tend back towards a home-base unless active regulation towards a goal state is sufficient. This home-base for affect-expression is the current perception of the felt-affect state, resulting in a tendency towards coherency and authentic expression.

The model for affect-expression can be built based around the same principles used for the model of felt-affect. Given that affect events have been considered in section 4.2.3 as disturbances to the felt-affect state in a control system, expressions from others can also be considered as a disturbance to the affect-expression control circuit. In Formula 4, affect-expression intensity (*R3*) at time *t* is dependent on both the affect-expression intensity at time *t-1* and others' affective expressions (*E*) at time *t*. These values are weighted by a single parameter *k3* determining rate of change of affect-expression[1]. The home state for affect-expression, the perceived felt-affect (*R*) is shown in Figure 4.5.

$$R3^{t} = k3\,(E^{t} - R3^{t-1}) + R3^{t-1} \qquad (4)$$

Figure 4.5 shows the visual representation of the leaky integrator circuit for affect-expression. Formula 4 is represented by the loop on the left side of the figure. The home state is an input to the system taken from Formula 1 representing perceived felt-affect (*R*) and is added to the outcome of Formula 4. In addition to the outcome of this circuit as a representation of perceived affect-expression, a feedback link from affect-expression is sent to the felt-affect circuit, combining with the existing signals to the felt-affect system: the affective events and felt-affect regulation. This strength of feedback is weighted (*F*) to represent the influence that affect-expression has upon felt-affect. The influence of this positive feedback is discussed in section 4.3.4.

---

[1] While Diefendorff and Gosserand (2003) consider affect-expression states to be a lower tier of control (and therefore liable to more rapid change), the current model represents affect-expression in broad terms only and situates affect-expression on the same tier as felt-affect. Nevertheless, the potential for more rapid dynamics is acknowledged with use of a separate parameter for affect-expression rate of change.

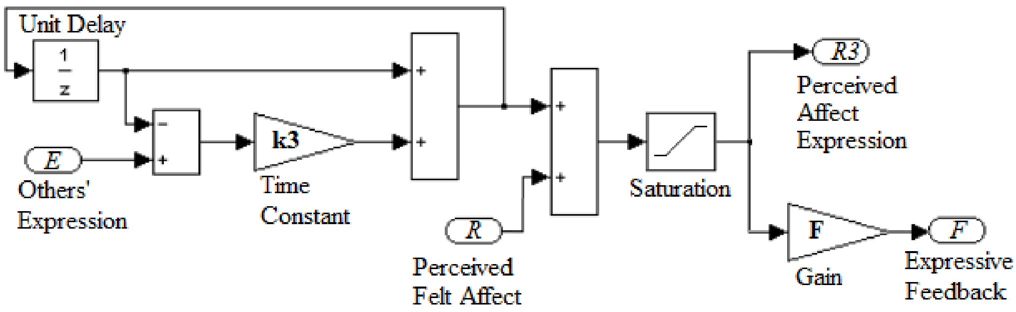

Figure 4.5 Model of affect-expression change in the Simulink environment
Information regarding affect-expression intensity flows from left to right in the diagram, through pathways marked with arrows. Current expression (*R3*) is determined by ongoing affective expressions from others (*E*), past expression states held in the loop passing through the block labelled unit delay), and the current perceived felt-affect (R). The rate at which expression changes is determined by the time constant block (*k3*), which acts as a gain on affect intensity passing through it. Feedback from affect expression to the felt state is determined by multiplying the current expressed state by a factor of F.

4.3.4 Representing Affect-Expression Regulation

As indicated in section 4.3.3, the established design for the felt-affect system can be adapted to suit the needs of the affect-expression system. The circuit's design for regulation is that of a generic, modular template, in which a system (such as Figures 4.2 or 4.5) can be interchanged and successfully regulated. The design intention of this is to keep the structure as simple and universal as possible to restrict the amount of individual assumptions and unique parameters for each section. As a result, the functional regulation circuit components of goal, comparator and actuator can be duplicated entirely to make a circuit for affect-expression regulation.

The regulatory circuit in section 4.2.4 introduces a single parameter, that of the time constant *k2,* determining the rate at which regulatory actions occur. A faster rate of change represents a greater degree of sensitivity to discrepancies and a larger output of regulation effort in response. In this section, a duplicate parameter for *k2* is created. The relative sizes of the regulatory constants for felt-affect and affect-expression regulation could be regarded as an individual's sensitivity to the two different regulation strategies, of reappraisal and suppression, respectively. This difference could reflect individual's preferential regulatory behaviours, for example being habitual reappraisers or suppressors, akin to the differences outlined by Gross and John (2003). For the purpose of parsimony in this chapter the two parameters (*k2* and its affect-expression regulation counterpart) are considered as identical.

In terms of regulation processes, the model now has two potentially competing goal states and the current affect-expression state is heavily dependent on the current felt-affect state (Figure 4.6). Moreover, there exists a feedback loop from the affect-expression state to influence the felt-affect state. Powers (1974) regards the interaction of one control loop on another as if it was any other typical disturbance. In terms of the loop formed by the influence of the affect-expression state to the felt-affect state, it is *positive feedback*. Positive feedback loops serve to destabilise control: a negative felt-affect state promotes a negative affect-expression, in turn increasing negative felt-affect in a continuous cycle. The existing negative control loops controlling both affective states must also serve to limit any runaway positive feedback effects; this is further explored in Chapter 5.

For the current design, two characteristics already emerge based on the structure of the model alone. Firstly, if both goal states are set at the same level, the model does not need to engage in prolonged affect-expression regulation (e.g., suppression) because affect-expression will be guided towards its goal through the changes made via regulating felt-affect. Once discrepancy is sufficiently reduced and regulation efforts are made to maintain felt-affect, affect-expression would be resting at the goal level without any need for affect-expression regulation. This may be considered akin to the effectiveness of deep acting reported in the emotional labour literature (Grandey et al., 2003).

Secondly, if the goals between the two states differ, then it becomes necessary for both control loops to engage in regulation as there would be a discrepancy between both held states and their goals. This may occur as an additional effort made to regulate affect-expression if the affect-expression goal is a higher intensity than that of the goal felt-affect state. If the goal states lie at the opposite ends of the valence scale, it may require a substantial regulatory effort in the expression loop. As the distance between these two goals increases, the greater efforts must be made to maintain a discrepancy between the two affective states; this process is further examined in section 4.4.

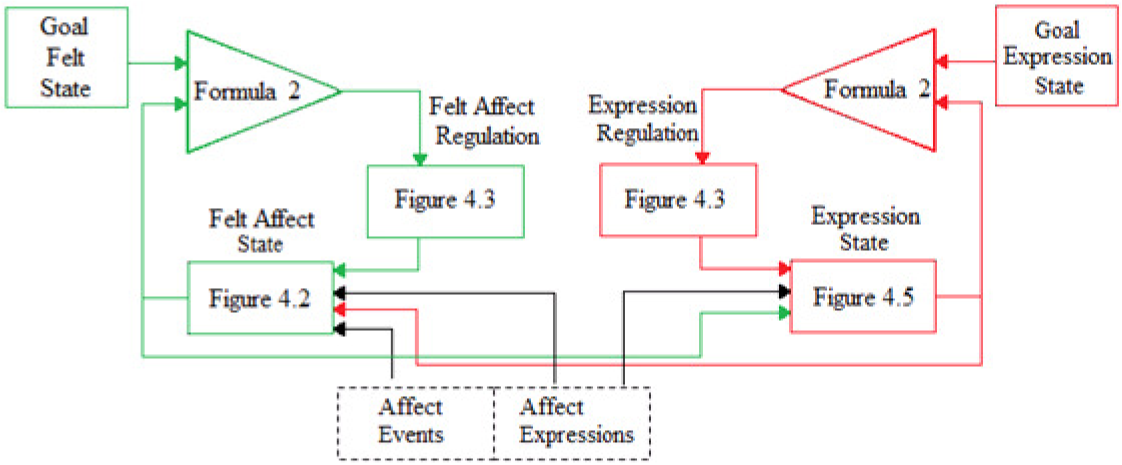

Figure 4.6. Complete control circuits for felt-affect and affect-expression regulation Schematic representation of the felt-affect and affect expression control loop. Affective states are determined by external disturbances, the current goal states and dynamics as a product of Simulink models described in Figures 4.2 and 4.3 and 4.5 and Formula 2.

Table 4.2 details the parameters used by the current section of the model, their function and the limits imposed on their range by the structure and design of the model. The minimum value of the expression time constant is dependent on the value of the felt-affect time constant reflecting the proposed faster rate of change. Regulatory momentum used in this section is the same as that outlined in Table 4.1.

Table 4.2 Parameters used in the model of affect-expression regulation

Parameter Name	Parameter Symbol	Parameter Function	Parameter Limits
Affect-Expression Change Rate	$k3$	Determines the rate of change of affect-expression.	Maximum < 1 Minimum $\geq k$
Expressive-Feedback	F	Determines expressive-feedback intensity to felt-affect.	Maximum = 1 Minimum = 0
Regulatory Momentum	$k2$	Determines the rate of change of affect-expression regulation.	Maximum < 1 Minimum > 0

4.4 Self-Regulatory Resource Control

4.4.1 Self-Regulatory Resources

There are two requirements for representing the capacity for regulation of affect in the model as it stands. Firstly, the capacity to regulate affect is considered to be dependent on a self-regulatory resource. Secondly, the process of affect regulation depletes this limited resource (e.g., Hagger et al. 2010). Harder tasks, ones requiring a greater degree of self-control, appear to result in a greater level of depletion (Hagger et al., 2010). In terms of affect regulation, as described in sections 4.2.2 and 4.3.2, this indicates that the greater the discrepancy between the goal state and the current affective state, the more regulation is necessary and therefore a greater depletion of resource. Similarly, an affective event which causes a disturbance away from the goal state will result in an increase in regulatory efforts to compensate for this, given that the purpose of the affect regulating behaviour is to prevent perceptions changing away from the references (e.g., Powers, 1974).

After sufficiently depleting regulatory efforts, subsequent regulation attempts are seen to suffer (e.g., Muraven & Baumeister, 2000). Resource is thought to be conserved and self-regulation activity is diminished. There are two means of representing this phenomenon and they have different implications for regulation. A threshold system may be introduced to the model; if a limited resource falls below a designated value of available resource, self-regulatory capacity is restricted so that remaining resource is conserved. Both felt-affect regulation and affect-expression regulation may have a threshold, below which the respective regulation efforts are limited. Dynamics of the model may then be structured around the relative levels of these thresholds, so that an individual may persist at one type of regulation longer than the other (for example, a customer service employee may persist longer with affect-expression regulation despite feeling depleted so that he or she meets job requirements).

Alternatively, the model for depletion can be structured so that a gradual depletion in resource is associated with a gradual detriment to self-regulatory capacity and thus regulation efforts. This process of a decrease in self-regulatory capacity, as measure in self-control tasks, being proportional to the self-perceptions or physical measures of depletion is indicated in ego-depletion research (e.g., Gailliot et al., 2007) and supported in Hagger et al.'s (2010) meta-analysis. Again, this consideration of using an analogue or digital representation arises in the model design, although, in this instance, the analogue representation has an unambiguous support in the literature; a gradual depletion process is implemented in the model.

As described in section 4.3.4, if the two goal states are congruent, then the model would tend to exhibit felt-affect regulation and not affect-expression regulation. However, it is plausible that as the capacity for felt-affect regulation begins to wane with the depletion of resource, the detected discrepancy between expression and goal expression generated by the movement of expression's home-base (felt-affect) is reduced through expression regulation. Expression regulation could therefore be both a cause and a symptom of resource depletion.

While depletion of resource has so far been considered in the model, it is also necessary to consider how resource is restored. Given that the model is designed to examine affect regulation across a multiple number of days, it becomes necessary to include a representation of resource restoration over an extended time. Across a long period of time, such as that of days, it is thought that sleep is the main mechanism for the restoration of the hypothetical resource and recovery of chronic depletion experienced through the pervasive need for regulation in everyday life (e.g., Baumeister et al., 1999; Gailliot, 2008; Hagger, 2010). Similarities between recovery from subjective or physical fatigue and self-regulatory fatigue are seen in these proposals.

4.4.2 Representing Regulatory Resource

An existing model of subjective alertness (the three process model: Åkerstedt & Folkard, 1996; Åkerstedt et al., 2004) is chosen to represent the daily cycle of self-regulatory resource. This model consists of alertness as a function of both a circadian cycle and the time since awakening. Alertness falls throughout the waking period due to the function representing time since awakening and is restored by its inverse during designated sleep periods. Sleep periods are determined by two factors, firstly through a manually set command to 'wake up' at a designated time. Secondly, if alertness reaches a specified level before the model is instructed to wake, it 'wakes' on its own accord (Åkerstedt et al., 2004). The model sleeps only when specifically instructed to, allowing for investigation into sleep deprivation, if required. Should the sleep/wake cycle not align with the circadian cycle, the model's alertness can vary substantially across a 24-hour period. For brevity, only a general description of the system is presented here, the formulae used in this current model representation of the three process model are presented in Appendix 1.

The output of this alertness model is used as an analogue for self-regulatory resource. The resource component implemented in the current control model varies from an output of 1 (maximum alertness) to 0 (maximum fatigue), and the output is used as a simple multiplier for the actuators' self-regulatory capacity. As a day progresses and resource depletes, the output from the actuator to the current felt-affect or affect-expression state decreases. The capacity to change affect decrease as the model grows fatigued and extreme states of fatigue result in a severely diminished impact from regulation on the current affective states. The self-regulatory capacity of the actuators is automatically restored, when the model restores self-regulatory resource through sufficient sleep. Regulation efforts and affective change are suspended during periods in which the model is asleep because no reasonable inferences in the model can be made about these processes at this time. Formula 3, the representation of affect regulation efforts, is modified to include the variable of resource capacity (*Rc*), to give resource capacity dependent control in Formula 5

$$R2^{t} = k2\,(C^{t} * Rc^{t} - R2^{t-1}) + R2^{t-1} \qquad (5)$$

As well as being dependent on self-regulatory resource, regulatory processes in the model are designed so that they deplete self-regulatory resource. The actuators output (Figure 4.3) is also fed to the alertness model's 'resource tank'. Both the outputs from the regulation of felt-affect and affect-expression are weighted so that a small amount of resource is used during the process of regulation (Table 4.3). This represents the depleting nature of regulation and the greater use of regulation coinciding with greater depletion. This use of, and dependency on, self-regulatory resource by the regulatory processes creates a closed loop between affect regulation and self-regulatory resource. Figure 4.7 outlines the closed loops between both forms of regulation and the central resource tank.

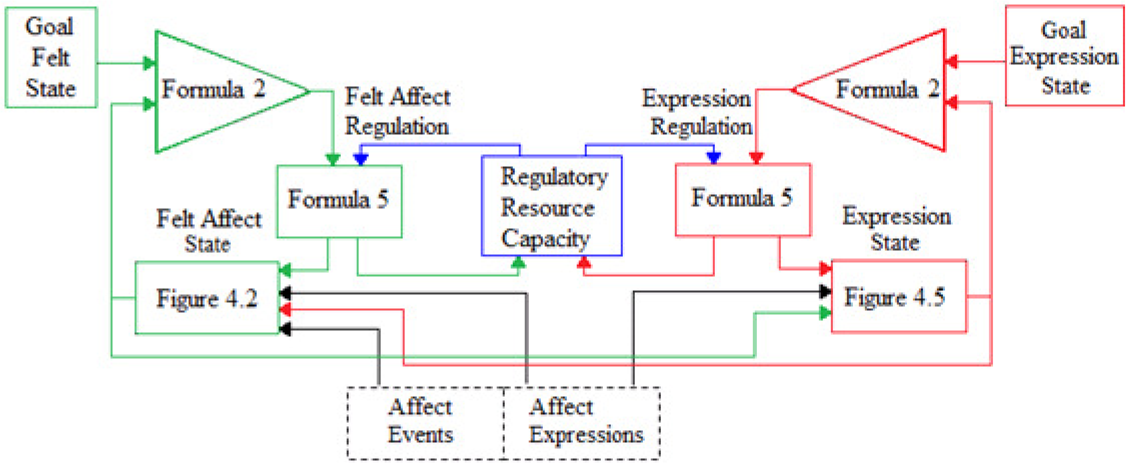

Figure 4.7 Self-regulatory resource included in the control circuits for felt-affect and affect-expression regulation

Schematic representation of the felt-affect and affect expression control loop. Affective states are determined by external disturbances, the current goal states and dynamics as a product of Simulink models described in Figures 4.2 and 4.5 and Formulas 2 and 5. The process of regulation drains resource from the Regulatory Resource Capacity block.

A number of predicted outcomes can be made, given the model's current structure. Rather than the control loops for regulation coming to rest at a stable state, as would be expected in the design seen in Figure 4.4, there is a continual change towards, or even away from the goal states, in this resource-dependent model. A particularly high intensity goal state could then result in sufficient resource depletion so that it is only pursued for a limited time before fatigue restricts self-reulatory capacity. Felt-affect's continual trend back towards the home-base may then no longer be overcome, effectively creating the observed behaviour of abandoning regulation towards a held goal. In contrast, a more moderate intensity goal state would require less regulatory efforts and so be maintained over a longer period of time. If a discrepancy between the two existing goal states is introduced, then, as described in section 4.4.4, the two regulatory processes need to both engage in regulation. This introduced discrepancy results in a greater use of self-regulatory resource and a more rapid onset of self-regulatory fatigue. The relative depleting nature of felt-affect and affect-expression regulation in the model is represented by the parameters seen in Table 4.3.

Table 4.3 Parameters used in the model for resource depletion

Parameter Name	Parameter Symbol	Parameter Function	Parameter Limits
Felt-Affect Regulation Cost	*Da*	Depletion of resource due to felt-affect regulation.	Minimum > 0 Maximum < ∞
Affect-Expression Regulation Cost	*Sa*	Depletion of resource due to affect-expression regulation.	Minimum > 0 Maximum < ∞

4.5 Regulation of Goal States

4.5.1 Goal States

Affect goals in the model have so far been described in terms of static references for the lower level regulatory processes. A control model may have tiers of loops, regulating a state to meet a higher goal, which in turn acts as a state to be regulated to meet a higher tier goal still (e.g., Powers, 1974). For example, the informal control model of emotional labour by Diefendorff and Gosserand (2003) has specific and concrete states at its lowest level (physical movement over a short term) which serve higher and more abstract goals so that at the highest tier, three levels above, the abstract process of maintaining a desired self-concept is met. It is in this light, of a tiered structure of changeable goals, that the process of affect regulation dynamics is examined in this section.

4.5.2 Goal State Regulation

One outcome of the system designed in section 4.4 is the now dynamic changes in the model due to self-regulatory capacity. As self-regulatory resource depletes, regulation efforts are impaired and the model may appear to reduce regulation efforts towards the held goal states. Higher intensity goal states require more regulation to reach as the discrepancy between them and the at-rest point of the affect states is larger. As it stands, the model will work towards these fixed states until depletion inhibits further effective regulation. However, further dynamics in the model may be introduced by considering the goal states as changeable values rather than fixed, broadening the range of affective goals across a day and subsequently testing a mechanism of goal adjustment.

Goal adjustment is considered a process of alleviating discrepancy in the model when attempts to reach a goal are unfruitful (e.g., Carver & Scheier, 2001; Lord & Hanges, 1987, Powers, 1974). Carver and Scheier (2001) suggest that the goal for a lower state is also regulated by the actuator via a secondary feedback link similar to that shown in Figure 4.1. This process is considered to be performed through making small changes to the goal value, which are maintained if they are successful in reducing discrepancy. Over time, a gradual decrease in the goal state towards the lower state's current value would reduce the discrepancy to more manageable levels. This process described loosely arises from the concept of reorganisation in perceptual control theory and makes use of its idea of a series of tiered control loops. If goal adjustment is unsuccessful in reducing perceived errors then more fundamental reorganisation of hierarchies may be required (e.g., Powers, 1974); however, this is beyond the scope of the current thesis.

When examining the hierarchy of control, formed by the inclusion of multiple, tiered control loops, it becomes necessary to consider which processes are active at any given moment. One of the guiding principles of perceptual control theory is the multilevel and parallel execution of control (e.g., Powers, 1974): control happens at the same time across all levels.

4.5.3 Representing Goal States

If goal states are considered to be flexible, changing components of the model, they cannot be represented by a static value as they have been in sections 4.2 and 4.3. Instead a changeable value, which can be altered through regulation, is necessary. For this, again, the leaky integrator mechanism is an appropriate representation. At rest, without any goal regulation present, the goal state sits at a predetermined value, given by a constant (*Hg*), a home-base for goals. This value would nominally be determined by a higher control loop, a potential third tier of the model; however, for simplicity it is considered as just a static value. Given that states in higher tier control loops are considered to be slower changing than states in lower ones (e.g., Powers 1974), an even higher tier control loop may be sufficiently slow to not show any change over the course of a simulated week. In terms of rate of change for this system it is considered to be slower than that of the lower tier control loop, establishing the need for another time constant (*k4*). There are not expected to be external disturbances to the system so the flexible goal can be represented by the simple schematic in Figure 4.8.

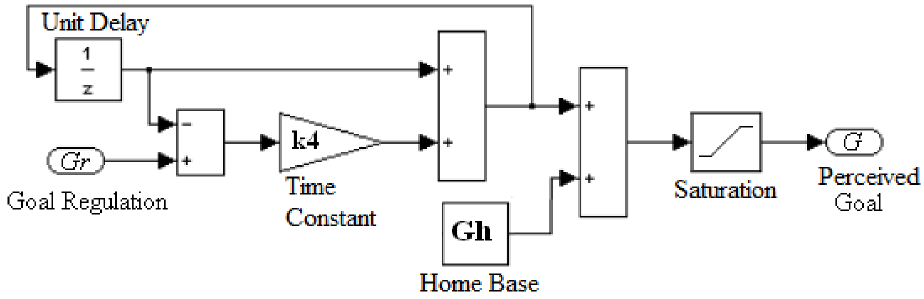

Figure 4.8 Model of goal adjustment in the Simulink environment
Information regarding affect goals intensity flows from left to right in the diagram, through pathways marked with arrows. Current goal state (*G*) is determined by ongoing affect goal regulation (*Gr*), past goal states held in the loop passing through the block labelled unit delay), and the home-base for the goal (*Gh*). The rate at which the goal changes is determined by the time constant block (*k4*), which acts as a gain on goal state intensity passing through it.

4.5.4 Representing Goal State Regulation

For the purposes of parsimony in this model, both the processes of goal adjustment for felt-affect and affect-expression are considered to operate in the same manner.

Carver and Scheier (2001, p. 151) describe '*meta loop*' which takes information from the comparator and, using a second actuator, adjusts goal states so that longer term discrepancies between states and goals are reduced. In the case of this current model, goal adjustment is considered to primarily occur during times of resource depletion, when discrepancies cannot be reduced through affect regulation. This design of adjusting higher goals to reduce discrepancy when lower states cannot be changed reflects proposed models of regulation (Lord & Hanges, 1987; Powers, 1974). Given the comparatively more depleting nature of more intense affect goal states, this represents, in effect, the process of adjusting more difficult goals to make them more achievable.

Affect goal regulation is represented with Formula 6. This formula is a modified version of resource contingent affect-regulation (Formula 5). There are two key modifications so that goal adjustment may be represented in the model. Firstly, signal from the comparator (*C*) is multiplied by -1; if in the control loop the comparator gives a signal of 1 (i.e., current state is less than goal state), the meta loop regards this as -1 (i.e., the goal state is greater than the current state). Secondly, the comparator signal is multiplied by resource depletion (1 - *Rc*) rather than resource capacity: greater resource capacity limits goal adjustment, while depleted resource capacity promotes goal adjustment.

This negative signal directs regulation in the meta loop in the opposite direction to that in the control loop, reducing discrepancy. The meta loop enacts changes when resource is depleted to reduce discrepancy because, during points of depletion, affect cannot be successfully regulated towards the held goals (Formula 5). This process of two parallel actions of reducing discrepancy reflects the process described in the control literature by (Lord & Hanges, 1987; Powers, 1974; Powers et al., 1960a, 1960b): with the persistent but unsuccessful attempt to regulate at the lower level, comes a change to reduce the discrepancy at the higher level.

$$Gr^{t} = k2\,(-C^{t} * (1- Rc^{t}) - Gr^{t-1}) + Gr^{t-1} \tag{6}$$

A further consideration for the system is that this operation is occurring as a means of conserving self-regulatory resource so the process of reducing a goal to more manageable, less depleting intensities: the process of changing affect goal intensity has no direct influence on resource. Instead, conservation of resource is seen on account of the affect goal's intensity adjustment because affect goals closer to the home-base for affect are less demanding to regulate towards.

The additional parameters used in representing goal regulation dynamics are shown in Table 4.4. The completed model is shown in Figure 4.10, with the added control loops for both felt and expression goal adjustment.

Table 4.4 Parameters used in the model of affect goal regulation

Parameter Name	Parameter Symbol	Parameter Function	Parameter Limits
Goal Change Rate	*k4*	Determines the rate of adjustment for affect goals.	Maximum < *k* Minimum > 0
Felt-Affect Goal Home-Base	*Felt_Goal*	Felt-affect goal resting point in absence of regulation.	Maximum = 1 Minimum = -1
Affect-Expression Goal Home-Base	*Exp_Goal*	Affect-expression goal resting point in absence of regulation.	Maximum = 1 Minimum = -1

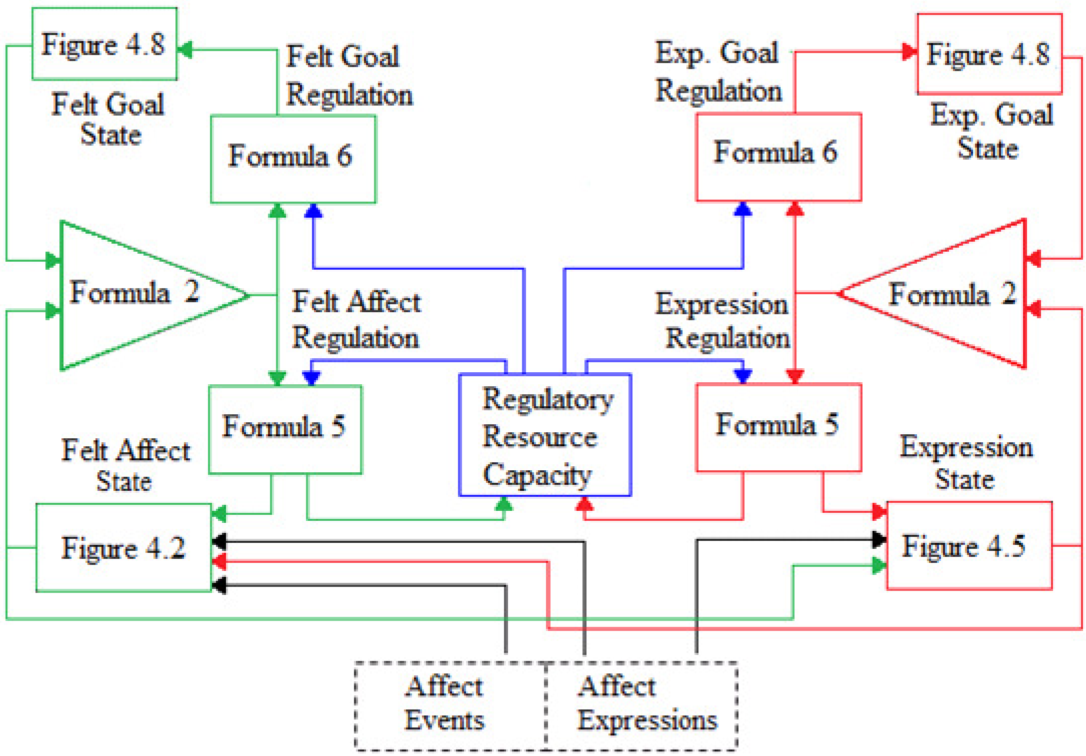

Figure 4.9 Representation of the complete model

Schematic representation of the complete model. Affective states and affective goal states are determined by external disturbances and dynamics produced by Simulink models described in Figures 4.2, 4.5, and 4.8 and Formulas 2, 5 and 6. The process of regulation drains resource from the Regulatory Resource Capacity block.

4.6 Noise and Parameter Variation in the Model

Across the model, there are a number of points in which noise in the system can impact on the system's behaviour. For example, the momentary perception of one's own affect state is unlikely to be a perfectly stable and accurate representation of the underlying core affect. Noise representing errors in perception may then be appropriate in the system as an input in the loop depicting affect change, shaping the overall input detected by the comparator. This difference between the perception of a state and the 'correct' noise-free underlying state can be more widely applicable so that at each comparator point in the model there is representation of a perception of the specific state.

In addition to this, noise may be applicable in the external disturbances introduced to the model in the form of affect events or affect-expressions from others. Again, perceptions of an affect event may differ across time and not be a stable nor accurate representation of its supposed 'objective' affective intensity. Noise introduced to the model at this point can represent such variation in perceptions of an appraised affective event. Even standardised affective stimuli, such as those in the International Affective Picture System (IAPS manual, Lang, Bradley, & Cuthbert, 2005) show substantial variability in their affective influence on individuals.

Finally, variations in the parameter strengths need consideration. As described earlier, individuals may have a preference for a particular form of regulation strategy (reappraisers or suppressors; Gross & John, 2003). Variation in the regulatory momentum parameters *k2* between simulations could represent the differences between individuals. Moreover, the costs of regulating both felt-affect and affect-expression could differ between individuals, as does the home-base for felt-affect and potentially the home-base for affect goals. Plausible ranges for each of these are considered in Chapter 5. While individual differences that may exist are not of primary concern in this endeavour to give a general representation of affect regulation dynamics, the potential differences between individuals may be worth bearing in mind for further model developments.

4.7 Summary

In this chapter, requirements for the development and implementation of a model of affect regulation have been outlined. Each sub-structure in the model has been constructed to meet the requirements presented to adequately capture the affect regulation and related phenomena examined in the preceding chapters. Further to this, the design of the model stays within the remit of keeping the number of free parameters limited, while still seeking to capture a broad range of behaviours and processes in affect regulation.

Working from the original, informal design offered in Chapter 2, using control theory framework in Chapter 3, this current chapter offers a formalisation of affect regulation dynamics. Parameter values, and the predictions associated with these, can therefore be examined in a structured and systematic approach through the means of examining influence of parameter variation on the dynamics of the model. This computational representation of affect regulation dynamics can be used to represent current known phenomena in affect regulation and offers a means of examining plausible affect dynamics in ways that informal models are not capable of. The process of testing the model against known data or informal models of affect dynamics is undertaken in Chapter 5.

Chapter 5: Parameter Testing

5.1 Introduction

Chapter 4 introduced the overall structure of the model and suggested how each individual component of the model may interact to simulate affect and affect goal regulation. While Chapter 4 may highlight that there are relationships and interactions between two values in the model (for example resource depletion may relate to a discrepancy between affect-expression and felt-affect states), the strengths of such relationships are still left to be determined. Appropriate parameterisation of the model is necessary to ensure that the model's behaviour faithfully reflects the phenomena modelled. This chapter details the systematic approach taken to identify parameter values that firstly, are in keeping with reasonable estimates based on theory, and secondly, provide model behaviour that can be compared with known, empirical data.

An organised, structured approach to testing the model will ensure that each parameter is adequately defined and, where possible, is grounded in relevant, existing data. An exhaustive exploration of each plausible parameter value against all others in the model is impractical because of the large numbers of parameters in the complete model and the factorial number of parameter combinations. This chapter outlines an approach that systematically identifies stand-alone components in the model for practical testing of low numbers of parameters and gradually builds up the complexity of circuits until the full model can be tested against empirical data.

5.2 Theory for Model Testing

This section offers an outline of the approach taken in this thesis to constrain the values of parameters within this model. Chapter 4 offered hard limits to the parameter ranges, based on the structure and design of the model; this chapter seeks to identify ranges of parameter values that reflect affect dynamics in the literature. Roberts and Pashler (2000) argue that for a model to be of value it must effectively constrain possible outcomes. They suggest that cognitive architectures, with many free parameters, such as the Adaptive Control of Thought model (ACT, Anderson, 1976) offer little in terms of theory development because parameter adjustments enable them to predict both **A** and **Not A**. If a model's predictions encompass all possible plausible outcomes, the fact it can fit results to known data offers no support for the model. An acceptable model design is dependent on having plausible outcomes that lie outside the range of possible model predictions. If actual, observed data then lie within the model's range of predicted outcomes, some support for the model is shown.

Parameter setting therefore should seek to constrain the possible outcomes of the model tightly: predictions from the model should result in narrow and specific results. Roberts and Pashler (2000) also suggest that with every additional parameter in the model a greater degree of flexibility in the range of outcomes occurs. A flexible model may be better able to fit more data but this may not necessarily provide any more support for the model because model results could have just been expanded to encompass the new data. Parsimony is therefore preferred.

However, having a large number of parameters does not automatically leave a model without merit. Louie and Carley (2008) argue that a large number of parameters, "*allows one to explore factors that are suspected but not yet known to have an influence on the target system*" (p. 254). Such models may be refined and simplified as better understandings of the modelled phenomena arise. The model in this thesis is designed with the focus of exploring a range of phenomena including: response to affect events; affect regulation effectiveness; and the rate of change of affect goals. This may inform future, simpler models or relationships in the areas examined. This exploratory approach may, in many cases, not have empirical evidence to compare against. Yet some circuits within the model may represent known behaviours that can be represented through parameter fitting. Although Roberts and Pashler (2000) argue parameter fitting is a weak approach for model testing, this has been challenged by others, who instead argue that fitting data is an important starting point for model development (Rodgers & Rowe, 2002).

Humphries and Gurney (2007) argue that data fitting is useful as a diagnostic tool. They outline a strong approach to the testing and validation of computer simulations, termed *models as animals*. They suggest that a model's quality can be measured by the degree of fit with empirical data by arguing that if the model does *not* fit existing data it may well be inadequate. They highlight four tiers of quality for fitting experimental data, each subsuming a lower tier (p.1892). First, by matching *trends*: replicating the correct direction in a relationship between variables. Second, by matching *means*: replicating mean changes in variables between experimental conditions. Third, by matching *distributions*: replicating the distribution of results across experimental conditions. Last, by matching *exact values*: replicating individual responses to experimental manipulation.

To achieve this, they recommend a framework of aiming to emulate not only the final outcome of empirical papers but also the procedure by which the results were collected. To this extent the sample size and method of collecting data is considered when running a simulation. While their framework is described in the context of neuroscience, it is applicable within the context of this thesis. For example, in section 5.4.5 trends reported by Franzen et al. (2008, p. 35) are replicated; in section 5.4.3, mean values reported by Strack et al. (1988, p. 772) are replicated; and in section 5.4.1, distribution of responses reported by Lang et al. (2005, p. 10-21) are replicated.

A consideration for the model is the potential for substantial variation across participants. This may include: differences in the effectiveness of their affect regulation strategies; their typical, or baseline, affect; and responses to affect events or stimuli. Variation reported in empirical data may offer appropriate limits or guidelines for the permissible variation within model parameters. For example, the IAPS manual offers both a mean valence and the standard deviation in participant affective responses to pictures (Lang et al., 2005, p. 10-21). A bank of data across a modelled group of participants may be compared to original, empirical findings to represent variations in responses to stimuli.

5.3 Model Testing

Testing is divided into two stages: setting parameter values based on theoretical constraints, and setting parameter ranges based on empirical data. The first tests specify a central value for each parameter that aims to constrain model behaviour to very narrow, theory-driven outcomes. The second tests aim to broaden the behaviour of the model by creating ranges of plausible parameter values around the initial, central value.

For both approaches to testing parameters, each component block of the model is isolated into the simplest circuit possible and plausible parameters are determined. The component blocks are tested in this manner for two reasons:

a. *Theoretical Validity:* If a component of the model represents a simple stand-alone behaviour outside the wider scope of the whole model (for example a dynamic model of affect regulation would necessarily contain a dynamic model of affect experience) it ought to be able to adequately represent such behaviour. Each component must be a valid representation of its purpose otherwise other components' behaviours are compromised.

The control theory literature suggests a hierarchy of behaviours; each higher layer impacts on the behaviour of those below it (Powers, 1974; Powers et al. 1960b). However, lower level behaviours can operate independently of higher control commands and the same low level activity may serve multiple independent goals. As lower levels can exist independent of the higher levels, a sufficient hierarchical model must be capable of modelling lower levels in an isolated circuit.

b. *Simplicity of Testing:* The results of testing a single parameter within the context of the whole model may be dependent on the values of each other parameter in the model. As a result, testing each parameter against variations of every other parameter becomes a factorial problem that could require an impractically large number of simulations to be run. A specific parameter may be highlighted as the optimal value but only within the context of all other parameters in the model but not necessarily a viable option if the component block is isolated and tested.

The above points suggest that an expedient and practical method of parameter testing is to work from the simplest, lower level operations, such as affect response to an event, upwards to the more generalised wider-reaching model components, such as the rate of resource depletion. The process of examining a model from its lowest structures upwards at the individual component level is outlined by Larsen (2000). This methodical approach can be adapted to fit a multi-layered, multi-pathway model by identifying the more basic, lower circuits as a starting point for testing parameters. Once these have been set, higher levels and more complicated circuits can be introduced, building on the established lower levels. The parameters tested and their locations are shown in Table 5.1.

Table 5.1 Outline of parameters to test and their colour coded location in the model

Parameter Test conducted	Parameter Location	Parameters Examined
Felt-affect Dynamics		
Felt-affect	Perceived felt-affect	Response variability
Felt-affect regulation	Felt-affect regulation	Regulation momentum
Affect-expression Dynamics		
Affect-expression and feedback	Perceived affect-expression	Feedback strength
Affect-expression regulation	Affect-expression regulation	Regulation momentum
Resource Dynamics		
Resource depletion	Resource control	Regulatory capacity Regulation depletion
Higher levels of control		
Felt-affect goal adjustment	Felt-affect goal regulation	Rate of change
Affect-expression goal adjustment	Affect-expression goal regulation	Rate of change

Many of the parameter tests listed in Table 5.1 may be thought of as small, stand-alone, investigations, an approach previously used in examining affect model plausibility. Bosse et al. (2010) evaluated their computer model of Gross's (1998a) informal model of emotion regulation through a series of self-contained scenarios. They track the model's *emotion response level*, analogous to this thesis' modelled felt-affect state, during periods of under-regulation, over-regulation, and appropriate regulation to highlight how variation in parameters causes change to modelled outcomes. For example, they offer a hypothetical scenario of an individual's response to anger management therapy. The outcome of the therapy is represented in the model by an increase in the parameter related to one's willingness to change the emotional state of anger. This change to the model's parameters in turn affects the emotion response level, reducing anger over time.

This thesis also presents parameter testing in the form of experimental investigation, where appropriate. This approach may prove a useful guide when investigating phenomena not commonly measured in the literature (such as goal adjustment rate) or when testing the limits of plausible outcomes against known outcomes. Specific parameter changes to affect the outcome of the model are regarded as predictions made by the model that can be compared against known data or serve as guide for what phenomena to examine when collecting data.

5.4 Component Testing

Components are tested in the descending order described in Table 5.1 to enable a progressive approach from the simpler, lower structures in the model to more comprehensive whole model tests. Each component is taken directly from the model shown in section 4.5.4 (copied as Figure 5.1 in this section) and each parameter test builds on the previous until the whole model is tested. Parameters in the following sections below refer to component *blocks*; these contain collected units, such as mathematical functions, which combine to form a specified and individual role within the model. Blocks may range in content from a simple difference comparison between values to that of a replication of Åkerstedt et al.'s (2004) three process model of alertness.

Where possible, parameter values are identified based on known data. In some cases, plausible estimates of parameter values are necessary, particularly where there is no available analogue in empirical data yet. In addition to this, an estimate of the interpersonal and intrapersonal variability can be offered for some parameters. Variability in the model is created by introducing a random modification of key parameters. For example some individuals may be more proficient at affect regulation than others; this may be modelled as variations between simulations in the parameter relating to regulation effectiveness.

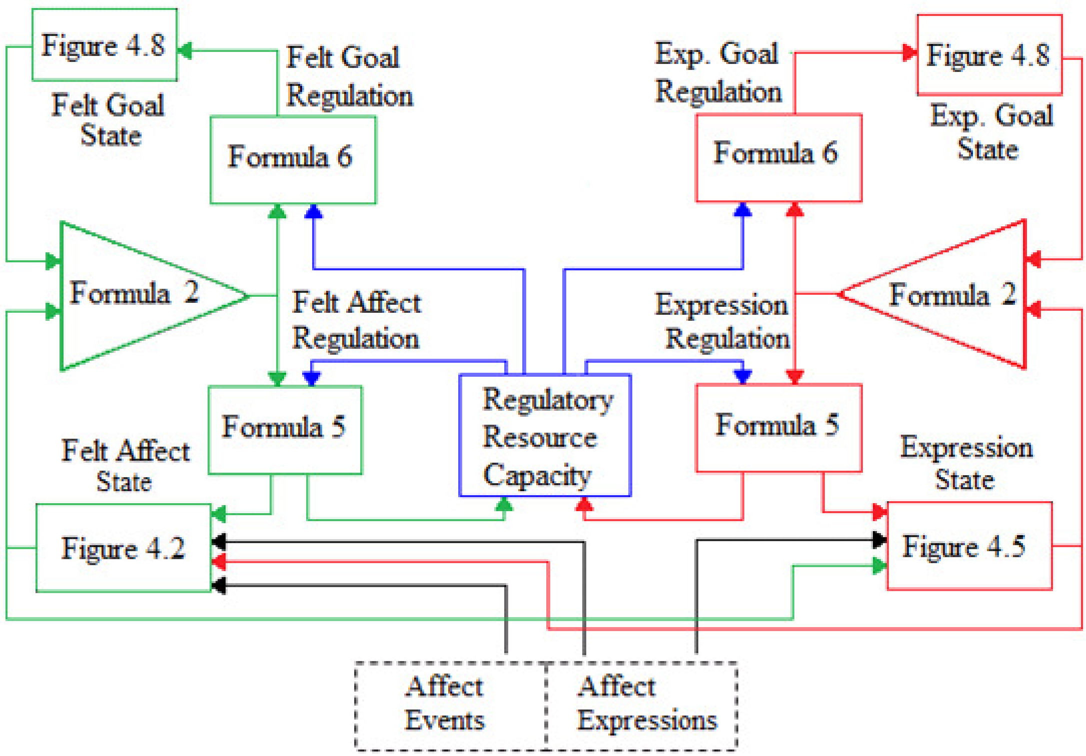

Figure 5.1 Representation of the complete model

Schematic representation of the complete model. Affective states and affective goal states are determined by external disturbances and dynamics produced by Simulink models described in Figures 4.2, 4.5, and 4.8 and Formulas 2, 5 and 6. The process of regulation drains resource from the Regulatory Resource Capacity block.

5.4.1 Felt-Affect

The Perceived Felt-Affect (PFA) block is the basic starting component of the model. It serves as both the main point that affective stimuli (such as another's affective expression or affective events) can impact on the model's behaviour and as a home-base for the affect-expression state (explored in section 5.4.3). The purpose of the following parameter tests is to ensure that the output of the PFA block plausibly represents responses to affective stimuli across a wide range of valences.

Affective events theory (e.g., Ashkanasy & Daus, 2002; Wegge, Dick, Fisher, West, & Dawson, 2006; Weiss & Cropanzano, 1996) suggests that experienced feelings (represented by the output of the PFA block) are directly affected by experienced events, such as daily hassles or uplifts. As the PFA block is the primary point of influence on the model from external stimuli, it is necessary that it can respond to stimuli in a manner that is useful to the rest of the model. In this instance, it needs to be able discriminate between stimuli of varying affective valence and represent typical affective change coinciding with the occurrence of affective events.

In section 4.2.3, a model of felt-affect is offered, based around a simple, leaky integrator model. This system was chosen because it meets the remit of representing changes in output intensity in accordance with input intensity and representing a return to a resting home-base in absence of input. Moreover, it is a simple system, with few free parameters (see Figure 5.2). In the preceding chapter, two parameters in this part of the model were identified: *k*, a value representing the *rate of felt-affect change* and *H,* a value representing the *home-base* that affect returns to. At present, plausible values of *k* are not examined because passing of time in current simulations is considered in arbitrary units 'ticks'. *k* is further examined in section 5.4.5, which introduces the resource model and a representation of time, based on daily cycles and sleeping and waking schedules but for all simulations leading to this specified at 0.01. For the purposes of this section *H* is specified at 0, meaning that affect returns to a neutral state in absence of affective input. *H* is further examined in section 5.4.2 in terms of affect regulation.

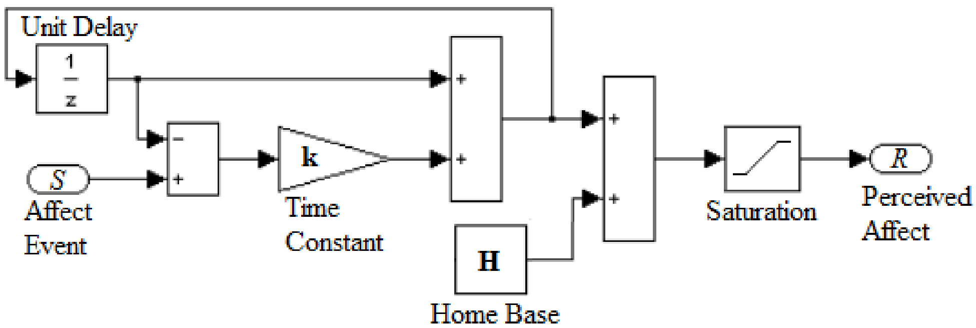

Figure 5.2 Model of felt-affect change
Information regarding affect intensity flows from left to right in the diagram, through pathways marked with arrows. Current affect (*R*) is determined by ongoing affect events (*S*), past affect intensity (held in the loop passing through the block labelled unit delay), and the home-base (*H*). The rate at which affect changes is determined by the time constant block (*k*), which acts as a gain on affect intensity passing through it.

In this section, the PFA block is tested and parameters specified to ensure that the block's output (perceived affect intensity) both accurately reflects the input values (affect events) and is constrained within a limited range of output values. A pre-determined limited range of output values is a necessary requirement for the model, if it is to be compared against empirical data. Scales measuring affect (e.g., Russell, 1980; 2003; Watson, Clark, & Tellegen, 1988) limit maximum and minimum affect intensity self-report scores; to make appropriate comparisons with self-report data, modelled affect intensity should be also constrained within similar bounds.

Constraining model affect intensity offers clarity in understanding differences between intensity values reported: a change in affect intensity scores from 1 to 5 implies a substantial change, if an intensity of 5 is the maximum possible output the model affords, but a minor change, if the maximum possible output is 100. This section looks at existing self-report data for perceived affective responses to a standardised set of affective stimuli: images taken from the IAPS manual (Lang et al., 2005).

While an aim for testing the model is to ensure that perceived affect intensity accurately reflects the input intensity of affect events in simulation, this cannot be well determined in real-life studies or observations. Affect experience is necessarily a subjective process of evaluation of affective stimuli (Lazarus, 1968, 1991). To enable a comparison to be made between responses to stimuli from the IAPS set and model responses to inputs, the distributions of participant responses to IAPS stimuli are used and a distribution of model responses to stimuli are generated. Participant response to multiple IAPS stimuli are first presented; following this, two means of constraining model data are examined and advantages and limitations considered.

Affect image standardisation procedure in the IPAS manual (Lang et al. 2005) is described as being: 60 images representative of a broad range of valences are shown to between 8 and 25 individuals. Individuals are asked to rate their first impressions of the image on a scale from 1 to 9 where 5 represents a neutral response. To reflect this in the current empirical data set used, 60 responses and response distributions to a range of IAPS pictures are selected from the IAPS database. Response intensities to IAPS slides were chosen to represent the complete range of mean valence responses and drawn from the ‘All Subjects’ database (p. 11 – 22). Because the standard distributions of responses are the values to be compared with the model data, these were not taken into account when selecting IAPS slide numbers, to reduce the potential for a biased data set. The affect responses to a variety of IAPS slides are given in Figure 5.3.

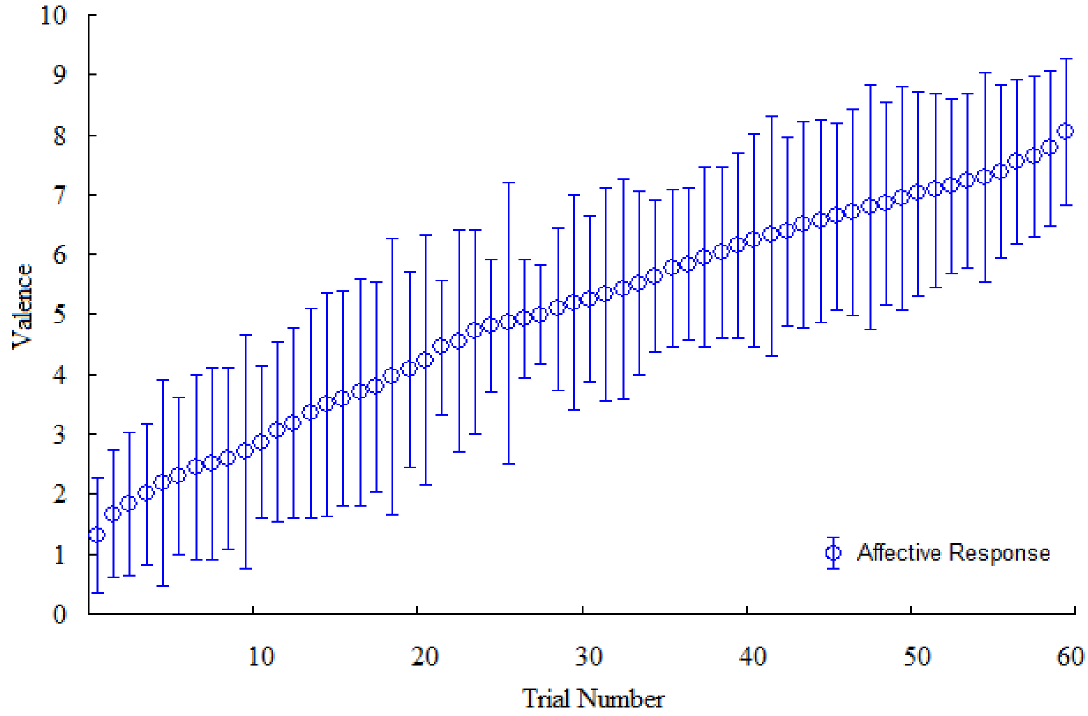

Figure 5.3 Affect response and response variation to slides from the IAPS database. Data retrieved from Lang et al. (2005); 60 independent measures of valence responses to affect image stimuli. Mean valence response and standard deviation shown.

The results presented in Figure 5.3 indicate that there is an overall general consistency in the variation of response to affective stimuli presented. As the mean image affect intensity (either as more positive or more negative) increases, standard deviation of perceived valence remains approximately consistent with that seen of neutral valence images.

To form a distribution of responses by the models to an affective stimulus, multiple instances of the models must be run. Variation in simulated evaluation of stimuli can be introduced by adding random values to the intensity of affective events. Random values have previously been used in emotion models to represent effects in affect change (Kuppens et al., 2010) and as an acknowledgment of the uncertainty in affect dynamics, given the multitude of internal and external factors that may change affect (Oravecz et al., 2009). As such, it is not the aim of this section to uncover how variation in response to affective stimuli may arise but to make a reasonable estimate on the variability in response to stimuli, given known data.

For the current model, a random value added to each stimulus is chosen as an approximate representation of variability in evaluation, both within and between individuals. Simulated evaluation of stimuli is achieved through a two-step process.

Firstly, what may be termed a variation in *disposition* is set; it may be considered an interpersonal variation that determines if the model is inclined to respond more positively or negatively to a stimulus. This value is fixed for the duration of a simulation and is only varied between simulation runs. Secondly, what may be termed *variability* is set; this determines an individual simulation's consistency in response to stimuli. This range is set for each simulation run but random values within this range are selected for each stimulus presented.

In terms of the model, the variation in evaluation is determined by a normal distribution random number generator. Disposition is represented in the mean value of the normal distribution and variability in represented in the normal distribution's standard deviation. Interpersonal differences are created at the start of a simulation run by the formation of a unique normal distribution. Intrapersonal differences are represented by the drawing of a new random number to add to (or subtract from) the valence of the stimuli presented.

Values for both disposition and variability for the model are determined by examining the standard deviations in individuals' affective judgements for neutral stimuli in the IAPS. Each picture has been rated by approximately 100 individuals (IAPS manual, Lang et al., 2005, p .3) and results given include the mean valence and the standard deviation in responses for each image (p. 10-21). On the affective scale used of 1 (most unpleasant) to 9 (most pleasant), neutral valence images (mean rating approximately 5) typically show a standard deviation of 1.1. To achieve this in simulations run, using the scale of -1 (most negative affect) to +1 (most positive affect), disposition values are randomly selected from between -0.15 and 0.15 (on the scale of -1 to +1 for affect response) and variability values from 0.01 to 0.05 for a sample of 20 simulations per stimulus.

In order to compare simulation data with the data shown in Figure 5.3, a protocol for generating model results is drawn from the standard procedure for rating IAPS pictures, outlined in the IAPS manual (p. 3); 60 images of varying affect intensity are shown to a group of between 8 and 25 individuals. To simulate this, 60 affective stimuli are created equally spaced in affective intensity values between -1 and +1. Twenty instances of both versions of the model are created, each with their own disposition and variability scores, representing differences between individuals. Each of the individual models is then subject to the varying affective intensities; affective response, once stable, is recorded for each affective input. For each of the 60 affective stimuli presented, the mean and standard deviation of the responses are recorded.

To simulate the largely uniform variation in response to all affect stimuli, a saturation function for constraining model affect output range is used. This saturation design does not influence the output values between -1 and +1 so, over time, any input value (e.g., affective events) to the PFA block leaky integrator between -1 and +1 will be reflected in the same output value (i.e., perceived felt-affect). However, if affective event intensities exceed the fixed thresholds, the perceived affect is capped at maximum affective intensities of +1 or -1. Figure 5.4 reports the means and standard deviations for 20 simulated individual's responses.

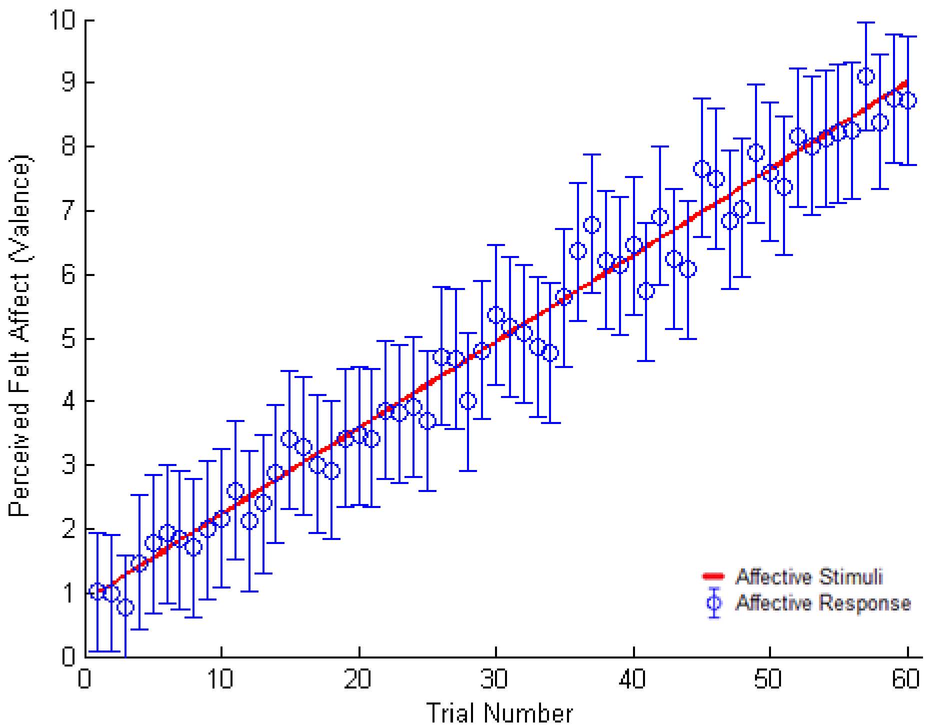

Figure 5.4 Modelled response to affective stimuli, using a saturation function.
60 independent measures of valence responses to affect image stimuli. Mean valence response and standard deviation shown.

The model results reflect the general trend seen in the IAPS data (Figure 5.3); distribution of responses is generally consistent across all stimuli intensities. Moreover, the model displays accurate representation of stimuli inputs as perceived felt-affect outputs. However, as previously mentioned, if hypothetical affect stimuli were presented which exceed the upper or lower bounds of the saturation function, perceived felt-affect outputs would no longer show accurate representation of the stimuli intensity. Therefore it becomes critical that affect intensity inputs are carefully monitored and specified to remain within the boundary limits produced by the saturation function. If the saturation function is replaced with an alternate means of representing affect output range limits, such saturation effects do not occur.

An alternative means of constraining affect response is the use of a nonlinear transformation of values output from the leaky integrator circuit to ensure that perceived felt-affect intensities remain bound between -1 and +1. The nonlinear transformation used for this comparison is the hyperbolic tangent function, a sigmoid compression of input values into output values ranging from -1 to +1. This function and the similar, logistic function are commonly used in firing neuron models (e.g., Kunkle & Merrigan, 2002). Unlike the saturation function, this approach offers differentiation at the output between any input intensities, although there is a variation in sensitivity to differences in input values, which is subject to parameter specification. A standard parameter specification might see model response to show substantial perceived affect differences between lower magnitude stimuli (i.e., 0.1 and 0.2 strength stimuli might give 0.1 and 0.2 affect intensities) when compared to higher magnitude stimuli (i.e., 10 and 20 strength stimuli might give 0.998 and 0.999 affect intensities). Figure 5.5 reports the means and standard deviations for 20 simulated individual's responses.

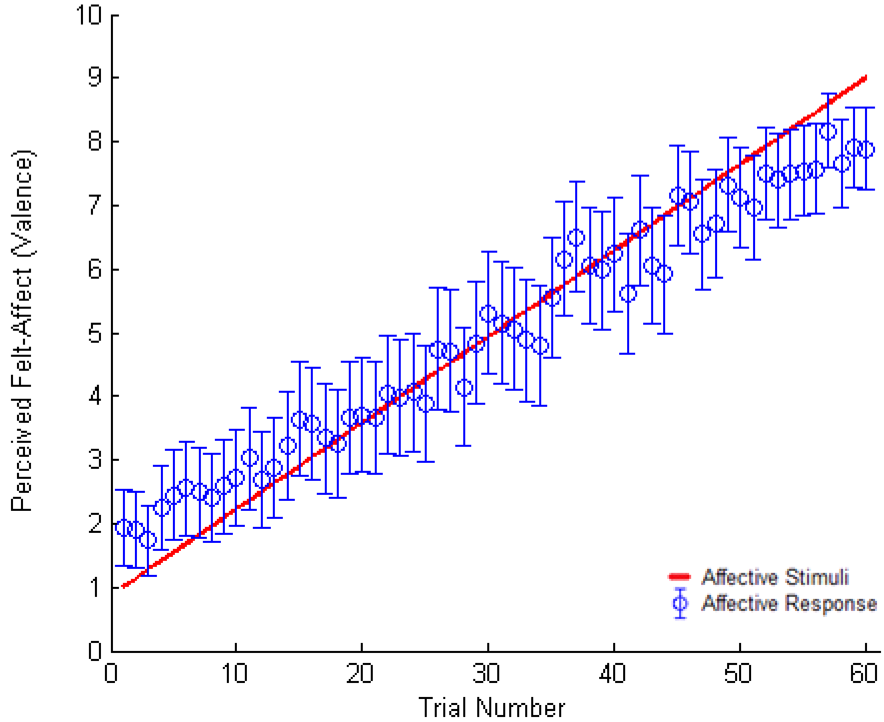

Figure 5.5 Modelled response to affective stimuli, using a hyperbolic tangent function 60 independent measures of valence responses to affect image stimuli. Mean valence response and standard deviation shown.

Results show that the modelled responses tend to deviate away from the 'true' values at both the more positive and more negative affective inputs. In addition to this, the distributions of responses begin to narrow at both the more positive and more negative inputs. While the hyperbolic tangent model solves the potential problem associated with the use of a saturation model, in its current form, the hyperbolic tangent model creates different issues in representing affect output. These issues may be resolved by just using a portion of the hyperbolic tangent function to transform the affective inputs. In the central range of the hyperbolic tangent, the transform from input to output is approximately linear. By increasing the limits of the function's outputs so that the approximately linear potion of the function reaches from +1 to -1, while restricting the ranges of input intensities to the PFA to ensure that the outputs do not exceed the designated range of +1 to -1, an accurate and consistent representation across all affective input intensities can be produced in the outputs. Moreover, should hypothetical affective events extend beyond the +1 to -1 range, the hyperbolic tangent function can accommodate for this and also show an increase in output within the wider range of the function.

However, the use of this function as a means of controlling affect output in response to affect inputs does introduce complexities as further parameters are necessary to determine the ‘slope’ of the transfer from the input to the output. In addition to this, the function ideally requires restrictions placed on affective input ranges to ensure that output ranges do not typically exceed the +1 to -1 limits. These restrictions on affect inputs are also used by the simpler saturation function, which aside from hypothetical affect inputs to the model beyond intensity ranges allowed in the simulation, adequately meets the needs for representing affective outputs. The saturation function is chosen for use in simulation over the hyperbolic tangent function because of the fewer parameters required for specification, promoting a simpler and faster running model. The use of this function does require that affective inputs are controlled so that they do not go beyond +1 or -1 in intensity.

This block is now integrated into the first control loop, felt-affect regulation, ahead of examining affect change in terms of both affective events and regulatory processes.

5.4.2 Felt-Affect Regulation

In this section, the relative cost of regulation is determined, which arises from parameter variations in the actuator component of the affect regulation loop. In addition to this, this section examines affective response to events, while affect regulation is ongoing. Affect regulation, in the context of a control loop, aims to keep a constantly changing value (affective intensity) as close to a specified goal state as possible (e.g., Powers et al., 1960a). The model is designed based on the theory that resource is recruited in order to meet regulation demands (e.g., Hagger et al., 2010). For this section, resource is unlimited (i.e., there is no impairment in the capacity for regulation) and the parameter examined is that of *regulatory momentum*. This refers to the degree of change that the model makes to the felt-affect state, given a detected discrepancy. A low regulatory momentum may represent an individual who insufficiently regulates; he or she fails to act on the known discrepancy. A high regulatory momentum would ensure that individuals rapidly regulate towards goals and makes frequent corrections to their state to maintain at that intensity.

The felt-affect regulation control loop examined in this section is shown in Figure 5.6, which builds upon the felt-affect block of Figure 5.2. The results from parameter variation in the affect regulation control loop can be measured in two ways: latency for affect reach the goal through regulation, and effort expended in maintaining affect at the goal. A starting point for parameter specification is to examine if there is a trade-off between expediency (i.e. rapid regulation and maintenance of affect at the goal state) and regulatory efficiency (i.e. the self-regulatory resource 'cost' associated with successful regulation). Once this has been established, further examination of affect regulation dynamics in light of affective events can occur.

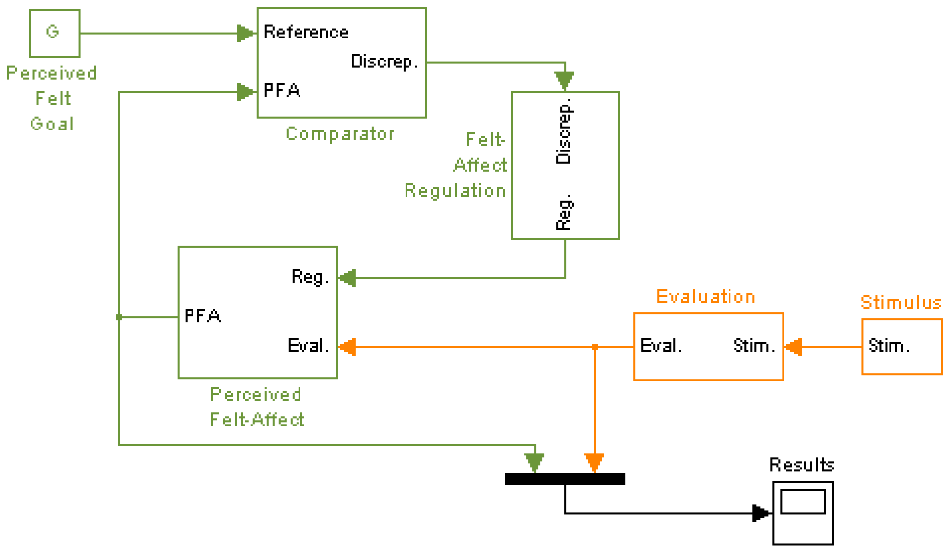

Figure 5.6 Felt-affect regulation control circuit with stimulus and results plotting Model represented in the Simulink environment; each block contains previously developed formulas or models specified using Simulink modelling. From top to bottom & left to right: Perceived felt goal is a specified constant; Comparator contains Formula 2; Felt-Affect Regulation contains Formula 3; Perceived Felt-Affect contains Figure 4.2; Evaluation contains additive random noise (specified in section 5.4.1); Stimulus contains variable strength inputs. Acronyms and abbreviations used in the figure are listed in Appendix 2. Information regarding affect and affect regulation flows through pathways marked with arrows.

To briefly recap the affect regulation process: a comparator detects discrepancy between current perceived affect and a held goal. If a discrepancy is detected, the comparator signals to the actuator to engage in regulation; this output of the actuator and input from any stimulus enact change on the felt-affect state. Input from the Felt-Affect Regulation (FAR) block occurring alongside an input from an affective event or stimulus may be considered akin to re-evaluation, should the subsequent perceived affect state change away from its typical response to the affective stimulus.

The regulation process examined is considered deliberate and effortful so variation in regulation momentum between individuals is plausible, and potentially measurable. A maximum and minimum possible value for regulation momentum is 0 and 1 where a momentum of 0 would predict no change during regulation and 1 would predict the model constantly making large corrections. Figure 5.7 highlights the difference in rate of change towards a held affect goal (a moderately positive value of 0.4) across 100 different degrees of regulatory momentum ranging in a logarithmic distribution from 0.002 to 0.5. As with the previous section, time is measured in the arbitrary unit of ticks.

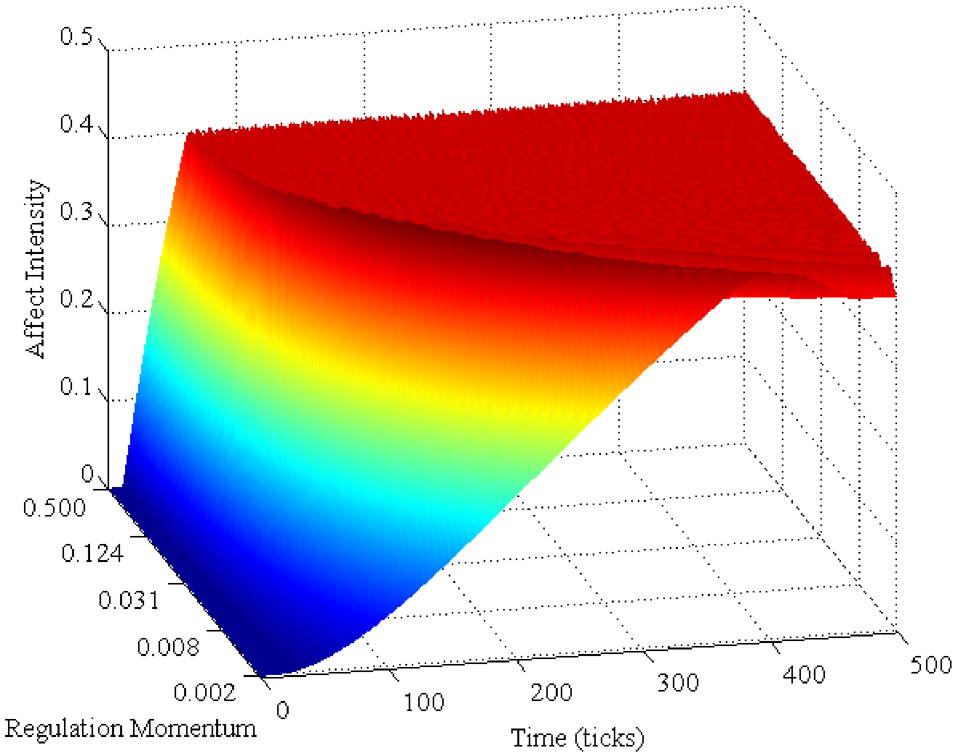

Figure 5.7 Variations in relative response time to reach a held felt-affect goal through felt-affect regulation

Felt affect goal is specified at 0.4 for the duration of each simulation. Time taken to reach the held goal is arbitrary and measured in ticks.

Results indicate that low regulatory momentum results in a comparatively slow shift towards the target state, taking over 3 times as long as a high regulatory momentum. At all values of regulatory momentum felt-affect overshoots the goal value of 0.4 marginally and settles at, or oscillates about, the goal value. Higher regulatory momentum parameter values show slight oscillation about the goal value as the relatively rapid changes made in regulatory output cause some overcorrection in the felt-affect state. This degree of oscillation about the goal value increases with higher regulatory momentum and given, sufficient time lower regulatory momentum offers a more stable maintenance of felt-affect at the held goal. However, there is the consideration of the time it takes affect to reach the held goal value for affect.

To further differentiate the influence of parameter values for regulatory momentum, the effort involved in regulating to held goal values is considered. Effort is calculated by summing the total output from the affect regulation block over the course of a single simulation. It is anticipated that the greater degree of oscillation about the goal value seen in models with a higher regulation momentum parameter will be associated with a greater overall effort in regulating affect towards the goal value. A further factor that is anticipated to influence the total effort in regulating affect is the affect intensity of the goal value regulated towards.

To examine resource depletion due to affect regulation, the total output from the model's FAR block is recorded. This recording is taken from the duration of all simulations, each lasting 3000 ticks: a time sufficient to allow the lower regulatory momentum models to reach all affect goal intensities. Fifty different parameter values for regulatory momentum are tested, again ranging in a logarithmic distribution from 0.002 to 0.5. For each of these parameter values, the felt-affect goal value is varied, ranging in a linear distribution from 0.1 (slightly positive affect) to 1 (maximally positive affect) for twenty values. Felt-affect home-base is specified at zero throughout for each simulation. In sum, 1000 simulations are run to examine the influence of both parameter variations and interaction between these variations. Results are shown in Figure 5.8, comparing the relative resource depletion. The influence of self-regulatory resource depletion on the capacity for affect regulation is not considered in this test.

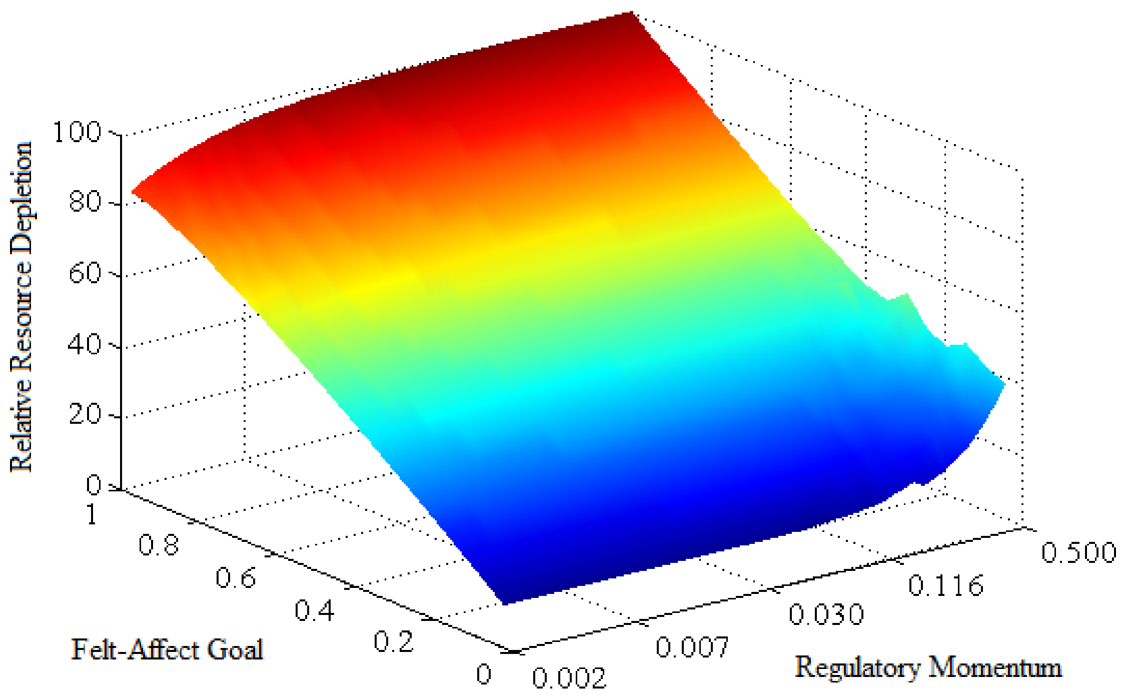

Figure 5.8 Relative resource depletion as a function of regulatory momentum and goal intensity

Figure 5.8 indicates that as the degree of regulatory momentum increases, the resource depleted in regulating towards even low affect goals, close to the home-base, increases. As predicted, as discrepancy between affect goal intensity and current affect state increases, resource depletion also increases. Low regulatory momentum appears to deplete less resource at high levels of affect regulation goals than either moderate or high regulatory momentum. Results further point towards regulatory momentum and intensity of affect goal value having a compounded influence on relative resource depletion.

Further analysis of the influence of felt-affect regulation can be achieved through examining how felt-affect regulation influences felt-affect's course during affective events. In the previous section, it is taken as axiomatic that felt-affect intensity tends towards current affective event intensity (or rather, the evaluated intensity of this affective event). In this section, with the introduction of the affect regulation loop, this may no longer be the case as, in response to an affective event disturbing the current affect state, regulatory processes engage to modify current felt-affect intensity.

Affect regulation's influence on the affective response to events is demonstrated in Figure 5.9. For this example, regulatory momentum is specified at $k2$ = 0.005, a value which shows relatively limited oscillation about the goal values and a relatively moderate cost of self-regulatory resource. The felt-affect home-base is specified at 0.2, representing the slightly positive affect typically reported as the most commonly felt state (e.g., Biswas-Diener, Diener, & Tamir, 2004). The felt-affect goal state is specified at 0.3, while the affective evaluation of the event presented is determined at an intensity of 0.6, which is presented at 500 ticks into the simulation and for duration of 500 ticks.

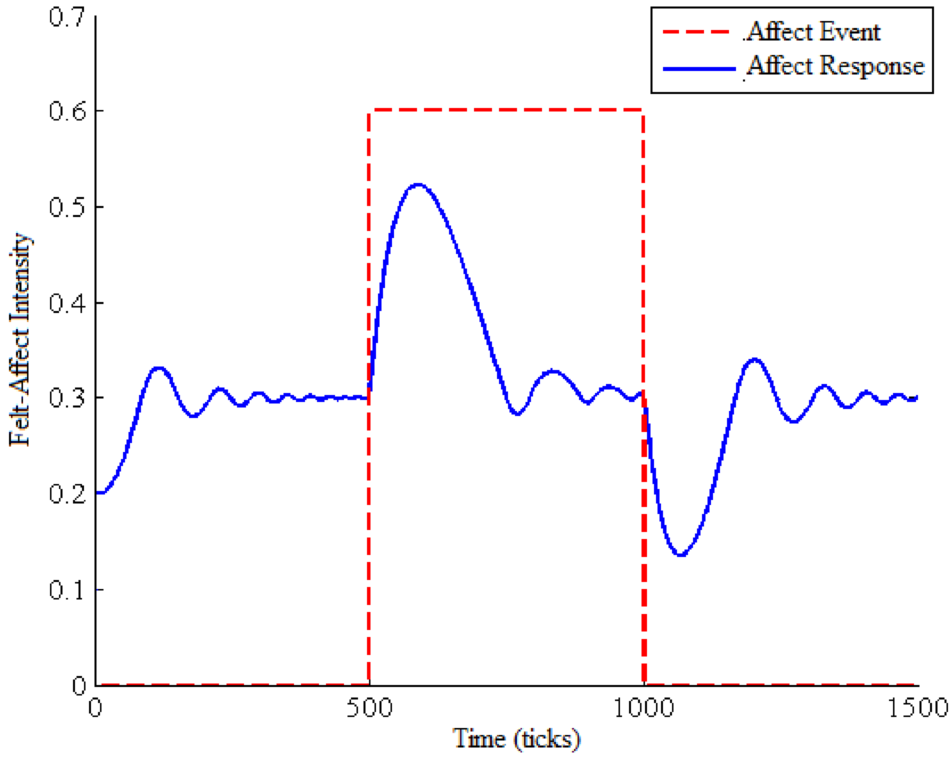

Figure 5.9 Felt-affect dynamics for affective event during felt-affect regulation
Felt affect goal is specified at 0.3 for the duration of each simulation. Both the duration of simulation and the period of affect event are arbitrary and measured in ticks.

Results indicate that affective dynamics are substantially influenced by the felt-affect regulation control loop. There are three key points of affect change in the simulation of affect regulation in Figure 5.9, which will be examined chronologically. To begin, between 0 and 500 ticks, affect is regulated away from the home-base of 0.2 and begins to stabilise at the goal state of 0.3. Secondly, at the introduction of the affect event, further self-regulatory resource is recruited to limit the influence of the affective event and again begin to stabilise affect at 0.3. While the affective event drives felt-affect upwards, regulation downwards is accumulating to counteract this affect change and is sufficient to do so shortly after felt-affect crosses the 0.5 intensity valence. Lastly, at the point of the affective event ending, the downwards affect regulation persists and is gradually reduced to ensure that affect again stabilises at the goal value.

The dynamics seen in Figure 5.9 closely resemble Solomon and Corbit's (1974) description of '*standard pattern of affective dynamics*' (p. 120), visually represented in Figure 5.10. If, in Figure 5.9, affect regulation was considered to only begin to occur *with* the affective event rather than throughout the simulation, the resemblance to their projected affect dynamics would be a stronger match still. Of particular note in Figure 5.9 are the relative deviations away from the goal value, 0.3, at the peak of the affective reaction and the peak of the after-effects. Like Solomon and Corbit's (1974) sketched model, the peak of the affective reaction is a further distance from the stable resting state than the affective after-effects (a difference of 0.05 in Figure 5.9). Matching dynamics predicted to occur in theories of affect and of actual affect data in the preceding section point towards the affect regulation loop as being an appropriate mechanism for representing affect regulation dynamics.

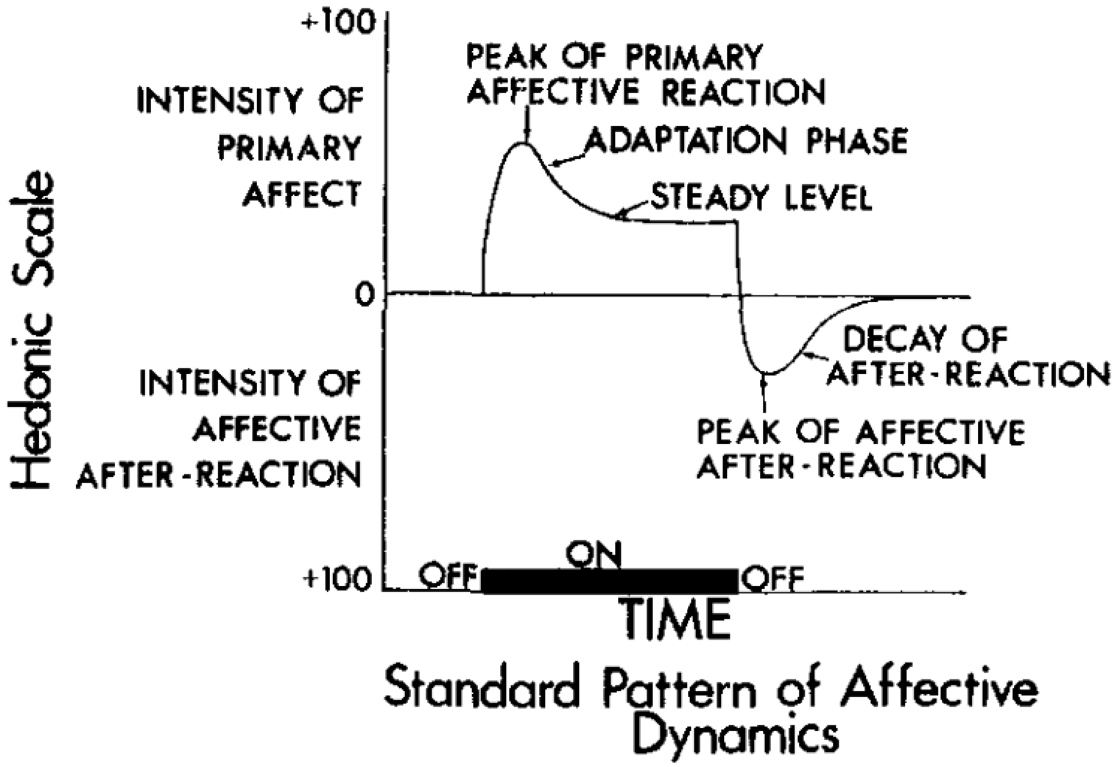

Figure 5.10 The standard pattern of affective dynamics

The standard pattern of affective dynamics showing the five distinctive features: the peak of the primary affective reaction, the adaptation phase, the steady level, the peak of the affective after-reaction, and, finally, the decay of the after-reaction. (The heavy black bar represents the time during which the affect-arousing stimulus is present. The ordinate represents two hedonic scales, each departing from neutrality, one for the primary affect, the other for the affective after-reaction.) Figure and caption reproduced with permission from Solomon and Corbit (1974).

5.4.3 Affect-Expression and Expressive-Feedback

In this thesis, the experience of affect and the expression of affect are considered as distinct but connected constructs. In the design of the model this is represented through the development of two different states (felt-affect and affect-expression) and two distinct control loops regulating these. The expressed state builds upon the previously defined felt-affect regulatory loop, existing outside of the prior control loop but nevertheless still interacting with the felt-affect state. The expressed state is designed to 'follow' the PFA block's output so that under typical conditions, the affect-expression state and felt-affect state maintain coherency. While the causative mechanism linking the felt-affect and affect-expression state is unclear, studies indicate that coherency exists (e.g., Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005) and that it may be effortful to introduce a discrepancy between the two (e.g., Goldberg & Grandey, 2007). It is plausible then that an affect-expression state is at least partially dependent on the current felt-affect state.

The model represents this link between felt-affect and affect-expression by designating the output from the PFA block as the home-base for the Perceived Affect-Expression (PAE) block. Rather than returning to a neutral baseline after expression regulation, expression will return towards the dynamically shifting felt-affect state. Establishing the current felt-affect state as the expressed state's home-base also has the benefit of explicitly encoding into the model an assertion by Diefendorff and Gosserand (2003) that individuals may prefer to display genuine, authentic representations of felt-affect.

By positioning felt-affect as the home-base for affect-expression, this obviates issues of maintaining coherency, which arise if alternate means of linking felt-affect and affect-expression are used. For example, if felt-affect is fed into the PAE block as if it were an affective stimulus, there is a continual lag between felt-affect and affect-expression; the leaky integrator for affect-expression continually tries to catch up with changing felt-affect. Degree of coherence would become dependent on the *rate of affect-expression change*, which is the parameter termed *k3*; fitting *k3* to this aspect of the model would also inadvertently influence affect-expression dynamics in response to affective stimuli such as expression from others.

In the previous section, addition of a regulatory control loop for felt-affect had influence on the affective response to an affective stimulus (Figure 5.9). Affective response can be further influenced through the development of a feedback loop from affect-expression to felt-affect. Feedback from affect-expression to influence felt-affect has long been theorised (e.g., Laird, 1984; Lange, 1885/1922) and manipulation of the expressed state has been demonstrated to influence individuals' felt state (e.g., Strack et al., 1988). In the model, a sufficiently strong connection from affect-expression back to felt-affect could serve to push peak affective response closer that of stimuli evaluation (i.e., closing the gap seen in Figure 5.9 between peak response and stimuli intensity). The addition of affect-expression and the expressive-feedback link are shown in Figure 5.11. In addition to this; a felt-affect junction box is included in the existing control loop in Figure 5.11. This simply sums the affective components entering the PFA block and is used to maintain clarity in the visual overview of the model; it does not influence results.

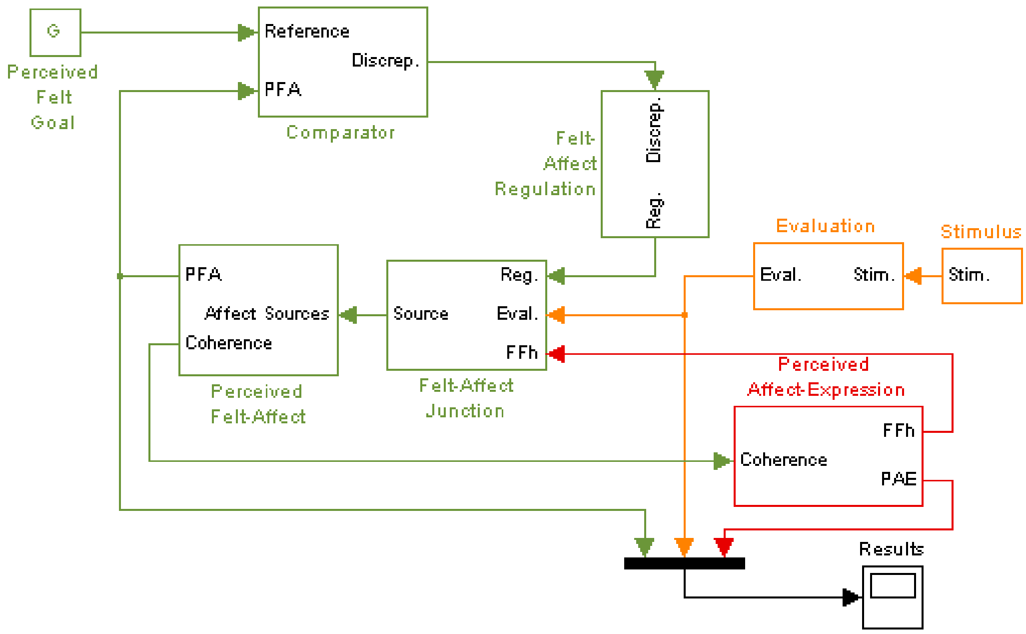

Figure 5.11 Felt-affect regulation control loop, affect-expression and expressive-feedback

Model represented in the Simulink environment, building upon Figure 5.6. Additional block used contains previously developed formulas or models specified using Simulink modelling: Perceived Affect-expression contains Figure 4.5. Acronyms and abbreviations used in the figure are listed in Appendix 2. Information regarding affect and affect regulation flows through pathways marked with arrows.

The final simulation from section 5.4.2 is rerun with the new model structure. The *expressive-feedback* link is varied in intensity in increments of 0.05 with each simulation until the peak felt-affect in response to the affective event reaches the affect event's intensity. This value is considered as the maximum strength of the expressive-feedback appropriate at this point in the model. Figure 5.12 indicates that expressive-feedback strength of 0.5 results in the peak amplitude of felt-affect intensity (and affect-expression in coherence) reaching the value of affective event intensity.

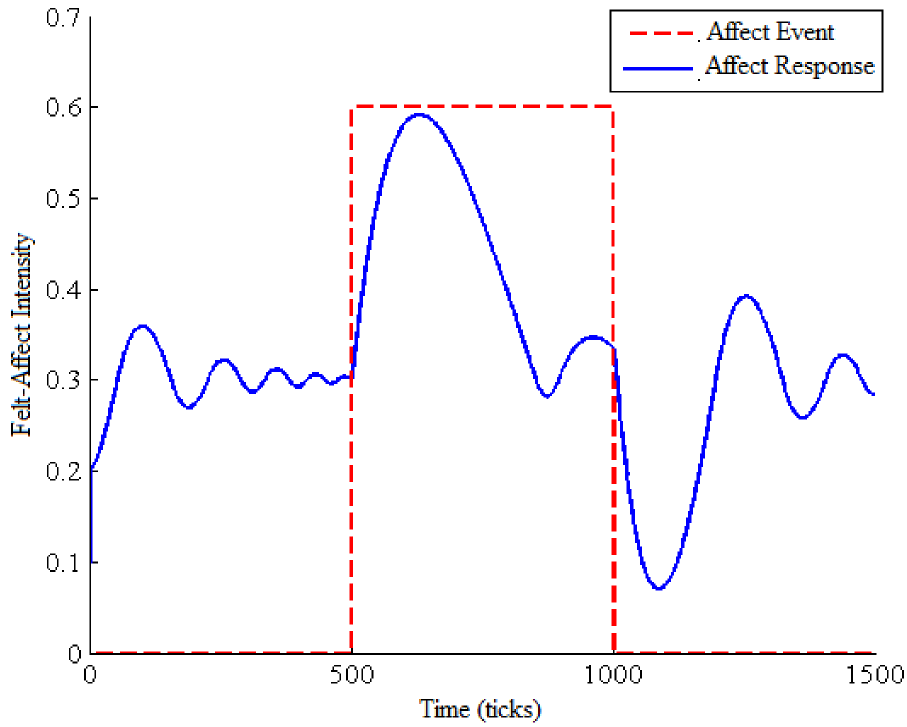

Figure 5.12 Felt-affect dynamics with expressive-feedback

Felt affect goal is specified at 0.3 for the duration of each simulation. Both the duration of simulation and the period of affect event are arbitrary and measured in ticks.

However, further results indicate that the current feedback strength has an adverse effect on the model's operation. Because the introduced feed-forward process of affect coherency and the feed-back process together form a closed, positive feedback loop, felt-affect and affect-expression can show affect change where none is anticipated. For example, felt-affect in the isolated PFA block will gradually return to the home-base in absence of affective stimuli or affective regulation; however, with the PAE block attached, felt-affect returns to a different level. For the given example of 0.2 as the home-base for felt-affect, expressive-feedback of strength 0.5 ensures that felt-affect will return to a 'created' resting point of 0.4, a moderate difference in the model. So it remains to determine appropriate expressive-feedback strength, which can influence the felt-affect state but not to such a degree that it *requires* continual and effortful regulation to prevent the runaway effects of a strong, positive feedback loop.

Recall from section 2.2.2, Strack et al. (1988) demonstrate affect-expression's influence upon felt-affect, through manipulation of expression; their results are used as a benchmark for determining appropriate expressive-feedback in the model. Because Strack et al. (1988) do not report distribution of results, only mean values can be replicated in the simulation. Model results are generated by applying a positive stimulus value to represent the positive valence cartoons used in their study. Facilitation or suppression of expression was achieved by further applying an expression enhancing or diminishing stimulus to the PAE block, increasing or decreasing the affect-expression state by 0.2 or -0.2 respectively. Results are shown in Table 5.2; positive valence in the model is rescaled and compared against mean scores of amusement from Strack et al. (1988, p. 772). Stimuli intensity and feedback strength were calibrated using the 'control' condition from Strack et al. (1988, p. 772) to best match empirical data. Peak amplitude of the initial affective response for a simulation regulating towards a felt intensity of 0.3 was recorded as the affective intensities in Table 5.2.

Table 5.2 Comparison of empirical data and modelled response to positive stimuli during manipulation of expression

	Mean affect intensity (0 – 9 Scale)		
	Inhibition	Control	Facilitation
Strack et al. (1988)	4.32	4.77	5.14
Simulation	4.49	4.77	4.82

The model results indicate an approximation of the empirical data, showing both the correct direction of the effects but a slightly reduced size of effects. Results indicate that feedback strength of 0.2 (with no feedback being 0 and maximum possible feedback being 1) gave both an exact fit of the control condition and the closest approximation to the experimental conditions. Expressive-feedback strength of 0.2 shows comparatively little influence on the resting state of felt-affect and limits possibility of a runaway positive feedback loop and high felt-affect intensities at rest.

The introduction of affect-expression allows for a further test on the influence of expressive-feedback to be run, repeating an earlier simulation. Keillor et al. (2002) report a case study of a female patient with bilateral Bell's palsy and thus the inability for facial expression. Despite the lack of facial-feedback, patient F.P showed no significant reduction in affective response to IAPS pictures. To examine this in a simulation, the IAPS design simulation seen in section 5.4.1 is run again, this time with a series of models that include the expressive-feedback loop. Further to this, a single model with the feedback loop removed, representing patient F.P, is run and results compared with the control models. At no point does the 'lesion' model respond with values outside the 95% confidence interval from the previous IAPS test and so matches the null result seen in Keillor et al. (2002). The results, while being from an extremely limited sample, suggest that expressive-feedback effects are small and the parameter value chosen for expressive-feedback is plausible.

5.4.4 Affect-Expression Regulation

There may be times when an individual chooses to display something other than what he or she feels, for example, when required to meet appropriate requirements of emotional display at work. This may be achieved through expression regulation, such as suppressing the outward signs of emotion or presenting a more intense affect state than that currently felt (e.g., Gross & Thompson, 2007).

As indicated in section 5.4.2, the outcomes of regulation differ in the model depending on the value of the parameter for regulatory momentum. Lower values resulted in under-correction or substantially extended durations to reach the goal state for felt-affect, while higher values resulted in over-correction and higher resource depletion. In this section, regulatory momentum for affect-expression is tested.

The perceived affect-expression regulation circuit is largely similar to that of the perceived felt-affect regulation circuit (Figure 5.6). The affect-expression comparator, seen at the top right of Figure 5.13, detects discrepancy between the current perceived affect-expression state and a held expressed goal. If a discrepancy is detected, the comparator signals to the Affect-Expression Regulation (AER) block, to engage in regulation. Regulatory momentum, like that in the FAR block, refers to the degree of change that the model makes to the affect-expression state, given a detected discrepancy.

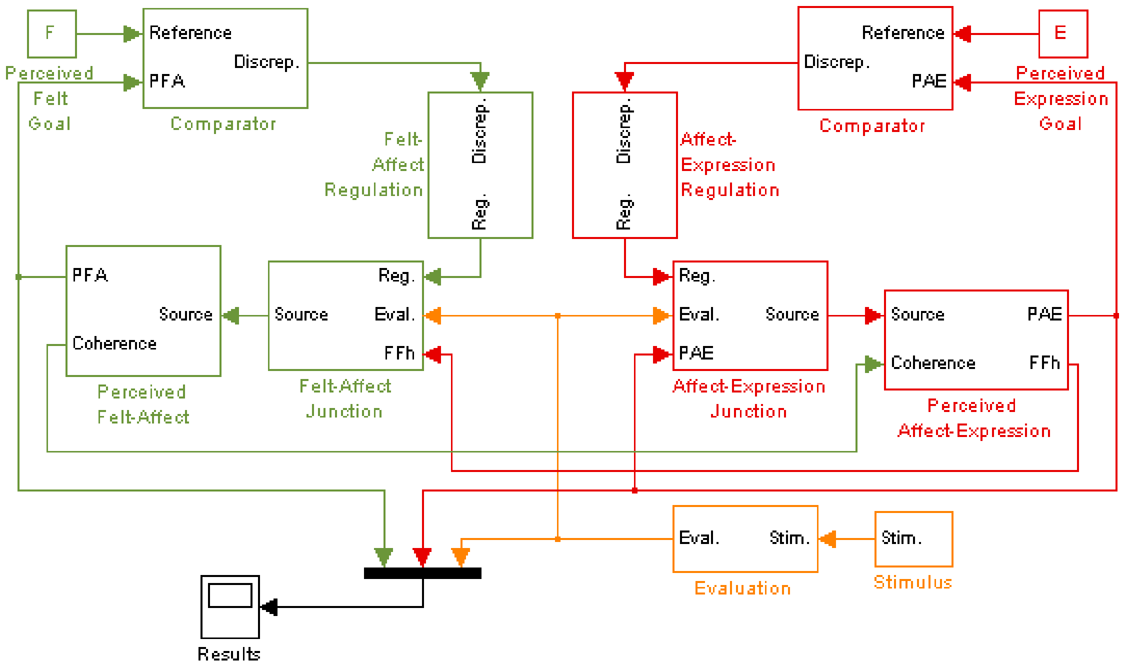

Figure 5.13 Complete circuit of affect-expression regulation added to existing model Model represented in the Simulink environment, building upon Figure 5.11. Additional blocks used contain previously developed formulas or models specified using Simulink modelling: The top right comparator contains Formula 2; Affect Expression Regulation contains Formula 3. Acronyms and abbreviations used in the figure are listed in Appendix 2. Information regarding affect and affect regulation flows through pathways marked with arrows.

The general purpose of the affect-expression regulation loop in this model is to drive affect-expression away from the moving home-base of felt-affect and towards a held goal state. However, if the goal state for affect-expression matches with current felt-affect, this might preclude affect-expression regulation away from the current felt-affect because no change is necessary. As with the results from parameter variation simulations in section 5.4.2, it is anticipated that a greater discrepancy between the goal state for affect-expression and current felt-affect state will result in more necessary regulation and a greater depletion of resource (to be further examined in section 5.4.5).

Again, a single parameter determines regulation momentum and a value for this parameter may be determined which serves to balance the requirements for expedient regulation and limited resource depletion. As with the parameter for felt-affect regulation momentum, the maximum and minimum possible values are 0 and 1 respectively, where a momentum of 0 would predict no change during regulation and 1 would predict the model constantly making large corrections. 100 different degrees of regulation momentum uniformly distributed on a logarithmic scale between 0.002 and 0.5 are shown in Figure 5.14. To reduce the influence of felt-affect on the process of affect-expression regulation, for all simulations felt-affect regulation is maintained at a goal value of 0. The *affect-expression goal* is held at 0.4 for each of the simulations. *Rate of affect-expression change* (*k3*) is specified at 0.04.

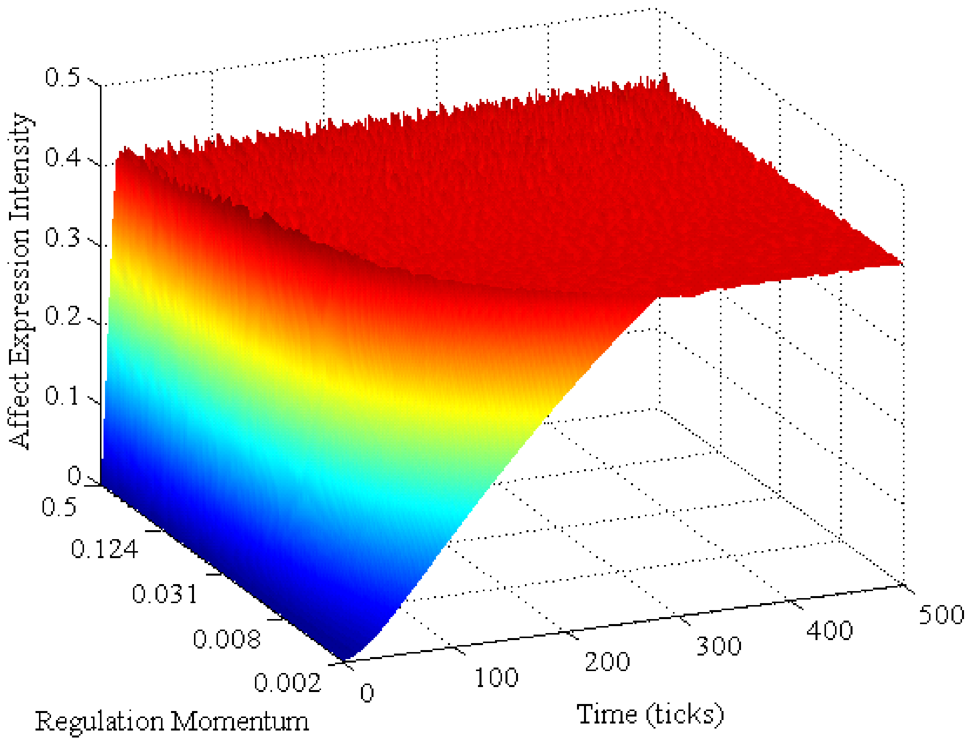

Figure 5.14 Relative response times to reach a held affect-expression goal through affect-expression regulation.

Affect-expression goal is specified at 0.4 for the duration of each simulation. Time taken to reach the held goal is arbitrary and measured in ticks.

The results indicate that for this goal state for affect-expression, higher regulation momentum results in faster regulation towards the held goal. This outcome resembles that of Figure 5.7, which is expected because of the similar design of the control loops. A model with lower regulation momentum may take up to four times as long as models with moderate to high regulation momentum to reach the held goal. However, models with higher regulation momentum over-correct far more and show more oscillation than models with lower regulation momentum. The shorter time to reach the held goal and greater degree of oscillation in Figure 5.14 compared to Figure 5.7 can be attributed to the faster rate of change of affect-expression in comparison to felt-affect (*k3* is greater than *k*). Relative rates of change were specified to reflect Diefendorff and Gosserand's (2003) original model design.

To further examine the influence of regulatory momentum parameter variation on affect-expression regulation, self-regulatory resource depletion is considered. Like the test run in section 5.4.2, resource depletion is recorded in simulations which vary both regulatory momentum and the goal state for affect-expression. However, there is a further consideration in this test; while felt-affect regulation simply looked at the *intensity* of the held goal, this test also examines the *discrepancy* between the felt-affect state (home-base for affect-expression) and the goal for affect-expression. The distinction made here can therefore be inclusive of expression regulation processes such as suppression of expression (e.g., Gross & Thompson, 2007) and highlights that it may not just be affective intensity that influences resource depletion but rather a discrepancy between the two states.

As with the resource depletion test from section 5.4.2, the total output from the model's AER block is recorded. This recording is taken from the duration of all simulations, each lasting 1500 ticks: sufficient time to allow models with less regulatory momentum to reach all affect goal states. The felt-affect goal is specified as being maintained at an intensity of 0.5 for all simulations. Fifty different parameter values for regulatory momentum are tested, ranging in a logarithmic distribution from 0.002 to 0.5. For each of these parameter values, the affect-expression goal value is varied, ranging in a linear distribution from 0 (neutral affect) to 1 (maximum positive affect) for 21 values. In sum, 1050 simulations are run to examine the influence of both parameter variations and interaction between these variations. Results are shown in Figure 5.15, comparing the relative resource depletion. The influence of self-regulatory resource depletion on the capacity for affect regulation is not considered in this test.

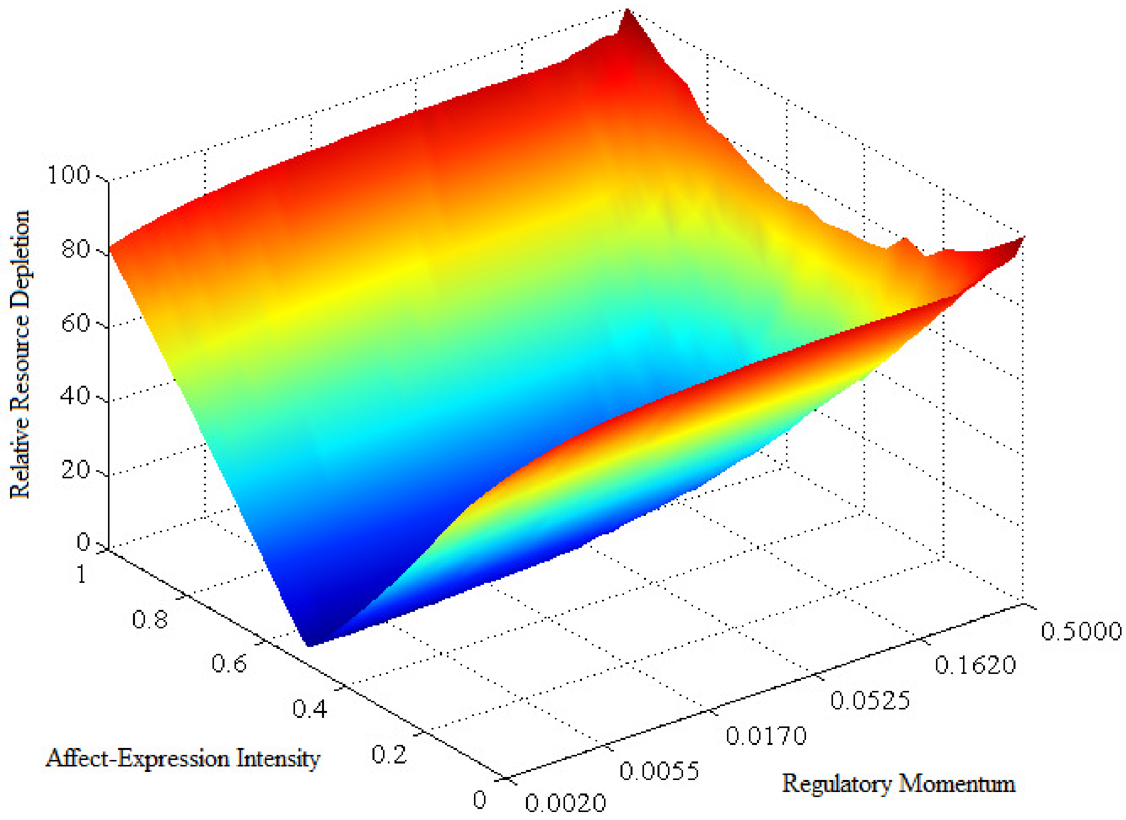

Figure 5.15 Relative resource depletion as a function of regulatory momentum and affect-expression intensity

Figure 5.15 indicates that affect-expression intensity itself does not linearly influence relative resource depletion. Rather, the relative discrepancy between felt-affect (in this instance, intensity of 0.5) and affect-expression influences relative resource depletion. As discrepancy between felt-affect and affect-expression increases, relative resource depletion increases; this occurs for both higher and lower affect-expression intensities. Results further point towards regulatory momentum and discrepancy having a compounded influence on relative resource depletion; as the degree of regulatory momentum increases, resource depletion for regulating to any expression goal state increases.

The results from this section point to some agreement and some contrast with previous findings in the literature. For example, Mann and Cowburn (2005) indicate that the main predictor variable for reports of fatigue in emotional labour was expression regulation (25%) and that the second predictor was expression intensity (16%). While the first aspect of their findings is comfortably met by the model, the model does not show the same indication that affect intensity *necessarily* predicts fatigue. However, it is conceivable that the more common aspects of emotional labour are the emphasising of positive expressions beyond that which are currently felt (e.g., salespersons, airline attendants, call-centre phone operators). In such examples, discrepancy increase between felt-affect and affect-expression could well coincide with expression intensity. The model also concurs with the Morris and Feldman (1996) proposition that attentiveness to expression is positively related to exhaustion; specifically, Figure 5.15 indicates that an increase in regulatory momentum (analogous to their proposal) depletes more resource.

5.4.5 Regulatory Resource

In sections 5.4.2 and 5.4.4, affect regulation was examined in terms of self-regulatory resource depleted. In both the prior parameter tests, the resource (the energy supply in the system enabling regulation) was unlimited. In this section I examine the effects of a depletion of this self-regulatory resource on affect regulation processes. Regulation of both felt-affect and affect-expression is considered to deplete resource (e.g., Muraven et al., 1998). Further to this, I introduce a limited resource capacity based on an established model of fatigue (Åkerstedt et al., 2004) to simulate the hypothesised dynamic effects of affect regulation in response to variation in resource availability across a daily cycle.

There are two interactions between resource and affect regulation to consider in designing and testing the model. Firstly, the requirements of resource by the regulation circuits must be considered. Resource depletion is known to limit individuals' capacity for further self-regulation (e.g., Hagger et al., 2010). It is therefore necessary to determine what in the model constitutes depleted resource. Secondly, there is the associated cost of affect regulation (Gailliot et al., 2007). In this model, affect regulation is considered an effortful process, both in the regulation towards a held goal and maintenance of affect at that goal. The relative cost of perceived felt-affect and affect-expression regulation therefore also needs to be examined. In the first test of this section, just the effects of resource depletion on regulatory processes are considered. To maintain simplicity in representation, the recurrent loop of regulation requiring presence of resource and regulation depleting resource is reduced to an open loop of resource depleting at a continuous rate. The complex, recurrent loop is considered in later tests in this section.

While there is only limited research on differing degrees of depletion, some studies do extend the concept of individuals being either 'depleted' or 'not-depleted' to a graded, continuous state (e.g., Gailliot et al., 2007; Muraven et al., 2002). This conceptualisation of resource capacity as a continuous state is used in the model. The actuator in both regulation circuits can be modified to include a percentage capacity based on resource. As resource varies from 0 to 1, the outputs of the actuators and so regulation toward goal states are varied as a function of this resource capacity.

The relationship between resource capacity and success at regulating towards goals requires consideration. A linear transformation is the simplest relationship between available resource and affect regulation; this would imply a continual and gradual decrease in affect regulation with the depletion of resource. In contrast, an exponential decay would imply that affect regulation is most susceptible to change at higher resource levels; individuals would become quickly impaired at affect regulation as resource depletes but would show little difference in regulation between moderately low levels of resource and complete depletion. Finally, a logarithmic decay model would predict an initial resistance in regulation to changes in resource but then substantial impairment in affect regulation if resource dropped sufficiently.

Results in the self-control literature suggest that significant drop in self-regulatory capacity can be induced through often brief requirements of self-regulation (e.g., Gailliot et al., 2007; Muraven et al., 1998; Muraven et al., 2002). This indicates that a logarithmic decay from available resource to self-regulatory capacity is *not* suitable and suggests that self-regulatory capacity may fall at least at a linear rate. The specific weighting on the actuators may only broadly be determined through estimation of parameter values. Estimates may be made to ensure that capacity for affect regulation is substantially limited during periods of low resource. The use of the 0 to 1 scale of available resource as a direct moderator of self-regulatory capacity currently achieves this purpose, although this range is considered to be subject to individual differences and may be appropriately changed to enable fitting of the model to collected data. For further consideration in this chapter, a linear model is used, although this may be revised in light of fitting collected data; use of an exponential model influences the onset and speed of changes seen in the following test but not the overall pattern of results.

Resource Depletion

Maintenance of affect states at goal values requires regulation and in sections 5.4.2 and 5.4.4, it was indicated that a greater distance between the home-bases (of either the set-point for felt-affect or the felt-affect state for affect-expression) and the goal value was associated with greater regulatory effort. It is anticipated that easier regulation tasks show a greater immunity to depletion effects and so affect regulation will appear to persist for longer. This is expected to occur for both felt-affect regulation and affect-expression regulation. The items of interest in this test are the relative timings that felt-affect and affect-expression show for depletion effects to become apparent. In adjusting the relative difficulty of the two tasks, felt-affect regulation and affect-expression regulation, it follows that the relative apparent persistence will also vary.

For this test, the capacity to engage in both felt-affect regulation and affect-expression regulation is depleted at a continuous fixed rate, determined by factors external to the model's typical operation. At a point during simulation at which both felt-affect and affect-expression are stable, a signal is sent to the model that restricts the capacity for further regulation. This signal lasts 1000 ticks and reduces self-regulatory capacity for affect regulation from maximum (1) to minimum (0) at a continuous rate over the duration of the signal. For the first part, the felt-affect goal is varied across 11 intensities, ranging from 0 to 1, with a home-base of 0 for each simulation. For the second part, the affect-expression goal is varied across 11 intensities, forming a discrepancy between felt-affect and affect-expression ranging from 0 to 1 also.

To compare the relative persistence at regulating towards the varying held goals, results output from the simulations are adjusted to reflect affect change, rather than actual affect intensity. This is achieved by simply subtracting the goal value from each simulation's affect results; this forms a baseline that affect deviates from during periods of depletion. Results are presented in Figure 5.16. The time '0' on the x axis refers to the starting point of depletion, which continues until available resource reaches 0 at 1000 ticks. The left graph shows change to felt-affect and the right shows change to affect-expression. Given affect-expression's higher value for parameter *k3* over felt-affect's value for parameter *k*, results for affect-expression show a faster change, although the overall pattern of results is unchanged.

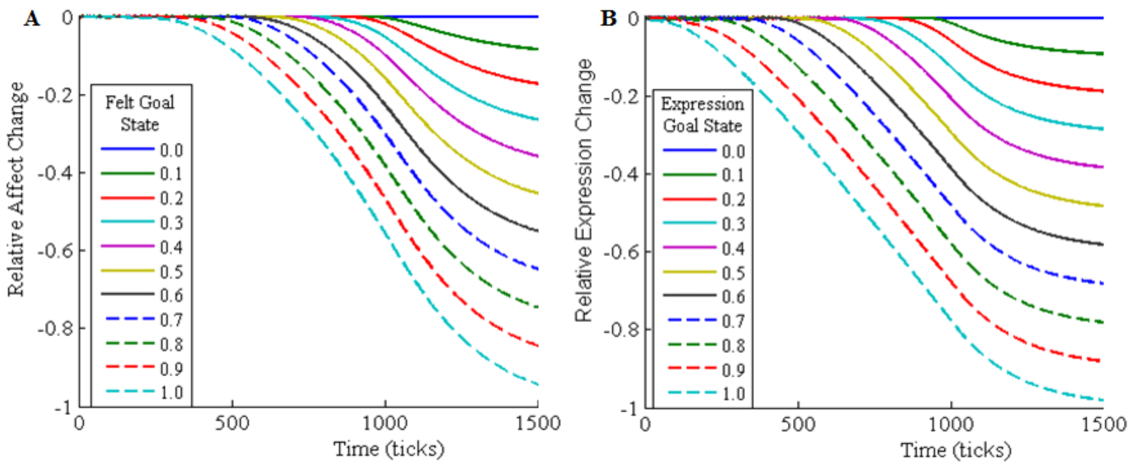

Figure 5.16 A) Relative persistence for felt-affect regulation B) Relative persistence for affect-expression regulation

Relative durations for maintaining affect at respective goal affect intensities and the subsequent dynamics of affect as depletion increases. Depletion limits capacity to regulate towards affect goals prompting further deviation away from greater intensity affect goals. Time in these simulations is arbitrary and measured in ticks.

The results indicate that, as anticipated, persistence at maintenance of affect at the held goal state is longer for goals deemed less effortful than goals deemed more effortful. A goal state that matches the respective home-bases shows no depletion under these conditions because no regulation is required to maintain affect. The mechanism for this relative difference in persistence arises from the distance between the goal and home-base and so the output from the affect regulation blocks. More effortful goals require substantially more regulation and so even slight depletion impairs capacity to reach effortful affect goals. In contrast, less effortful affect goals are to a greater degree immune from depletion because even small amounts of resource are sufficient to maintain sufficient regulation. The affective states do not follow a linear decline with self-regulatory resource depletion because of the gradual decline in a leaky integrator actuator output and affect's gradual return to the home-base. Use of a standard integrator, as discussed in section 4.2.4, does not show appropriate decline in regulation with depletion, further supporting use of the current model design.

Results from this test point towards a potential for developing propositions and predictions regarding affect regulation strategies. In the model, felt-affect regulation and affect-expression regulation are concurrent processes, which can direct their respective affective states towards independent affect goals. It has been determined that as the effort required to reach a goal state decreases, persistence in regulating at this goal state increases. The selection of regulation strategies in the model (i.e., the use of felt-affect regulation over affect-expression regulation, or vice-versa) is ultimately dependent on the relative effort required to regulate towards goals and current self-regulatory capacity.

Strategy switching behaviour can be seen in the model if goal states for felt-affect and affect-expression are congruent and a moderate to large distance from the felt-affect home-base. In a ‘real life’ analogy, this state of positive affect-expression and this positive felt state could be affect goals that an individual working at a customer service post would be expected to hold (e.g., Diefendorff & Gosserand, 2003; Hochschild, 1983). Initially, in simulation of this scenario, the model shows particular use of felt-affect regulation and minimal expression regulation (as there is no need to deviate away from authentic expressions). However, as depletion increases, the felt-affective state begins to shift away from the goal state. This begins to create a discrepancy between affect-expression and the expression goal state and so affect-expression regulation is increased, being - at least temporarily - a low effort task, somewhat immune to resource depletion. Once the model becomes sufficiently fatigued, goals can no longer be regulated towards (this is further considered in section 5.4.6). The key aspect of this chain of events is the switch from the model initially being felt-affect regulation-focused to affect-expression regulation-focused. This has implications for the emotional labour literature because often correlations are reported between surface acting (affect-expression regulation in the model) and feelings associated with depletion (e.g., Grandey, 2003; Martínez-Iñigo et al., 2007). However, the general assumption made in such studies that surface acting is a causal factor in depletion overshadows the potentially confounding factor highlighted by this simulation: while expression regulation may lead to depletion, depletion may promote use of expression regulation.

Circadian Cycles and Sleep

The three process model of alertness (Åkerstedt & Folkard, 1995; Åkerstedt et al., 2004) has been selected as a representation of resource in the model. It captures the influence of the interactions of the circadian cycle and time spent awake on one’s alertness, which is used as a proxy for resource capacity in this model. The *circadian* function is represented by the sum of two sinusoidal waves: the first wave follows a regular circadian pattern of maximum alertness in the late afternoon and a minimum approximately 12 hours later in the early morning; the second, ultradian wave has a 12-

hour cycle and is included to model the early afternoon slump in alertness. The *time spent awake* function is represented by an exponential decay, which is reversed during sleep, representing the restorative effects of sleep on alertness. Prolonged periods of wakefulness lead to a diminished level of alertness that follows the circadian rhythm. Parameter values are drawn unmodified from the original paper (Åkerstedt et al., 2004).

The three process model bounds the available resource through two limiting factors. Firstly, resource is only restored by sleep and once levels of alertness reach a limiting threshold, the sleep function is switched off. As such, the model will always awaken when fully rested and extended sleep cannot lead to an excessive store of resource. Secondly, the *time spent awake* function is modelled as an exponential decay: this function's contribution to alertness cannot fall below the asymptotic value it tends towards. The decay and restoration of resource functions limit the range of available resource to values between 0 and 1. This offers a representation of percentage capacity to engage in affect regulation in the same means as the graded decline from the prior test (as shown in Figure 5.16). Figure 5.17 shows the current model with regulation circuits adapted to include the three process model (Åkerstedt et al., 2004).

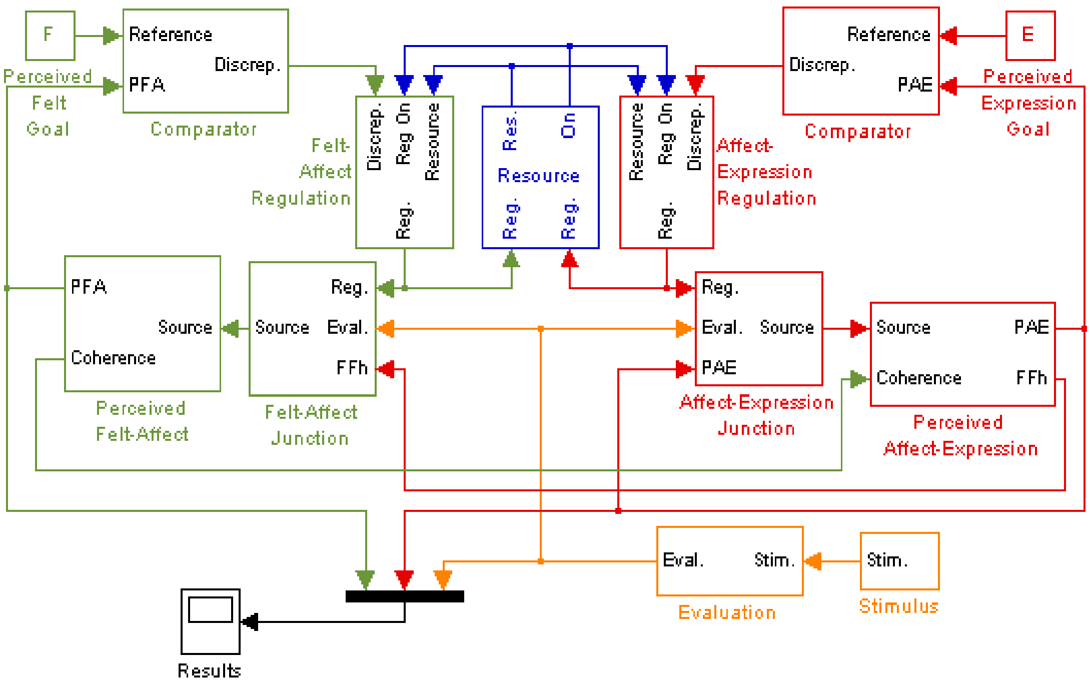

Figure 5.17 Complete regulation of affect circuit with a central resource controlling regulation activity

Model represented in the Simulink environment, building upon Figure 5.13. Additional block used contain previously developed formulas or models specified using Simulink modelling: Resource block contains the Åkerstedt et al (2004) 3-process model, specified in Appendix 1. Felt-Affect Regulation block and Affect-Expression Regulation block contain Formula 5. Acronyms and abbreviations used in the figure are listed in Appendix 2. Information regarding affect and affect regulation flows through pathways marked with arrows.

Representing the capacity to regulate affect as, in part, a function of circadian cycles offers a means of further integrating regular known fluctuations in affect with hypothesised variations in self-regulatory capacity. Studies repeatedly indicate felt-affect has underlying circadian cycles, particularly if examined as positive mood, (e.g., Watson, Wiese, Vaidya, & Tellegen, 1999), typically showing elevation throughout the morning, and then decline in the evening (e.g., Clark, Watson, & Leeka, 1989; Watson & Clark, 1994). Such cycles can be represented in the model, if a felt-affect goal is held as being more positive than the felt-affect home-base and self-regulatory resource is represented by the Åkerstedt et al. (2004) model.

Previous tests in this chapter have represented time in arbitrary units (ticks) and have been sure to check that variations in parameters reflecting rate of affect change do not influence the overall trends in results. Parameter specification in the resource model, derived from the Åkerstedt et al. (2004) model, offers one time point passing in the model as a representation of one minute passing. A value of 0.02 for the parameter k is chosen, which allows for both the representation of circadian change in affect and rapid affective response to stimuli. In this section, felt-affect's change as a function of the dynamic capacity for self-regulation is explored using a simulated sleep deprivation study.

Franzen et al. (2008) report a significant decline in positive affect in individuals experiencing a single night's sleep-deprivation in comparison to non sleep-deprived individuals. To model this result, experimental protocol of Franzen et al. (2008) was replicated where possible in simulation. Reflecting participant group sizes, 15 models were used as the control sample and 14 were subject to a simulated night's sleep deprivation. Simulations lasted a total of two virtual days: for the first, all models had a sleeping period from 23:30 pm for eight hours; for the second, control models had the same sleeping period, while sleep deprivation models remained awake throughout the night. Individual differences were represented in models by varying parameters H, $k2$, Da, and Sa, and by introducing noise to the perceived felt-affect state (Variations reported in Appendix 3). Scores for felt-affect were recorded from all models by averaging current felt-affect across eight hours in day two, starting at 4 pm; these were rescaled to match the scale used by Franzen et al. (2008); results are presented in Table 5.3. The simulations show the same overall trend of a less positive affect state in the sleep-deprivation condition when compared to the non sleep-deprivation condition; simulation means and standard deviation approximate those of empirical data.

Table 5.3 Comparison of empirical and model data for influence of sleep deprivation on felt-affect

	Mean positive affect (10 – 50 Scale)	
	Non-SD group (n =15)	SD Group (n = 14)
Franzen et al. (2008)	25.6 ± 6.0	20.2 ± 7.2
Simulation	29.3 ± 3.9	20.9 ± 4.6

The prior simulation makes an assumption that affect-expression regulation is more depleting than felt-affect regulation. While specific rates of depletion through different affect regulation processes are not yet examined in the literature, affect-expression regulation is considered to be more depleting than felt-affect regulation (e.g., Richards & Gross, 1999, 2000). This is also seen in the emotional labour literature (e.g., Grandey, 2003, Goldberg & Grandey, 2007; Martínez-Iñigo et al., 2007). The exploration of this general trend in results by the model could offer further insights into the depleting nature of affect regulation. Replication of this trend by the model could offer further indication of the model's capacity to represent affect dynamics; collected data in the following chapter regarding the dynamics of affect regulation and resource depletion offer means to further test the model.

5.4.6 Goal Adjustment

When regulation towards a goal becomes too difficult, a change to the goal value may be appropriate (Powers, 1974). Higher levels of self-regulation in control theory are argued to be more stable than that of lower levels and more likely to change slowly (Carver & Scheier, 2001; Lord & Hanges, 1987; Power, 1974). In addition to this, Carver and Scheier (2001) argue that goal adjustment will occur once it becomes apparent that the current regulation of behaviour is insufficient to reach the held goal (or if it continually exceeds the held goal but for simplicity I will only focus on the former here).

Meta loops for both felt-affect and affect-expression goals are the final circuits to be added to the model. As little is known about the dynamics of affective goal adjustment, little differentiation can be made between either circuit so parameter values are considered equal in both. The meta loop compares the current affect goals against their respective current affect states. If there is a discrepancy and if it is apparent that regulation of the affect state is insufficient to reach the goal, the goal is adjusted towards the state. The structure of the complete model is shown in Figure 5.18.

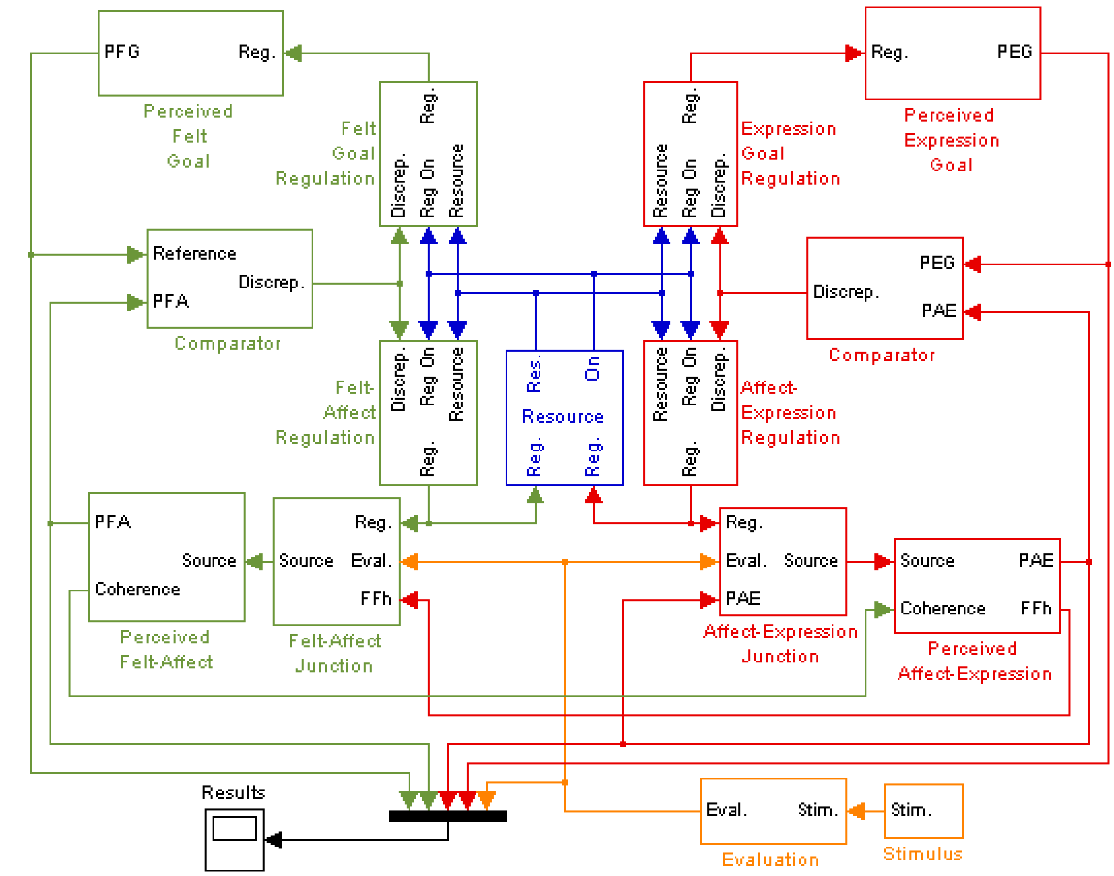

Figure 5.18 The complete model in Simulink

Model represented in the Simulink environment, building upon Figure 5.17. Additional blocks used contain previously developed formulas or models specified using Simulink modelling: Perceived Felt Goal and Perceived Expression Goal blocks contain Figure 4.8; Felt-Goal Regulation and Expression-Goal Regulation contain Formula 6. Acronyms and abbreviations used in the figure are listed in Appendix 2. Information regarding affect and affect regulation flows through pathways marked with arrows.

The felt-affect goal circuit and affect-expression goal circuit are structurally identical. The actuators in each are copied from the lower circuits and the regulatory momentum parameter is kept as a consistent value in all actuators. Fixed constants that were the goal states used previously have now been modified to act as a fixed point about which the movable goals vary. These may be considered as outputs from a third tier of control that changes at such a slow rate it is considered a constant for the duration of simulations. The Perceived Felt Goal (PFG) and Perceived Expression Goal (PEG) blocks each contain a leaky integrator, which uses the permanent goals as home-bases but output values are modified by regulation circuits. The first goal adjustment parameter, *k4* the rate of goal adjustment, is found in both blocks. It is necessary to specify *k4* as this value determines the relative rates of change for affect states and affect goals. A smaller value for *k4* in comparison to the value of *k* is suggested by the literature (e.g., Powers, 1974). To the author's knowledge there is no current study exploring such a prediction; data collection and subsequent model fitting to examine this prediction, is described in Chapter 6.

In section 5.4.5, a linear decline in the self-regulatory capacity is proposed as a means of representing the influence of depletion of resource on the regulation towards held goals. As resource depletes, it is anticipated that the goal states will begin to shift towards the current affective states. To achieve this, it is necessary for the capacity to change held affective goals to *increase* with an increase in depletion, adjusting goals away from their depleting intensities to more achievable levels.

It does not appear that dynamics of affect goal adjustment have been examined before in the affect regulation literature. Therefore, there is no known data to fit the rate of goal adjustment to. A starting estimation is made of the rate of goal adjustment to be one fifth of that of perceived felt-affect change. This rate allows for a steady but slow approach from the held goal towards current affect states, alongside a partial return towards the home-base for affect goals during rest. This value will be modified to fit the dynamics of goal adjustment in collected data.

5.5 Summary

Chapter 5 highlights key parameters in the model and their influence on affect dynamics through testing against known results and identified trends. In areas where this has not been possible due to limited empirical research, propositions and predictions have been offered based on the influence of parameters on the dynamics of the model. A comprehensive review of all parameter values against every other is not possible given the size of the model and the small scope of investigation. A structured scaffold of tests on small stand-alone affect regulation circuits has been presented, to reduce the number of tests to that which is both manageable and still covers all aspects of the model's representations of affect.

The testing process has identified key parameters and constants within the model and, to some degree, specified plausible or necessary values for the operation of the model and representation of affective dynamics. Constants that are not further examined in the thesis are: *k*, the rate of felt-affect change; *k3,* the rate of affect-expression change; *H*, the home-base for felt-affect; and *F,* the strength of expressive-feedback. Parameter values that are further investigated, in comparisons of the model with collected diary data consist of: *k2,* regulatory momentum; *k4,* rate of affect goal adjustment; *da,* resource depletion due to felt-affect regulation; *sa,* resource depletion due to expression regulation; *felt_goal,* home-base for felt-affect goals; *exp_goal*, home-base for affect-expression goals.

PART 2

Chapter 6: Validation Against Diary Data

6.1 Introduction

Chapter 5 examined model dynamics in terms of known data from existing affect studies and from established theories of affect dynamics. Ranges of parameter values were examined for individual sections of the model and their influence on the course of affect, affect goals, and self-regulatory capacity were considered. In the course of testing the model, indications of suitable parameter values for modelling aspects of affect dynamics were derived. However, it so remains in the thesis to further test the model because some model sections, and predictions arising from these, do not currently have sufficient empirical data for making comparisons with. For example, discrepancy reduction in control theory indicates that higher tiers of control should be typically slower to change than lower tiers (e.g., Carver & Scheier, 2001; Lord & Hanges, 1987; Powers, 1974); however, measurements specifically regarding the relative dynamics of affect and affect goals still remain to be gathered. Collecting such data allows for such aspects of the model to be tested and the validity of the model further assessed.

This chapter reports on the collection of new empirical data used to validate the model and the subsequent process of validation. This process of validating the model against collected data further allows for strengths and limitations of the model to become apparent, parameters to be refined, or even restructuring of the model. This chapter is divided into three main sections: the first overviews the collection of new data, the second describes the process of parameter variation to fit the model to the data, the third reports a comparison of the model's representation of felt-affect dynamics with human estimates of the same.

6.2 Diary Data

This thesis has detailed the development and construction of a computational model of affect and affect regulation dynamics. The model simulates dynamics across multiple days for felt-affect, affect-expression, felt-affect goals, affect-expression goals, and self-regulation capacity. As a result, it is necessary for the further testing of the model to collect appropriate data that reflects changes in each across such a period of time. Diary studies are considered an effective means of capturing the change in affect over extended periods of time (e.g., Bolger & Rafaeli, 2003; Fisher, 2000; Fuller et al., 2003) and could be a useful means of collecting data on related concepts, such as affect goal adjustment.

Diary studies provide a strong suitable means of collecting many instances of the same few measures across multiple time points (e.g., Fuller et al., 2003), tracking responses over time. Many data points can therefore be produced even with small numbers of participants and analysis power comes from the number of diary entries made, rather than sample size. This data collection approach is ideal for generating data sets for testing the model, particularly as the aim for the model is to represent trends in affect *within* individuals, rather than *between* groups. Diary studies are particularly useful for exploring states where fluctuations across days or within the day are likely, such as affect (Fisher, 2000), again proving ideal for testing the current model, which can generate hundreds of data points across each simulated day.

Participants

A total of fourteen staff and students from the University of Sheffield volunteered to participate in this study. Individuals had applied to participate in an affect study on mood and music, unrelated to this thesis, after the cut-off for applications had closed and were asked to apply to participate in this study instead. Of the fourteen prospective participants, six were available during the course of recording in April 2010 and were not excluded during the screening procedure described below; a further participant withdrew participation during the study. Due to the sampling strategy and the intensive nature of the data collection, the sample size is small but suitable for the purpose. Five participants completed the study (three were female; mean age ± S.D.: 25.8 ±7.2 years); four were post-graduate students and one was a member of research staff. All participants had applied to the mood and music study with the understanding that they would receive £20 for participation; participants were paid in full on the return of the diary booklets at the completion of the study.

Procedure

Prior to the study, each individual who had expressed interest in participating was given a pre-screening questionnaire. Informed consent of participation was obtained from those who met the screening criteria and were available for the duration of the study. Participants' attention was particularly brought to the right to withdraw participation at any time and the anonymity of data, given the intensive nature of recording data that could be considered personal.

Participants were each given three pen-and-paper diary booklets at the start of the study that contained instructions when and how to complete diary entries. Each booklet contained enough pages for data entry to last two days and participants were instructed that once a booklet was completed to continue on to the next, giving six continuous days of recording. Participants started the study the morning after receiving the booklets. The first diary booklet asked for recordings to be made at 3-hourly intervals from 9AM to 12 midnight; recordings were not taken if the participant remained awake between 12 midnight and 9AM the next day. The second diary booklet asked for recordings to be made at 1-hourly intervals, again from 9AM to 12 midnight and again not requiring entries after 12 midnight. The third booklet followed the first's procedure. The diary recording schedule was more intensive in booklet two in comparison to booklets one and three because the recording period for booklet two coincided with a week-end, so it was anticipated that participants would have more available time to complete entries. An additional recording was made on waking each day, also requesting the participant to estimate the duration of sleep. If participants missed any entries, they were instructed to not retroactively complete entries but to continue with the diary as normal.

Measures

Examples of the pre-screening survey and the affect diary are found in Appendix 4.

Pre-Study Screening Survey

The pre-study screening survey consisted of two parts. The first part comprised two questions to determine participants' suitability for the study. Participants were asked if they experience an erratic sleep pattern (such as that due to shift work) and if they experience or have experienced a diagnosed mood disorder. If a participant answered yes to either question they were not included in the main diary study because the present focus for the model is the representation of typical affect dynamics. The second part comprised of a sample page of the diary to familiarise participants with the study and procedures for completing each entry.

Diaries

Felt-affect was recorded on the two dimensions of valence and arousal, put forwards as the standard means of representing core affect (Remington, Fabrigar, & Visser, 2000; Russell, 1989; 2003). In the paper diaries used, this comprised of a two-item scale of bipolar, 11-point measures of *Gloomy* to *Happy* and *Sluggish* to *Energetic*. A bipolar representation of such affective states has previously been indicated as a suitable means for representing affect (Eaton & Funder, 2001; Russell & Carroll, 1999) because it enables representation of both experience of affect and feeling neutral, without ambiguity in responses. Bipolar scales for felt-affect ranged from -5 (indicating feeling a negative state to a great extent) to +5 (indicating feeling a positive state to a great extent) with 0 representing feeling neutral. This two-item scale is repeated in this same form in each diary entry for reporting both felt-affect goals and affect-expression goals.

In addition, the valence and arousal of affect events were recorded (using the same scale as above); the events' times of onset and durations were also recorded. Individuals' own affect-expressions were recorded using the same scale for valence and arousal; times of onset and durations of affect-expressions were also recorded.

The final scale used in regular diary entries concerns one's perceived self-regulatory fatigue. It was adapted from Clarkson et al.'s (2010) single item measure of self-regulatory exhaustion to examine perceptions of how emotionally exhausted individuals feel. This is a unipolar measure with a range from 0, not drained at all, to 10, feeling drained a great extent.

For the scales measuring felt-affect, felt-affect goals, affect-expression goals, and self-regulatory exhaustion, participants were instructed to record their present states in each entry (e.g., How alert do you feel at this time?). For recordings of affect events and individuals' own expressions, participants were instructed to recall occurrences since the last diary entry was scheduled.

At the start of each day, participants were also asked to record their time of waking, approximate time of sleeping and an estimation of minutes of sleep lost in the night.

Analysis

On average, participants completed a total of 41 entries of the maximum 56 regular entries. The most common reason for not completing an entry in the diary was that the scheduled entry fell outside of the participants' waking hours. All of the six diary entries scheduled to be completed on waking were completed by each participant. 153 of the regular diary entries (74%) included one recorded affective event, 24 (12%) included the recording of two events and there were just five instances (2%) of three or more affective events recorded. There were substantially fewer recordings of individuals' own affect-expressions: just 58 of the regular diary entries (28%) included any recorded affect-expression. Because of the limited entries across the diaries, affect-expression is not considered in subsequent sections of this chapter but will be addressed in the next diary study in Chapter 7.

Circadian Analysis

Circadian analysis in this study is used to determine the presence of underlying cyclical patterns in resource. Self-regulatory capacity has often been associated with a subjective feeling of alertness and periods of subjective fatigue are considered to coincide with periods of regulatory fatigue (e.g., Hagger, 2010; Hagger et al., 2010). It is proposed in this thesis that, given the association of self-regulatory capacity's with both subjective fatigue and physical energy available to the brain (e.g., Gailliot, 2008; Gailliot et al., 2007), self-regulatory capacity may show similar dynamics to those seen in fatigue. Indication of a circadian cycle of self-regulatory capacity would further justify the use of a circadian based model (Åkerstedt et al., 2004) to represent self-regulatory capacity as a component of the wider model of affect regulation dynamics. In this study, the measure of feeling emotionally drained was used as an indicator for the self-regulatory capacity of affect regulation. This is based on the assumption that a perceived sense of regulatory fatigue is a limiting factor in self-regulatory capacity (e.g., Clarkson et al., 2010).

To examine for the presence of a circadian cycle of self-regulatory capacity, each of the six day time-series for feelings of being emotionally drained are subject to a 'Binfit' analysis. Binfit is bespoke software that examines time-series data for cyclical patterns;

the time-series data as a whole is first divided into sections each the duration of the cycle examined (e.g., a 24-hour cycle divides the time-series data into sections lasting 24 hours). Within each section, the time-series data is further sub-divided into equally spaced time ‘bins’, which recur with every cycle the time-series lasts; all data points within that time bin are clustered together. Bins are grouped by their label (e.g., the data points in the first bin in every daily cycle are collated) and differences in data points between bins examined.

In this study, the circadian cycle for self-regulatory capacity is considered; Binfits are generated for feelings of being emotionally drained for cycles between 22 hours and 26 hours in 0.2 hour intervals, offering a range that can be considered approximately daily cycles. Within these cycles, reported feelings of being emotionally drained are fit into 8 equally spaced bins, given the intervals between diary recordings. The width of time bins therefore varies from 2.75 hours in the binfit for a 22 hour cycle to 3.25 hours in the binfit for a 26 hour cycle. Analysis of the collated data is performed using one-way repeated measures ANOVA with independent variable being *bin label* and dependent variable reported *feelings of being emotionally drained*. Table 6.1 reports the circadian period for each of the diaries that is associated with highest variance explained by the fitted cycle for feelings of being emotionally drained.

Table 6.1 Periods for each diary recordings of feelings of being emotionally drained

Diary No.	Period (hrs)	F	Df	Variance %	p
1	23.2	2.76	(7, 35)	35.56	0.02
2	24.4	3.31	(6, 42)	32.07	0.0095
3	23.0	3.03	(6, 50)	26.36	0.013
4	23.4	4.61	(6, 38)	42.13	0.0016
5	25.4	2.49	(6, 33)	39.38	0.0075

These above results are used to inform the circadian component of the resource capacity block in each model simulation. With each diary, the period for the circadian component is specified according to the results above (see Section 6.3, sub-section *Simulation Procedure)*. This parameter value is kept constant across all testing of the models, while fitting the variable parameters (Table 6.2) to the diary data. This circadian component alongside the sleeping and waking schedule for each individual forms the primary basis of the dynamics of the Åkerstedt et al. (2004) model of fatigue, which is used in this thesis as representation of self-regulatory capacity.

6.3 Validation of the Model

The model's capacity to represent the dynamics of affect, affect goals and self-regulatory capacity is considered through the adjusting of parameters in the model and subsequent comparison of variables with the diary data. Chapter 5 overviews the strengths and limitations of fitting model parameters to available data; model results successfully reflecting collected data offers an initial step in testing its validity and diagnostics for further model development (Humphreys & Gurney, 2007; Rodgers and Rowe, 2002).

Validation Design

In the study described in section 6.2, five diaries of affect data were collected. To compare simulation results against diary data, five separate MARDy models are constructed to reflect each individual's experiences during the study. The differentiation between the models to reflect each individual's experience and parameter variation for fitting the models to the collected data is specified in the section *Validation Procedure*, below. These specifications are used to estimate the dynamics of felt-affect, felt-affect goals, self-regulatory capacity, and affect-expression goals. Validation against collected diary data is divided into three separate approaches. These may briefly be described as validating individual specificity, temporal specificity and relational representation.

a. *Individual specificity:* A simulation of an individual's data set can be tested by correlating the collected data and model results, with higher correlations indicating better matches. However, a high quality fit would not just be dependent on representing the individual's data set. The model's results should show a higher correlation with the intended individual's data than with any other individual's data. Also, diary data should have a higher correlation with the intended model than with any other model.

b. *Temporal specificity:* Simulation of affect dynamics can be further assessed by examining dynamics within each data set. The model's simulation of a specified section of an individual's data would be expected to better correlate with that section over any other chosen section. Because affect data across time exhibits a serial dependency, it would be expected that as the temporal distance between the modelled data section and any other section of the diary data increases, the correlation strength decreases.

c. *Relational Representation:* Correlations are anticipated to exist in each individual's diary data between conceptually related measures, such as felt-affect and felt-affect goals. The direction and degree of these correlations should be reflected in the modelled results.

In using parameter variation to fit model data to collected data there is the potential for over-fitting, particularly if the number of data points to be fit is low (e.g., Farrel & Lewandowsky, 2010b). Over-fitting is characterised by a strong representation of data that the model has been trained on but limited capacity to represent novel data, due to the model representing idiosyncrasies in the original data set. As a result, *individual specificity* is conducted ahead of *temporal specificity* because the *individual specificity* approach examines each individual's diary data measures as a whole, rather than examining sections of the data. To examine potential of over-fitting the diaries in the *individual specificity* approach, the model is compared to a further diary set it has not been trained on; this is reported in Chapter 7.

Validation Procedure

This section reports the means used to obtain the closest representation of the diary data through parameter variation in the models. Each diary is paired with a unique MARDy model, which reflects differences between the diaries and so varies from each of the other models in four key ways; this is covered in the subsection S*imulation Procedure* below, but can be summarised as differences in sleeping schedules, self-regulatory capacity cycles, occurrence of affect events, and starting affect. The results from the five unique models for any given combination of tested parameters are termed *simulation results*; these simulation results are validated against the diary data. The closest representation of diaries by the simulation results is reported in section 6.3.1 and further explored in sections 6.3.2 and 6.3.3.

Parameter Variation

The capacity for MARDy to represent diary data is determined through the process of parameter variation. In Chapter 5 the influence of various parameters on affect dynamics in the model was explored and, in some cases, suitable parameter ranges considered. Six of these parameters are further considered in this chapter and are listed, along with the ranges considered for investigation, in Table 6.2. Where possible, parameter ranges have been taken from the ranges used in Chapter 5 and are now reexamined in light of varying configurations of other parameters. Four parameters in the model have been specified as constants in this chapter to limit the already broad testing approach. These constants are: rate of felt-affect change ($k = 0.02$), rate of affect-expression change ($k3 = 0.08$), the home-base for felt-affect ($H = 0.2$), and expressive-feedback strength (F = 0.2). Home-base is specified at a mildly positive state to generally maintain a slightly positive affect state as argued in theories of affect (e.g., Biswas-Diener et al., 2004), and expressive-feedback strength, specified in Chapter 5 to ensure the loop between felt-affect and affect-expression is sufficiently weak.

Importantly, the parameter ranges covered include values which can contradict established theories of affect regulation. Expression regulation is considered to be more costly than felt-affect regulation (e.g., Holman, Martínez-Iñigo, & Totterdell, 2008; Hülsheger & Schewe, 2011; Richards & Gross, 1999); if the closest matching simulation requires affect-expression regulation to be less depleting than felt-affect regulation, it indicates the model or current theories need revision. In addition to this, the felt-affect goal home-base can be specified at its lowest value to match the felt-affect home-base; if this is the case for the closest matching simulation, it would indicate that the model needs revision, given the differences seen in the diary data between typical goals and felt-affect.

Six parameters are tested in this chapter, each across five different values. To better understand the influence of each of the parameters and the interactions with other parameters on affect dynamics, it is necessary to run a large number of simulations. To test all combinations of parameters, 15,265 (5^6) unique simulations are run. The variation of multiple parameters is a factorial problem, in which just doubling the number of values tested from five each to ten results in 1,000,000 (10^6) simulations.

Table 6.2 Parameter variation for data fitting of multiple diaries

Parameter Name	Parameter Symbol	Range of Values
Felt-Affect Goal Home	*Felt_Goal*	0.2, 0.4, 0.6, 0.8, 1
Affect-Expression Goal Home	*Exp_Goal*	0.2, 0.4, 0.6, 0.8, 1
Felt-Affect Regulation Cost	*Da*	1, 2, 3, 4, 5
Affect-expression Regulation Cost	*Sa*	2, 4, 6, 8, 10
Regulatory Momentum	*k2*	0.0025 0.005 0.01 0.02 0.05
Rate of Goal Adjustment	*k4*	0.0025 0.005 0.01 0.02 0.05

Simulation Procedure

Within the simulations, each of the diaries is represented by a unique MARDy model, which differs from all other models in simulations by four means; the first two directly influence the modelled felt-affect state and the last two influence self-regulatory capacity. First, all the recorded affect events across the diaries are represented in their respective models as stimuli to the felt-affect block. The time of occurrence, duration, and affect intensity of affect events recorded in the diaries are modelled as transient disturbances, directly influencing the modelled felt-affect states. Second, all models are specified so that the initial felt-affect state reflects that recorded on waking in the first diary entries.

Third, recorded waking times, sleeping times and any sleep interruptions are represented in the models. Individuals' sleeping and waking times are used to instruct the central block determining self-regulatory capacity. Periods in which the models are considered 'awake' result in depletion of resource and 'sleeping' periods restore self-regulatory capacity to the models. Fourth, the proposed circadian components to self-regulatory capacity overviewed in Table 6.1 are specified in each of the models and phase adjusted to represent the cycles seen in current diaries. The three process model (Åkerstedt et al., 2004) experiences asynchrony between the 24-hour clock and the circadian cycle, if the circadian period is specified to anything other than 24 hours. As a result, the peaks and troughs in modelled alertness (or, as this thesis argues, self-regulatory capacity) become either progressively advanced or delayed, depending on whether the circadian period falls shorter or longer than 24 hours, throughout the course of a single simulation. To correct for this, the phase is adjusted by moving the starting point in the modelled circadian cycle either forwards or backwards until it best represents the perceptions of self-regulatory exhaustion.

The four specifications to distinguish the models from each other and reflect experiences reported in the diaries are kept constant across all simulations so that the effects of the individual's daily life on affect, goals and self-regulatory capacity can be seen. In selecting a single set of parameters to best represent the diaries as a whole, the differences between models outlined in this section give each model its unique affect dynamics. To further explore individual differences between diaries, individual parameter profiles could be examined and models further tailored to represent individuals, although this is currently considered to be a future direction for the model.

Data Recording Procedure

In Chapter 5, a theory of testing the model against known data is presented. Variables and parameters in the model can be estimated based on the results given by participants and the model results (such as its representation of felt-affect) can be compared against those recorded in the diary data. In effect, the model's outcomes can be regarded as another data set equivalent to that of the diary data. However, some steps are necessary to ensure that appropriate comparisons are made: firstly, the model results are sampled at time-points equivalent to times diary entries were recorded; secondly, model results are rescaled to reflect the scales used in recording diary entries.

Unless otherwise specified, all simulations in this thesis have a fixed temporal resolution of one minute, meaning that every tick or cycle of the model represents the passing of a minute in time. The model makes a continuous and graded change across time at a resolution far beyond which is recorded in the majority of the diary data. In some cases in the diaries, affect event duration, time of waking and estimates of sleep duration each have been recorded at a comparable scale of minutes but the majority of entries in the diary data are at temporal resolutions no finer than an hourly basis. In their raw forms, model results and diary data cannot be suitably be compared. Model results are therefore converted to match the structure of diary entries; as such, model simulations are treated as a series of results from virtual participants in the diary study.

Model results are sampled and recorded at each time point in the simulations that correspond to diary entry times. Sampling consists of taking a small window of the model data (10 continuous points) at the appropriate time points (for example, time point 720 corresponds to 12 Noon on day 1 in the diary study) and averaging values sampled. This snapshot of a few time-points in the model may then be considered similar to that of the diary data on a temporal basis. These values are then recorded after being scaled and rounded to match the scales used in the diary study. Unlike the continuous range of values used in the model, the diary data entries are made on an 11 point scale. Results from simulations that fall between any of these points are rounded to the nearest value, to reflect the participant responses available in diary entries.

Before proceeding with comparing the various model fits with diary data, the diary data is examined to determine if it has sufficient number of data points to be used for the *temporal specificity* approach. In that test, the diary data is divided into three equal duration sections and then correlated to determine the predictive quality of each section of the data against later sections. If, however, due to the division of the diary into sections there are insufficient data points in a particular section, this part of the diary is discounted from further analysis. Should two sections show an insufficient number of data points for a correlation to arise, a sufficient number of data points have been discarded for the diary data as a whole to no longer meet the threshold for *individual specificity* (20 data points) to guard against over-fitting. In this chapter, three measures do not meet the minimum number of data points through this method and so are not included in analysis for fitting the model to the diary data. These measures are *felt-affect goals* in Diary 5 and *affect-expression goals* in Diaries 2 and 5; all other measures are included in the analysis.

Correlations between each individual's diary data and model recordings are made for four different variables: felt-affect, felt-affect goals, affect-expression goals, and self-regulatory. All correlations are converted to normally distributed measures using a Fisher transformation. In *individual specificity*, this enables the average correlation strength to be calculated between all models and diaries for all measures and so determines the closest average representation of the diaries by the models. In *temporal specificity* this enables the average correlation for each section of the models with each section of the diaries to be determined. All results are transformed back to correlation values before being reported in this chapter. Model results, representative of the simulations capacity to fit diary data, are presented against corresponding diary data in graphs for each of the measures in the individual specificity category. It is anticipated that the models will show variation in their capacity to fit their respective diary data sets; a representative model is chosen on the basis of being the median ranked correlation in the degree of fit between models and their respective diaries.

6.3.1 Individual Specificity

This test aims to identify the single parameter set which results in the highest average correlation between each model and its respective diary across the four dimensions of felt-affect, felt-affect goals, affect-expression goals and self-regulatory capacity. Models considered successful in representing the diary data are those which show a stronger correlation with its respective diary than with any other diary and show a stronger correlation with its respective diary than any other model does. Table 6.3 reports the parameter values used in generating the closest representation on average of the diary data in a simulation.

Table 6.3 Parameters giving closest representation across multiple diaries

	Felt_Goal	Exp_Goal	Da	Sa	k2	k4
Model Value	0.8	0.8	2	2	0.02	0.02

There are four key points to consider regarding the parameters used. First, the felt-affect goal home-base is much higher than the felt-affect home-base (specified at 0.2) implying a general trend in regulation towards more positive affect states. Second, the affect-expression goal home-base is the same intensity as the felt-affect goal home-base, suggesting that the two goals may typically be close and implying an aim of authentic expression. Third, the cost associated with felt-affect regulation matches that of the affect-expression regulation, an outcome not anticipated in simulation. Finally, the rate of affect goal adjustment matches the specified rate of affect change (0.02); this is a surprising outcome because it is a parameter built in to the higher tier of the control model and affect goals were expected to engage in change at a slower rate than that of lower tiers.

Felt-Affect

Results for the correlations between felt-affect reported in the diaries with felt-affect from the respective models are shown in Table 6.4 and highlighted in bold font; all other correlations between diaries and models are shown in the same table in plain font. Results indicate a range of correlation fit quality across the diary data sets. Four out of the five model results for felt-affect significantly correlate with their respective diaries at the defined statistical significance of $p < 0.002$ after the Bonferroni correction for multiple comparisons (25 comparisons). In addition to this, four of the five models represent their respective diaries closer than they do any others, with only Model 1 representing other diaries closer than its counterpart. Finally, four of the five diaries are best represented by their respective models, with only Diary 3 being better represented by a model other than its counterpart

Table 6.4 Correlations for felt-affect between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5
Model 1	**.54***	-.18	.68**	.63**	-.28
Model 2	.01	**.43**	-.40	-.27	-.21
Model 3	.28	.13	**.65****	.42	-.15
Model 4	.31	-.27	.29	**.65****	-.10
Model 5	-.36	-.12	.10	-.20	**.53***

** = $p < 0.0004$, * = $p < 0.002$

Table 6.4 reports correlation strengths for model fits against their respective diary data ranging from .43 to .65; to offer a representation of the models' fit to diary data, results for felt affect for both Model 1 and Diary 1 are presented in Figure 6.1. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 6.4. The model data captures the changes at the start of Day 2, the end of Day 6 and changes throughout Day 5 seen in the diary data.

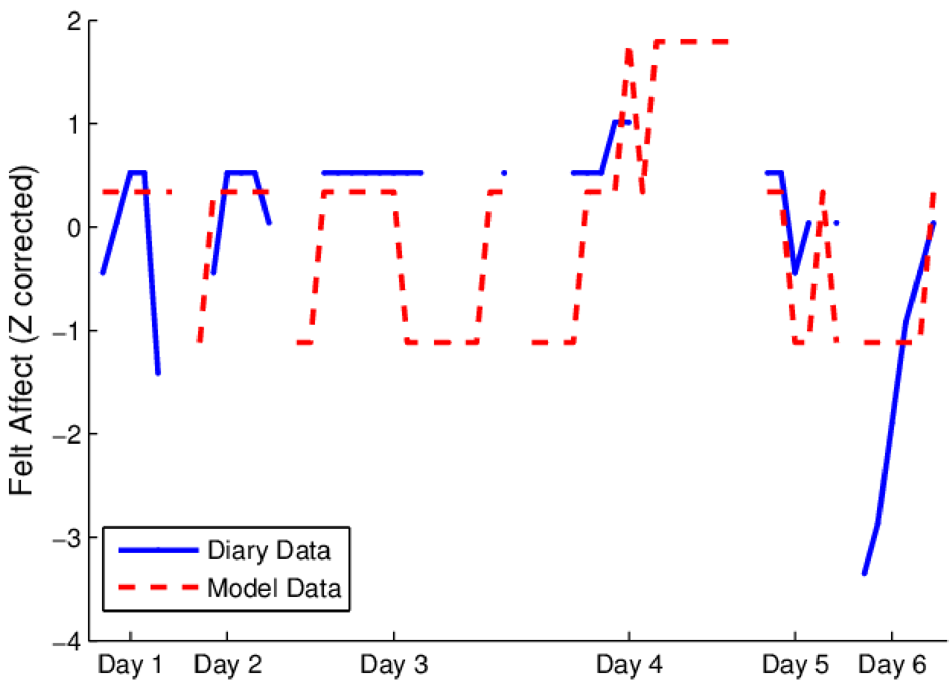

Figure 6.1 Felt affect results for Model 1 and Diary 1

Results for diary data are taken from the 35 diary recordings made in Diary 1; all 56 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

Felt-Affect Goals

Further strengths and limitations in the model's capacity for representing diary data can be seen in correlations between the models and diaries for affect goal data (Table 6.5); correlations between diaries and their respective models are highlighted in bold font, while all other correlations between diaries and models are shown in the same table in plain font. Diary 5 was excluded from analysis based on the limited available data-points to correlate with. No significant results are seen between diaries and models at the defined statistical significance of $p < 0.0025$ after the Bonferroni correction for multiple comparisons (20 comparisons). However, three of the four models represent their respective diaries closer than they do any others, with only Model 3 representing another diary closer than its counterpart. In addition to this, three of the four diaries are best represented by their respective models, with only Diary 3 being better represented by a model other than its counterpart.

Table 6.5 Correlations for felt-affect goals between all models and diaries

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5
Model 1	**.46**	-.23	.40	-.05	--
Model 2	.19	**.37**	-.29	-.14	--
Model 3	.35	.00	**.10**	-.11	--
Model 4	.08	-.23	.11	**.37**	--
Model 5	-.40	-.03	.20	-.20	--

** = $p < 0.0005$, * = $p < 0.0025$

Table 6.5 reports correlation strengths for model fits against their respective diary data ranging from .10 to .46; to offer a representation of the models' fit to diary data, results for felt affect for both Model 2 and Diary 2 are presented in Figure 6.2. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 6.5. The model data captures the changes at the start of Day 5 and the end of Day 3 and Day 2 seen in the diary data.

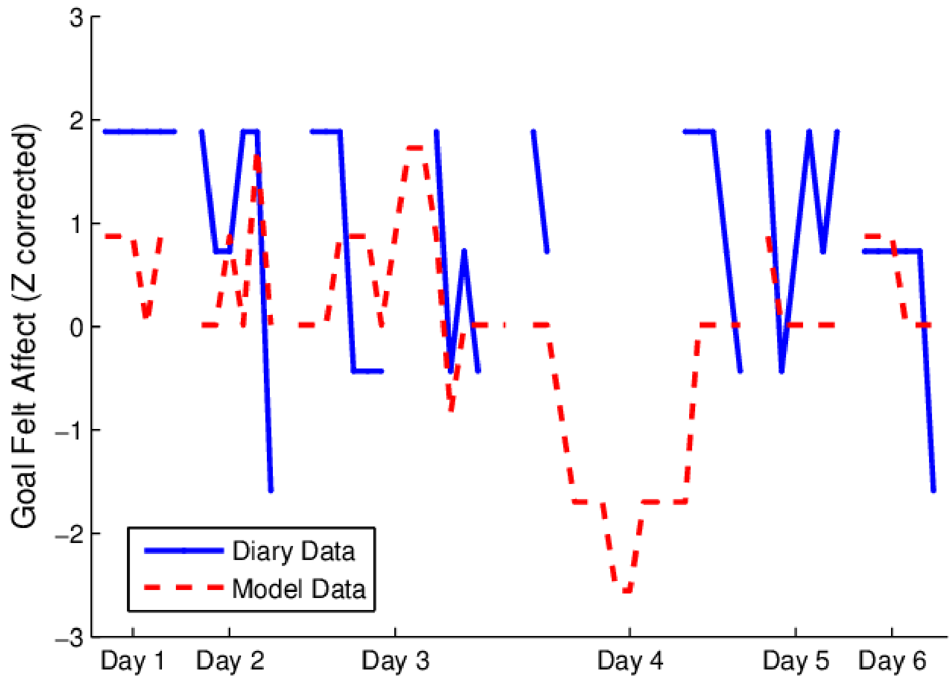

Figure 6.2 Felt affect goal results for Model 2 and Diary 2

Results for diary data are taken from the 43 diary recordings made in Diary 2; all 56 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

Affect-Expression Goals

Correlations for affect-expression goals between diaries and their respective models are highlighted in bold font in Table 6.6; all other correlations between diaries and models are shown in the same table in plain font. Diaries 2 and 5 were excluded from analysis based on the limited available data-points to correlate with. Of the three remaining diaries, two show a significant correlation with their respective models at the defined statistical significance of $p < 0.0042$ after the Bonferroni correction for multiple comparisons (12 comparisons). Alongside this, two of the three models represent their respective diaries closer than they do any others, with only Model 1 representing other diaries closer than its counterpart. Finally, all three diaries are best represented by their respective models.

Table 6.6 Correlation of affect-expression goals between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5
Model 1	**.37**	--	.38	.44	--
Model 2	-.01	--	-.32	-.22	--
Model 3	.20	--	**.47****	.32	--
Model 4	.18	--	.27	**.66****	--
Model 5	--	--	--	--	--

** = p < 0.0008, * = p < 0.0042

Table 6.6 reports correlation strengths for model fits against their respective diary data ranging from .37 to .66; to offer a representation of the models' fit to diary data, results for felt affect for both Model 3 and Diary 3 are presented in Figure 6.3. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 6.6. The model data captures the changes throughout Days 1 and 2 and the middle of Days 3 and 4.

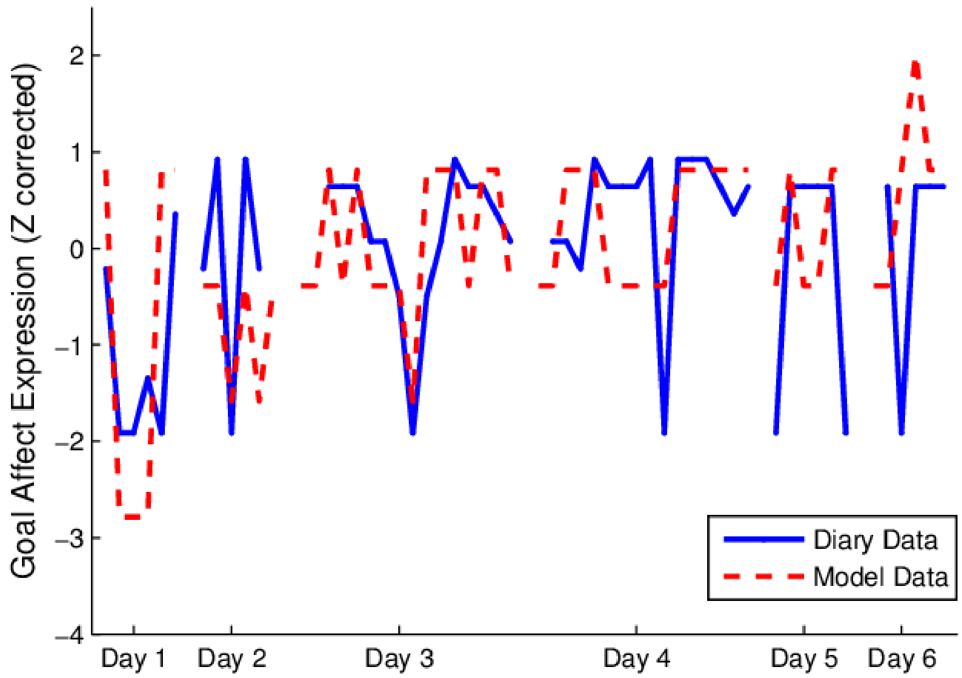

Figure 6.3 Felt affect goals results for Model 3 and Diary 3

Results for diary data are taken from the 51 diary recordings made in Diary 3; all 56 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

Self-Regulatory Capacity

Finally, MARDy's capacity for representing diary data can be seen in correlations between the models and diaries for self-regulatory capacity (Table 6.7); correlations between diaries and their respective models are highlighted in bold font, while all other correlations between diaries and models are shown in the same table in plain font. Two out of the five model results for self-regulatory capacity significantly correlate with their respective diaries at the defined statistical significance of $p < 0.002$ after the Bonferroni correction for multiple comparisons (25 comparisons). In addition to this, three of the five models represent their respective diaries closer than they do any others, with Model 1 and 4 each representing another diary closer than their counterparts. Finally, four of the five diaries are best represented by their respective models, with only Diary 1 being better represented by a model other than its counterpart.

Table 6.7 Correlation of perception of feeling drained between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5
Model 1	**.09**	-.10	.62**	-.23	-.35
Model 2	-.21	**.58****	-.76**	-.15	-.07
Model 3	.26	-.12	**.63****	-.22	-.49
Model 4	.02	-.24	.45*	**.19**	-.01
Model 5	-.53*	.29	-.49**	-.39	**.47**

** = $p < 0.0004$, * = $p < 0.002$

Table 6.7 reports correlation strengths for model fits against their respective diary data ranging from .09 to .63; to offer a representation of the models' fit to diary data, results for felt affect for both Model 2 and Diary 2 are presented in Figure 6.4. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 6.7. The model data captures the changes throughout Days 1 and 5 and the end of Days 4 and 6.

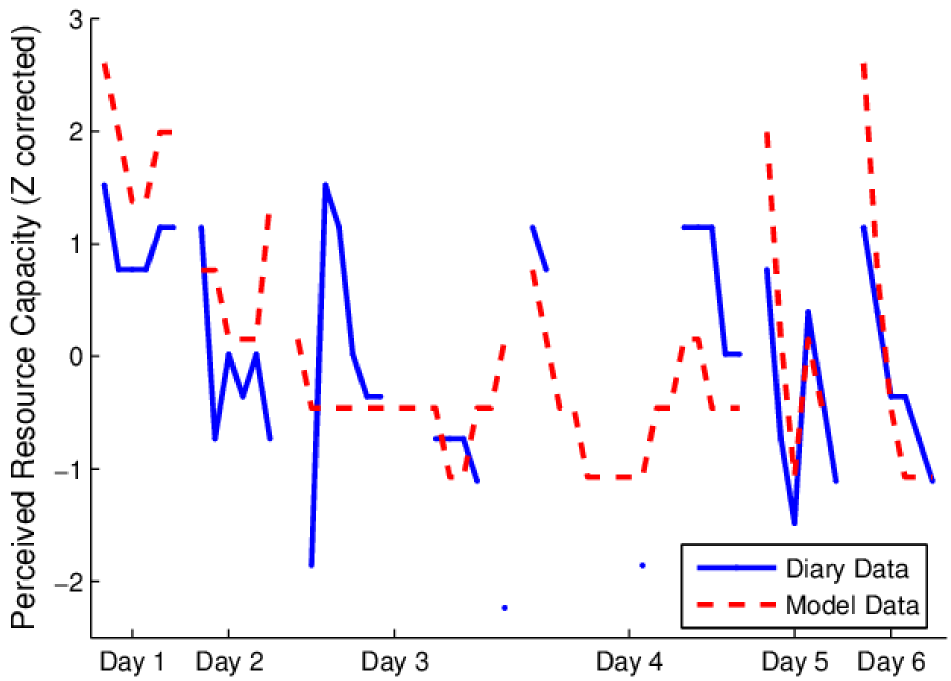

Figure 6.4 Perceived self-regulatory resource capacity results for Model 2 and Diary 2 Results for diary data are taken from the 43 diary recordings made in Diary 3; all 56 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

6.3.2 Temporal Specificity

Parameter values for the model have been established by finding the best overall correlation for the model across the entirety of the six day duration of the diary studies. To further understand how well the model captures the dynamics of diary data, changes within each diary are examined. The prior tests represent a general fitting of the model to diary data and so may match long trends over the whole of the data sets. Reducing the window of data examined and comparing different sections of each data set allows for a closer examination of trends and changes within the data.

To examine correlations within the diary data, the existing diary data is divided into three separate sections, each lasting two days. Correlations within the diaries indicate the consistency across time of the affect states in the diary data. High correlations would imply a cyclical pattern in the data with a period of two days; an absence of correlation could indicate a high dependency of affect state on affect events not likely to repeat with any regularity. As affect states are serial dependent, it would be expected that adjacent sections in the data would have a stronger correlation than more distal ones (e.g., Bolger, DeLongis, Kessler, & Schilling, 1989). Mean correlations between each section of the diary data are taken across results from all diaries

To determine MARDy's capacity to represent a subsection of the diary data and correlations within the time-series results, the model data is divided into three separate sections equivalent to the diary sections described above. Correlations seen in each model indicate the consistency across time of the affect states in the model data. The mean correlations between each section of the model data are taken across results from all models just as they are for the diary data. Each section of the model data is further correlated with each section of the diary data, and mean correlations are reported.

Felt-Affect

On average there are 13.7 time points completed in each diary section. Table 6.8 indicates that there is little potential of correlation within the diaries on average across the three sections. This is reflected in the similar pattern within the models on average across the three model sections. The table further points towards correlations between the models for sections A and C and their respective diary sections. These outcomes generally support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 6.8 Average correlations for felt-affect within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	.25				
Diary Section C	.06	-.09			
Model Section A	**.70**	.33	.18		
Model Section B	.10	**.19**	-.14	.01	
Model Section C	-.25	.25	**.66**	-.08	-.23

Felt-Affect Goals

Results in Table 6.9 show a similar pattern to that seen in Table 6.8; the correlations shown are averages from four of the five diaries for felt-affect goals, with Diary 5 omitted due to the limited number of data points. On average there are 14.2 time points completed in each diary section. A small correlation between diary section A and B is indicated, while there is no indication of correlation apparent between the more temporally distal sections A and C. However, this overall trend is not reflected substantially in the model results. The table does point towards correlations between the models for sections A and C and their respective diary sections. These outcomes partially support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 6.9 Average correlations for felt-affect goals within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	.31				
Diary Section C	.07	-.11			
Model Section A	**.70**	.33	.22		
Model Section B	.12	**.23**	-.18	.01	
Model Section C	-.31	.30	**.76**	-.10	-.29

Affect-Expression Goals

The results in Table 6.10 for affect-expression goals show a contrasting pattern to results seen for felt-affect and felt-affect goals; the results shown are averages from three of the five diaries, with Diaries 2 and 5 omitted due to the limited number of data points. On average there are 13.9 time points completed in each diary section. A negative medium sized correlation between diary section A and B is indicated, while there is a small correlation apparent between the more temporally distal sections A and C. Moreover, this (somewhat surprising) overall trend is reflected closely in the model results; the further negative correlation between diary sections B and C is also reflected in the model data. The table further points towards correlations between the models for sections A, B and C and their respective diary sections. These outcomes generally support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 6.10 Average correlations for affect-expression goals within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	-.58				
Diary Section C	.30	-.37			
Model Section A	**.68**	-.57	.36		
Model Section B	.01	**.36**	-.18	-.31	
Model Section C	.12	-.51	**.24**	.29	-.49

Self-Regulatory Capacity

Finally, results for self-regulatory capacity show the anticipated trend for the time-series data (Table 6.11). On average there are 13.7 time points completed in each diary section. Within the diary data there is an indication of a strong correlation between sections A and B, which reduces to a medium strength correlation between the model temporally distal sections A and C. Alongside this, the correlation for sections B and C within the diary data appear to be of similar strength to that of section A and B. Model results reflect each of these outcomes, representing the overall trend seen in the diary results. Further to this, the table points towards correlations between the models for sections A, B and C and their respective diary sections. These outcomes generally support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 6.11 Average correlations for perceptions of feeling drained within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	.71				
Diary Section C	.40	.80			
Model Section A	**.84**	-.77	.49		
Model Section B	.65	**.47**	.81	.92	
Model Section C	.66	.21	**.93**	.71	.98

6.3.3 Relational Representation

The final approach for identifying the capacity for the model to represent diary data is the replication of relationships and trends between measures recorded. If two variables show a significant correlation within the diaries' recorded data, a model that aims to simulate both of these variables well ought to also represent the existing correlations.

Three comparisons between variables are made in this test for each of the diaries. These are: correlation of felt-affect and perceived self-regulatory capacity, correlation of felt-affect goals and perceived self-regulatory capacity, and correlation of felt-affect and felt-affect goals. It would be anticipated from theory informing the model's design that there would be a positive correlation between variables. Felt-affect is considered to be regulated towards positives states and influenced by one's self-regulatory capacity (Muraven et al., 1998); a greater self-regulatory capacity is anticipated to be associated with a more positive affect state. In addition to this, positive affect goals are considered to be maintained until self-regulatory capacity is depleted, at which point it is anticipated that goals shift towards less intense, more manageable levels (e.g., Carver & Scheier, 2001; Powers, 1974); resource depletion is anticipated to be associated with less positive affect goals. Finally, these processes of goal adjustment and affect change are considered to happen concurrently and in the same direction, so are anticipated to show association.

Table 6.12 overviews the correlations between core concepts described above for each of the diaries. Firstly, there are positive correlations between felt-affect and self-regulatory capacity at the defined statistical significance of $p < 0.01$ after the Bonferroni correction for multiple comparisons (5 comparisons) in four of the five diaries. Second, two of the four diaries examined show positive correlations between felt-affect goals and self-regulatory capacity; Diary 5 is again excluded from analysis due to limited data points for affect goals. Finally, two of the four diaries examined show positive correlations between felt-affect and felt-affect goals.

Table 6.12 Correlations of core concepts in each diary

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5
Felt-affect & Regulatory Capacity	.91**	.61**	.67**	.14	.75**
Felt-affect Goals & Regulatory Capacity	.80*	.66*	.19	.01	--
Felt-affect & Felt-affect Goals	.77**	.65**	.28	.40	--

** = p < 0.002, * = p < 0.01

The results in Table 6.13 for the correlations between core concepts within the models show some similarities with the diary results seen in Table 6.12. Four of the five models show a positive correlation between felt-affect and self-regulatory capacity at the defined statistical significance of $p < 0.01$ after the Bonferroni correction for multiple comparisons (5 comparisons); although, just three of these correspond to the positive correlations seen in the diary data. The two diaries that show a positive correlation between felt-affect goals and self-regulatory capacity are matched by positive correlations seen in their model counterparts; a further model also shows positive correlation, unlike its diary counterpart. Finally, all models show a strong positive correlation between felt-affect and felt-affect goals; while this includes two models that reflect the trends seen in the diary data, two models do not reflect their diary counterparts.

Table 6.13 Correlations of core concepts in each model

	Model1	Model2	Model3	Model4	Model5
Felt-affect & Regulatory Capacity	.61**	.36*	.41**	.73**	.33
Felt-affect Goals & Regulatory Capacity	.59**	.44**	.33	.69**	--
Felt-affect & Felt-affect Goals	.85**	.95**	.65**	.90**	--

** = p < 0.002, * = p < 0.01

6.4 Comparison with Human Predictions

A further assessment can be made on the model's utility to represent affect dynamics, by comparing the model results to estimates on affect dynamics by human raters.

Twelve volunteers from an undergraduate psychology class were recruited to make estimates of affect dynamics seen in the current diary data. Ratings of felt-affect using the gloominess and happiness scale were made by all volunteers for each entry for the first two days of each diary; in total, each rater made 55 estimations of affect. In order for a comparison to be made with the models' performance, diary raters were given supporting information to help guide their decisions. Information that the model uses to generate representations of affect dynamics were provided to raters; this consisted of: individuals' sleeping times, duration and perceived intensity of affective events, and waking mood for the first day. In addition to this, raters were provided with goal mood at each data point and the diary owner's general mood over the two weeks before starting the diary. Raters were instructed to use as much or as little of the available information that they considered relevant to aid in estimating individuals' felt-affect.

Raters were given Figure 6.2 as an example of completed ratings, along with a key describing each part of the figure; the black horizontal bars represent recorded affect events, grey open diamonds represent target mood, and larger greyed out blocks represent time spent sleeping, red X's represent estimates of affect at each diary entry point. Raters were asked to complete further diary ratings for each of the five diaries by marking Xs as their estimates of felt-affect for each diary entry.

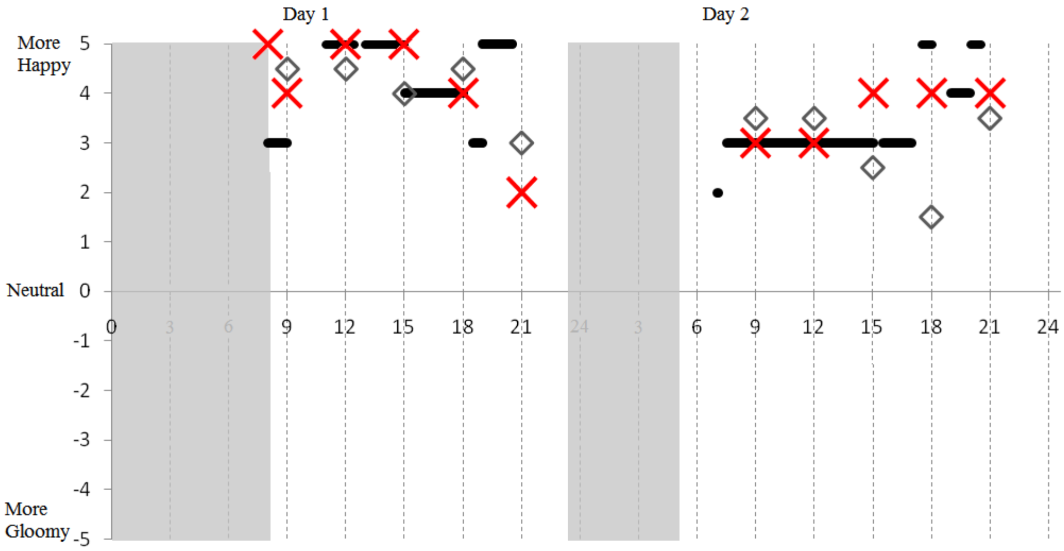

Figure 6.5 Example provided to raters of a completed affect change rating sheet.

One set of ratings was discarded as the individual had not estimated any affect change across time but rather kept estimates constant for each diary, thereby preventing any correlation from being made. The remaining ratings of affect change were correlated against their respective diary entries. The resulting correlations were converted to normalised scores using a Fisher transformation, to enable further comparison of raters' relative performance at estimating affect. These scores, alongside the scores from the model were then subject to a Friedman test to determine if any of the raters, including the model, show a statistically different judgment from the group.

Results indicate there is no significant difference in any rater's judgements, including the model's, in representing the diary data $\chi^2(11) = 17.077$, $P = 0.106$. Based on this test the model is not considered unsuitable for estimating individual's affect change over time. Moreover, the results indicate that only two of the eleven raters performed, on average, better at rating affect dynamics than the model.

6.5 Summary and Discussion

Over the course of this chapter, a variety of tests have indicated the model's capacity for representing diary data for the dynamics of felt-affect, affect goals, and self-regulatory capacity.

In general, the *individual specificity* approach indicated encouraging results for the model. In total, there were eight significant correlations between models and their respective diaries of the 17 comparisons made, using the conservative Bonferroni correction for determining a threshold for significance. In addition to this, the models show highest degree of correlation with their respective diaries ahead of any other diaries 12 times out of the 17 comparisons made. Finally, the diaries show highest degree of correlation with their respective models ahead of any other models 15 times out of the 17 comparisons made. A recurring limitation in the models' capacity to represent the diary data is seen in the representations of felt-affect goals and the few positive signs of models matching the diary data there, while the other variables show more consistent positive results. The strongest representation of the diary data seen is for felt-affect.

Further supporting evidence for the model's capacity to represent the diary data is seen in the *temporal specificity* approach. Generally correlations seen in the diary data are reflected by correlations in the models. This is particularly apparent in both the results for affect-expression goals and self-regulatory capacity; while these show different overall patterns in the correlation directions and strengths in the diary data, they are each reflected in the model data. Alongside this, the models consistently show strong positive correlations with diaries, when the data for each is subdivided into the three sections; these are particularly apparent in the correlations for sections A and C between models and diaries.

The third means of the validation process for the model was the representation of correlations between variables in the diary data. In all cases in which a significant correlation was found in the diary data, the direction was positive, as anticipated; this overall direction in trends was represented in the model data. The diary data shows eight significant correlations between core variables across the diaries; of these eight significant correlations, seven are repeated in the model data. However, an additional three significant correlations are seen in the model data, which are not found in the diary data. The strongest correlations in the model variables are seen between felt-affect and felt-affect goals, exceeding those seen in the diary data. This could indicate that felt-affect dynamics and felt-affect goal dynamics are too closely related in the model, which may arise from using a linear influence of depletion on regulatory momentum for both affect and affect goals, although this remains to be investigated. Issues with representing linear correlations may even be arising from the diary data rather than the model data, given the presence of measurement error in self-report scales and the possibility of non-linear relationships between variables.

Overall, the parameters used to generate the closest representation of the diary data by the model offer a suitable starting point for further model development. If the generated affect dynamics can be considered an estimate made by the model, results also indicate a capacity to estimate affect dynamics closer than most intuitive estimates by individuals. Further validation of the model is considered in Chapter 7, examining the capacity of the model to represent a novel data set, which it has not been trained on.

Chapter 7: Model Validation Against a Second Data Set

7.1 Introduction

This chapter reports on the collection of further diary data and the continued process of model validation. Validation in this chapter is based on the comparison of parameter values developed from the first study against this second diary study and so builds upon the results from Chapter 6. The representation of previously collected diary data by the model has been demonstrated in the last chapter across a number of different measures and means of comparison. This representation arises from the variation of model parameters to shape the profiles of felt-affect, affect goals and self-regulatory capacity to best match across the diaries. This chapter tests the model's capacity to represent a new set of diaries to aid in determining the model's value in representing affect regulation processes.

This diary study serves a dual purpose: firstly, as a validation tool for the results from the previous chapter. Data fitting the original diary set gives an optimal parameter set for the model to use. These parameter values can ultimately be considered as predictions (i.e. the model has made the prediction that people generally hold a higher affect goal than their current affect state). These predictions can be tested against a new data set independent of the first. If the model's parameters fit this new set well, it can be considered that there is value in both the predictions made and the structure and design of the model.

In addition to this, a second diary study offers the opportunity to examine other aspects of affect regulation that the first does not adequately cover. Across the board, participants in the first study only made a small number of recordings for affect-expressions, which could not be used for model validation. The design of the new diary study presented in this chapter places a greater emphasis on expressive states and gives expression related questions more prominence in the diaries themselves. In addition, participants in the current study are all teaching staff and are anticipated to be more attentive to their expressive state due to the demands of the profession, such as display rules (e.g, Näring, Briët, & Brouwers, 2006), than the student sample used in the prior study, who may not have such expectancies placed upon them.

7.2 Diary Data

This chapter continues the process described in Chapter 6 of collecting data that capture variation across time in affect, affect goals and self-regulatory capacity. This section outlines collection of suitable time-series data for further validating the current model of affect regulation dynamics.

Participants

A total of seven volunteers were recruited to the study via an advertisement placed at their shared workplace at a local primary school. All members of the study were teaching staff for children of age groups 3-11, being either full time teachers or teaching assistants. Of the seven prospective participants, all were available during the course of recording in July 2011 and not excluded during pre-study screening; one participant withdrew participation during the study. Six participants completed the study (one male; mean age ± S.D.: 41.6 ± 14.9 years); three were teachers and three were teaching assistants. Each participant was paid £20 at the close of the study for taking part in the research.

Procedure

Prior to the study, informed consent was obtained after the procedures for the study had been explained, and pre-screening questionnaires were completed that indicated volunteers were suitable for participation. Participants were informed that they were under no obligation to continue with the study, should they wish to leave. Participants were further informed data is kept anonymous and confidential, given the intensive nature of recording data that could be considered personal and potentially about a shared work environment.

The study covered six consecutive days, started on a Thursday, and took place during July 2011. Each participant was given two diary booklets the day before the commenced that contained instructions when and how to complete diary entries. Each booklet contained enough pages for data entry to last three days and participants were instructed that once a booklet was completed to continue on to the next, giving six continuous days of recording. The books were modelled on the previous study's design, although some changes to the layout and questions were made (described in subsection *Measures*, below). Participants were instructed to complete a section of the diary every two hours on the even hour during the waking day. Each diary entry took up to five minutes to complete. An additional recording was made on waking each day, also requesting the participant to estimate the duration of sleep. If participants missed any entries, they were instructed to not retrospectively complete entries but to continue with the diary as normal.

Measures

An example of the affect diary used in this study is found in Appendix 5.

Pre-study screening survey

The pre-study screening from the first study was reused without alteration for this current study. Participants were asked if they experience an erratic sleep pattern and if they experience or have experienced a diagnosed mood disorder. As with the previous study, if a participant answered yes to either question they were not included in the main diary study. Participants were also given a modified sample page of the diary to familiarise themselves with the study.

Diaries

This study used many of the measures used in the previous diary study and, where possible, measures have been left unchanged. As described earlier, an emphasis was placed on affect-expression and efforts were made to present the measures for affect-expression in a more accessible and prominent form. Each of the measures used in the regular diary entries and the additional measures used in the diary entry at the start of the day are listed below. For this study, diary entries were scheduled for every two hours between 8am and 12 midnight each day; this was a change from the recording schedule used in the previous study, which had been described as a factor for participants missing diary entries.

Felt-affect was recorded on the two dimensions of valence and arousal, put forwards as the standard means of representing core affect (Remington et al., 2000; Russell, 1989; 2003). In the paper diaries used, this comprised of a two-item scale of bipolar, 11-point measures of *Gloomy* to *Happy* and *Sluggish* to *Energetic*. The scales for felt-affect ranged from -5 (indicating feeling a negative state to a great extent) to +5 (indicating feeling a positive state to a great extent) with 0 representing feeling neutral. This two-item scale is repeated in this same form in each diary entry for reporting felt-affect goals.

Affect-expression was also recorded from a scale of -5 to +5, and was referred to in terms of more positive and more negative expressions rather than specified affect states. The measure for affect-expression also included an additional option for no recalled expression to disambiguate between an active attempt at maintaining a neutral expressed state and perceiving an absence of expression. Goal affect-expression was recorded on another numerical scale, using the same structure as that for affect-expression, with the exception of the absence of an option for no affect-expression.

The measure for recording felt-affect events was kept unchanged from the first diary study. The timing, duration, affect intensity on the prior -5 to +5 scale, and a brief description of affect events were all recorded. Participants were instructed to recall any affective events of significance to them that occurred over the past two hours.

The measures for perceptions of being physically, mentally or emotionally drained were also kept unchanged from the first diary study. Each of these measures ranged on an eleven point scale from 0 (not feeling drained at all) to 10 (feeling drained a great deal). For each measure of feeling drained, participants were instructed to record their current perceived state.

For the scales measuring felt-affect, felt-affect goals, affect-expression goals, and self-regulatory capacity, individuals were instructed to record their present states (e.g., How alert do you feel at this time). For recordings of affect events and expressions, individuals were instructed to recall moments since the last diary entry was scheduled.

The recordings made on waking were left unchanged from the previous diary study, in which participants recorded their estimated time of sleeping, time of waking, and estimated the duration of minutes of lost sleep.

Analysis

On average participants completed a total of 46 entries of the maximum 54 regular entries. All of the six diary entries scheduled to be completed on waking were completed by each participant. Over half of the regular diary entries included one recorded affective event (180 events, 55% of entries), 28 entries included the recording of two affective events and there were just four instances of three affective events recoded.

The most common reason for not completing an entry in the diary was the scheduled entry fell outside of participants' waking hours, with participants typically going to sleep before the last entry at 12am on weekdays and waking up after the first entry at 8am on weekends. One participant forgot to complete a diary entry at the scheduled time and so completed that section of the diary an hour later, making sure to note the time it was completed. For the remainder of the day, she proceeded to complete the diary every two hours after that entry so recorded her affect on the odd hour rather than the even hour, each time making sure to note the time the diary entry was made. Subsequent analysis in this chapter and comparisons with model data take account for the seven diary entries affected. Across the study, four participants marked the scale for affect-expression to indicate that they were not aware of having displayed any affect-expression state in at least one diary entry and so made estimations of their affect-expression state. Participant 1 indicated this on seven instances, participant 3 indicated this three times and participants 2 and 4, indicated this just once. Analysis in this chapter examines the fit of model data with the estimated ratings included.

Circadian Analysis

As done in the analysis of the previous diary data, self-regulatory capacity is examined to determine if a circadian cycle is present in participants' recorded data. Procedure for analysis of the data is preserved from the previous chapter and a Binfit analysis is run. As with the previous analysis, the circadian cycles examined range from 22 to 26 hours in increments of 0.2 hours. Within these cycles, reported feelings of being emotionally drained are fit into 12 equally spaced bins, given the two hourly intervals between diary recordings. Time bins width therefore varies from 1.83 hours in the binfit for a 22 hour cycle to 2.17 hours in the binfit for a 26 hour cycle. Analysis of the collated data is performed using one-way repeated measures ANOVA with independent variable being bin label and dependent variable reported feelings of being emotionally drained. Table 7.1 reports the circadian period for each of the diaries that is associated with highest variance explained by the fitted cycle for feelings of being emotionally drained.

Table 7.1 Periods for each diary recordings of feelings of being emotionally drained

Diary No.	Period (hrs)	F	Df	Variance %	p
1	25.8	2.83	(11, 46)	40.40	0.007
2	25.8	3.60	(11, 32)	55.32	0.0025
3	23.6	2.47	(8, 36)	53.15	0.0001
4	24.4	5.85	(8, 41)	35.42	0.03
5	23.2	3.68	(9, 41)	44.05	0.002
6	25.0	2.98	(10, 42)	40.69	0.0065

The results in Table 7.1 are used to inform the circadian component of the resource capacity block in each model simulation. With each diary the period for the circadian component is specified according to the results above. This parameter value is kept constant across all testing of the models, while fitting the variable parameters (Table 7.2) to the diary data. This circadian component alongside the sleeping and waking schedule recorded by each participant forms the primary basis of the dynamics of the Åkerstedt et al. (2004) model of fatigue, which is used as representation of self-regulatory capacity in this thesis.

7.3 Validation of the Model

The aim of this chapter is to determine the capacity of the model to represent a novel diary data set. Chapter 6 describes in detail the process of validating the model against a single data set; this section overviews the process used to validate the model against a second data set.

Validation Design

To compare simulation results against the novel data set six new models are constructed to reflect each individual's experiences during the study. To achieve this, values from each diary on affective events transpired, sleeping patterns, and circadian cycle of resource are input as constants into the models; each model, therefore, reflects the experiences of a single individual. These values, alongside parameters specified under the section *validation procedure*, below, are used by the model to estimate the dynamics of felt-affect, felt-affect goals, self-regulatory capacity, affect-expression, and affect-expression goals.

The three tests applied to the model described in section 6.3 are repeated for this set of diaries and models; these tests are briefly summarised here. For individual specificity, each diary is compared against its corresponding model; correlations between each diary and its respective model are expected to be greater than that model for any other diary and that diary for any other model. For *temporal specificity*, sections of diary data are compared to their equivalent sections of the model data, which are expected to correlate better than any other parts within the diary or modelled data. Correlations that occur within the diary data between one section and another are expected to be preserved by the simulation. For r*epresentation of data trends*, correlations between variables within the diary data are expected to be replicated by their equivalent variables in the models.

Validation Procedure

In the previous chapter, data-fitting simulations were run so that parameters could be determined, which result in models on average best representing data from the diaries. In this chapter, the process is repeated with the same parameter ranges (Table 7.2) and the parameter set determined in Chapter 6 as the best representation of the diary data is considered in terms of its capacity to represent the novel diary data set.

Table 7.2 Parameters varied for data fitting of multiple diaries

Parameter Name	Parameter Symbol	Range of Values
Felt-Affect Goal Home	*Felt_Goal*	0.2, 0.4, 0.6, 0.8, 1
Affect-Expression Goal Home	*Exp_Goal*	0.2, 0.4, 0.6, 0.8, 1
Felt-Affect Regulation Cost	*Da*	1, 2, 3, 4, 5
Affect-Expression Regulation Cost	*Sa*	2, 4, 6, 8, 10
Regulatory Momentum	*k2*	0.0025 0.005 0.01 0.02 0.05
Rate of Goal Adjustment	*k4*	0.0025 0.005 0.01 0.02 0.05

Simulation Procedure

The simulation procedure is preserved from validation against the original diary data set. Within the simulations, each of the diaries is again represented by a unique model, which differs from all other models in simulations by the four means of: experiencing unique affective events, the initial felt-affect state on the first day, sleeping and waking schedule, and the proposed circadian component to self-regulatory capacity. The four specifications to distinguish the models from each other and reflect experiences reported in the diaries are kept constant across all simulations so that the effects of the individual's daily life on affect, goals and self-regulatory capacity can be seen. In selecting a single set of parameters to best represent the diaries as a whole, the differences between models outlined in this section give each model its unique affect dynamics.

Data Recording Procedure

The method for recording model data at specific intervals to reflect that of the data recording times in the diary data is preserved from the previous model validation process. Alongside this, affect states recorded in the model are scaled and rounded to reflect the range of values that could be recorded in each of the affect measures, as described in the previous chapter. Before proceeding with comparing the various model fits with diary data, the diary data is examined to determine if each variable has sufficient number of data points to be used for validation. Using the process outlined in Chapter 6 it is indicated that two measures are to be excluded from further analysis; these are *felt-affect goals* in Diary 3 and *affect-expression goals* in Diary 3; all other measures are included in the analysis.

7.3.1 Individual Specificity

Given the limited sample size of both studies and the contrasting nature of those who have participated in each study, namely that of students in the first and teaching staff in the second, it is anticipated that an exact match of the parameters across the two studies is unlikely. Similarities and differences for each study are considered. For reference, the parameter values of the first study are shown in Table 7.3.

Table 7.3 Parameters used as a best representation of diary data in study 1

	Felt_Goal	*Exp_Goal*	*Da*	*Sa*	*k2*	*k4*
Model Value	0.8	0.8	1	2	0.02	0.02

Results from the current simulation indicate that the parameter values given by the best representation of diary data in the previous study do not form a comparably strong fit with the current diary data. Of the 15265 (5^6) simulations run this parameter set ranks just outside the top 10% of simulation fits (ranked 1676). The strongest fitting model shows different parameter values across the board (Table 7.4), although this difference could potentially arise due to the limited number of parameter values possible to examine in the tests and could both be indicating further parameter values for investigation.

Table 7.4 Parameters used as a best representation of diary data in study 2

	Felt_Goal	*Exp_Goal*	*Da*	*Sa*	*k2*	*k4*
Model Value	0.6	0.6	4	8	0.05	0.05

An explanation for the differences seen, particularly that of the difference in the value for the affect-expression goal, and cost of regulation could come from the participant samples used. The demands of affect regulation within the teaching profession are well reported (Burke & Greenglass, 1995; Näring et al., 2006) and are likely to contras with those of university students.

To consider the potential for extensive differences in the affective environments that the two participant groups were drawn from a further parameter set is considered for representation of the teachers' diary data. Three of the parameters are fixed from the previous study, these being: felt-affect goal-home state, regulatory momentum and rate of goal adjustment. The remaining parameters were varied to potentially better consider the differences in working environment and emotional labour demands between participant groups. Table 7.5 indicates the best fitting parameter set for the second diary data set given the prior constraints. This parameter set ranks just outside the top 1% of simulation fits (ranked 209) and is further exploded in this chapter.

Table 7.5 Parameters used as representation of diary data in study 2

	Felt_Goal	*Exp_Goal*	*Da*	*Sa*	*k3*	*k4*
Model Value	0.8	0.6	5	6	0.02	0.02

As with the process of Individual specificity in Chapter 6 (section 6.3.1), this section serves to compare the degree of correlation between each diary and its modelled counterpart against all other diaries and models. Indication of a model that fits the data is seen by a stronger positive correlation between a model and the diary it represents than any other model with that particular diary. In addition to this, the model should also show a stronger positive correlation with the diary it represents over any other diary. Further considerations include the existence of any correlations between the diaries and respective similarities between the models designed to represent them.

Felt-Affect

The first correlation matrix presented is that of the correlations between the felt-affect state recorded in the diaries and the corresponding felt-affect state as an output from the models (Table 7.6). Correlations between each model and its respective diary are highlighted in bold; all other correlations are in plain font. Just two out of the six model results for felt-affect significantly correlate with their respective diaries at the defined statistical significance of $p < 0.0014$ after the Bonferroni correction for multiple comparisons (36 comparisons). However, five of the six models represent their respective diaries closer than they do any others, with only Model 4 representing other diaries closer than its counterpart. Finally, five of the six diaries are best represented by their respective models, with only Diary 4 being better represented by a model other than its counterpart.

Table 7.6 Correlations for felt-affect between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5	Diary 6
Model 1	**.69****	.08	.08	-.08	-.02	.03
Model 2	-.03	**.46**	-.03	.09	-.16	-.10
Model 3	.21	.03	**.49***	-.11	.07	-.14
Model 4	.05	-.52*	-.07	**.16**	.16	.29
Model 5	.01	-.09	-.04	.25	**.33**	.10
Model 6	-.10	.18	.01	.26	-.22	**.30**

** = $p < 0.0003$, * = $p < 0.0014$

Table 7.6 reports correlation strengths for model fits against their respective diary data ranging from .16 to .69; to offer a representation of the models' fit to diary data, results for felt affect for both Model 2 and Diary 2 are presented in Figure 7.1. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 7.6. The model data captures the changes at the end of Days 1, 2 and 4 and the middle of Day 3 seen in the diary data.

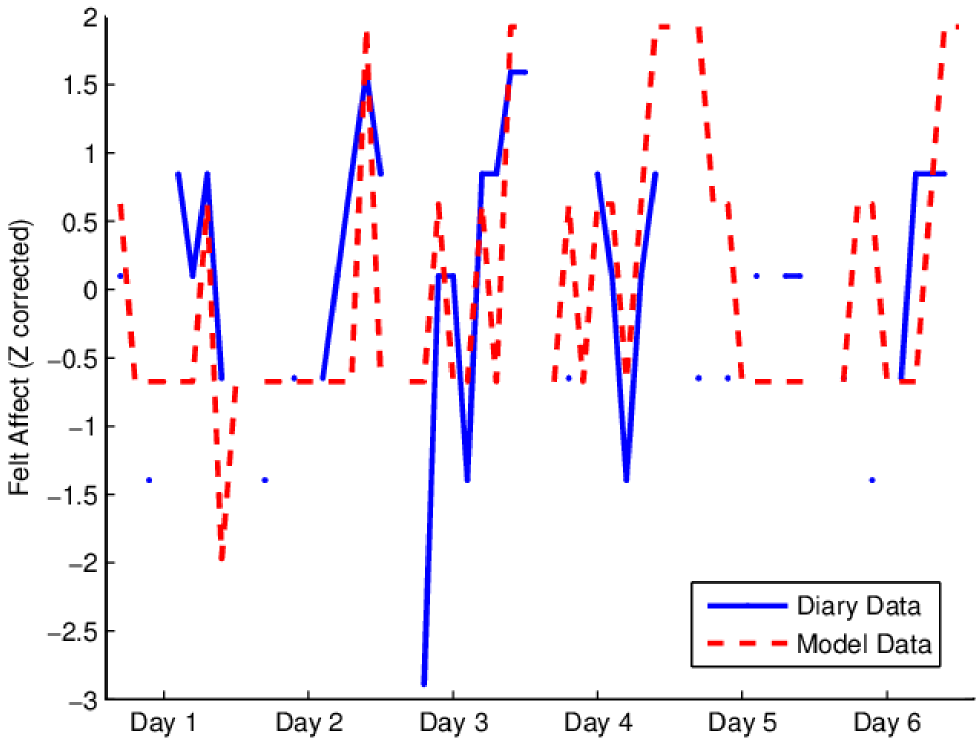

Figure 7.1 Felt affect results for Model 2 and Diary 2

Results for diary data are taken from the 38 diary recordings made in Diary 2; all 54 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

Felt-Affect Goals

Correlations between diaries and models for felt-affect goals are shown in Table 7.7; correlations between diaries and their respective models highlighted in bold font, while all other correlations between diaries and models are shown in the same table in plain font. Diary 3 is excluded from analysis based on the limited available data points for correlation; a dummy column for the excluded diary data is included in the correlation matrix to keep the visual appearance of the correlation matrices consistent. Results in Table 7.7 show a mixture of outcomes, supporting and challenging the models' capacity for representing this diary data set. Only two out of the five model results for felt-affect goals significantly correlate with their respective diaries at the defined statistical significance of $p < 0.0017$ after the Bonferroni correction for multiple comparisons (30 comparisons). Alongside this, three of the five models represent their respective diaries closer than they do any others, with Models 4 and 6 representing other diaries closer than their counterparts. Finally, four of the five diaries are best represented by their respective models, with only Diary 6 being better represented by a model other than its counterpart.

Table 7.7 Correlations for felt-affect goals between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5	Diary 6
Model 1	**.58****	-.29	..	-.14	-.01	.04
Model 2	-.10	**.36**	..	-.32	-.08	-.24
Model 3	.18	-.09	..	-.04	.04	-.06
Model 4	.45*	-.40	..	**.23**	.01	.56*
Model 5	.15	-.20	..	.00	**.55***	.00
Model 6	-.14	.14	..	-.21	-.06	**.07**

** = $p < 0.0003$, * = $p < 0.0017$

Table 7.7 reports correlation strengths for model fits against their respective diary data ranging from .07 to .58; to offer a representation of the models' fit to diary data, results for felt affect for both Model 2 and Diary 2 are presented in Figure 7.2. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 7.7. The model data captures the changes throughout Day 3 and the end of Day 4 seen in the diary data.

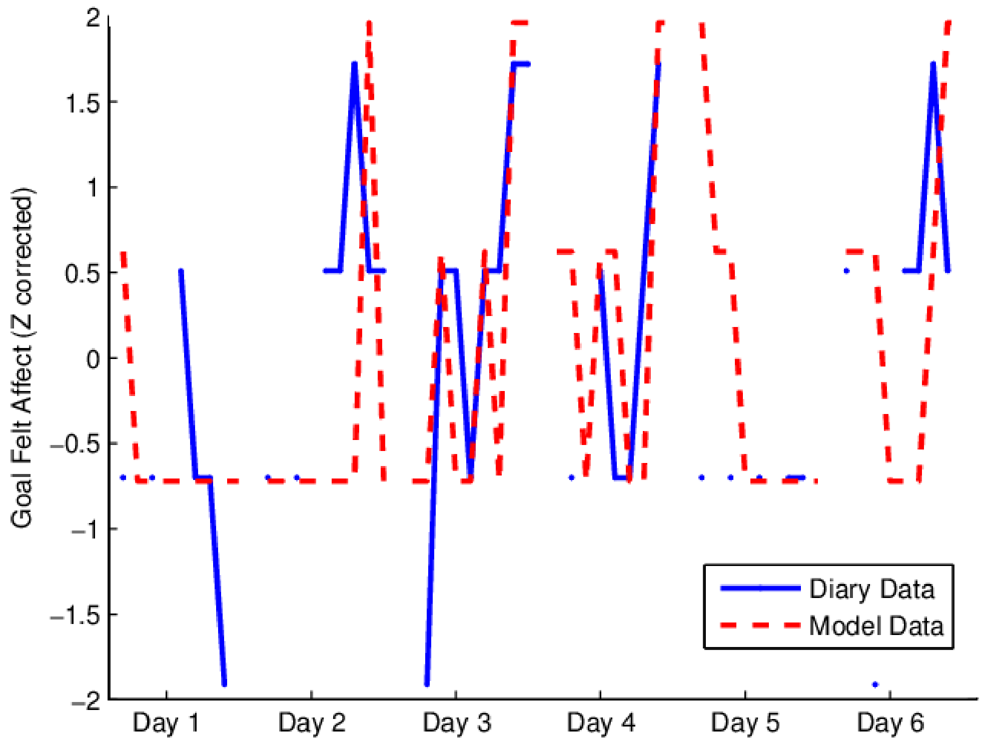

Figure 7.2 Felt affect goal results for Model 2 and Diary 2

Results for diary data are taken from the 38 diary recordings made in Diary 2; all 54 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

Self-Regulatory Capacity

Further representations of the diary data can be seen in correlations between the models and diaries for self-regulatory capacity (Table 7.8); correlations between diaries and their respective models are highlighted in bold font, while all other correlations between diaries and models are shown in the same table in plain font. Two out of the six model results for self-regulatory capacity significantly correlate with their respective diaries at the defined statistical significance of $p < 0.0014$ after the Bonferroni correction for multiple comparisons (36 comparisons). In addition to this, four of the six models represent their respective diaries closer than they do any others, with Models 2 and 5 representing another diary closer than their counterparts. Finally, three of the six diaries are best represented by their respective models, with Diaries 2, 4 and 5 being better represented by a model other than their counterparts.

Table 7.8 Correlations for feeling emotionally drained between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5	Diary 6
Model 1	**.50****	-.06	.03	.27	.33	.56**
Model 2	.22	**-.04**	.13	.31	.15	.54**
Model 3	-.15	-.18	**.43**	.04	-.46*	-.05
Model 4	.17	-.05	-.13	**.31**	.11	.35
Model 5	.18	.06	-.29	.35	**.22**	.33
Model 6	.49**	-.08	.07	.15	.47*	**.65****

** = $p < 0.0003$, * = $p < 0.0014$

Table 7.8 reports correlation strengths for model fits against their respective diary data ranging from -.04 to .65; to offer a representation of the models' fit to diary data, results for felt affect for both Model 3 and Diary 3 are presented in Figure 7.3. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 7.8. The model data captures the changes in the middle of Days 1, 2, 3 and 6 seen in the diary data.

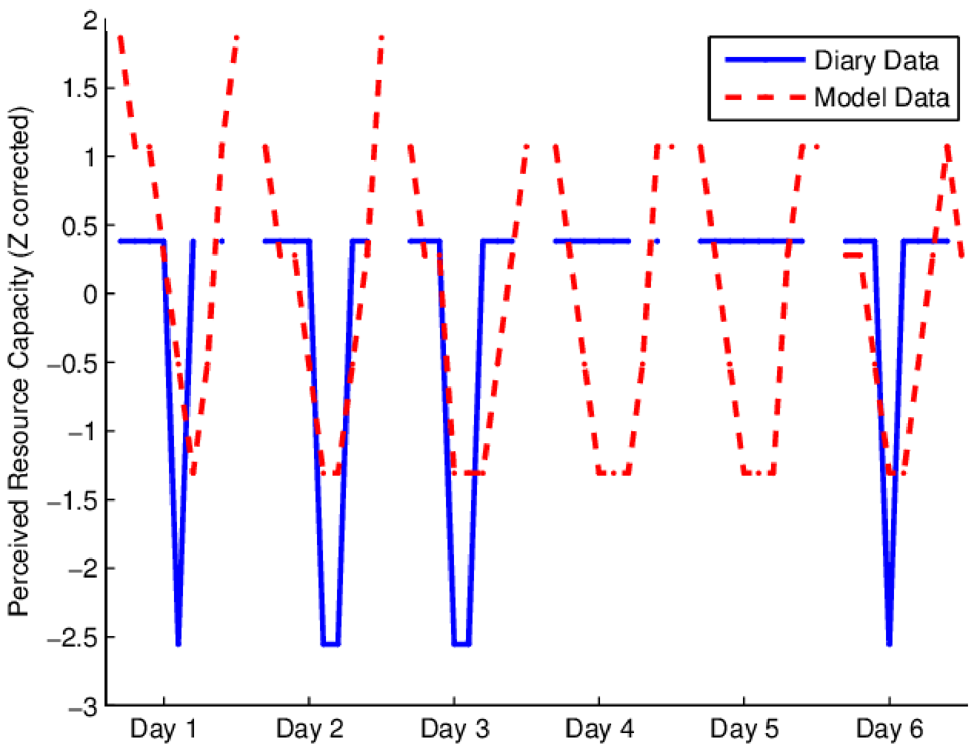

Figure 7.3 Perceived self-regulatory resource capacity results for Model 3 and Diary 3 Results for diary data are taken from the 46 diary recordings made in Diary 3; all 54 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

Affect-Expression

The use of a second diary set has given the opportunity to examine the model's capacity to represent changes across time for affect-expression. Table 7.9 overviews the correlations between models and their respective diaries (shown in bold font) and correlations between models and all other diaries (shown in plain font). Results show limited support for the models' representation of diary data. One of the model results for self-regulatory capacity significantly correlate with their respective diaries at the defined statistical significance of $p < 0.0014$ after the Bonferroni correction for multiple comparisons (36 comparisons). Two of the six models represent their respective diaries closer than they do any others and finally, three of the six diaries are best represented by their respective models.

Table 7.9 Correlations for affect-expression between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5	Diary 6
Model 1	**.56****	.00	-.09	-.04	-.06	.02
Model 2	-.07	**.47**	-.22	.00	.18	-.25
Model 3	.27	-.15	**.26**	.03	-.12	.08
Model 4	.20	-.50	.16	**.09**	-.08	.32
Model 5	-.04	.00	.24	.26	**.10**	-.06
Model 6	.01	-.06	.10	.65**	-.06	**.15**

** = $p < 0.0003$, * = $p < 0.0014$

Table 7.9 reports correlation strengths for model fits against their respective diary data ranging from .09 to .56; to offer a representation of the models' fit to diary data, results for felt affect for both Model 3 and Diary 3 are presented in Figure 7.4. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 7.9. The model data captures the changes seen in Day 5; model data is mostly unchanging throughout simulation indicating a potential limitation in fitting the general model across multiple data sets.

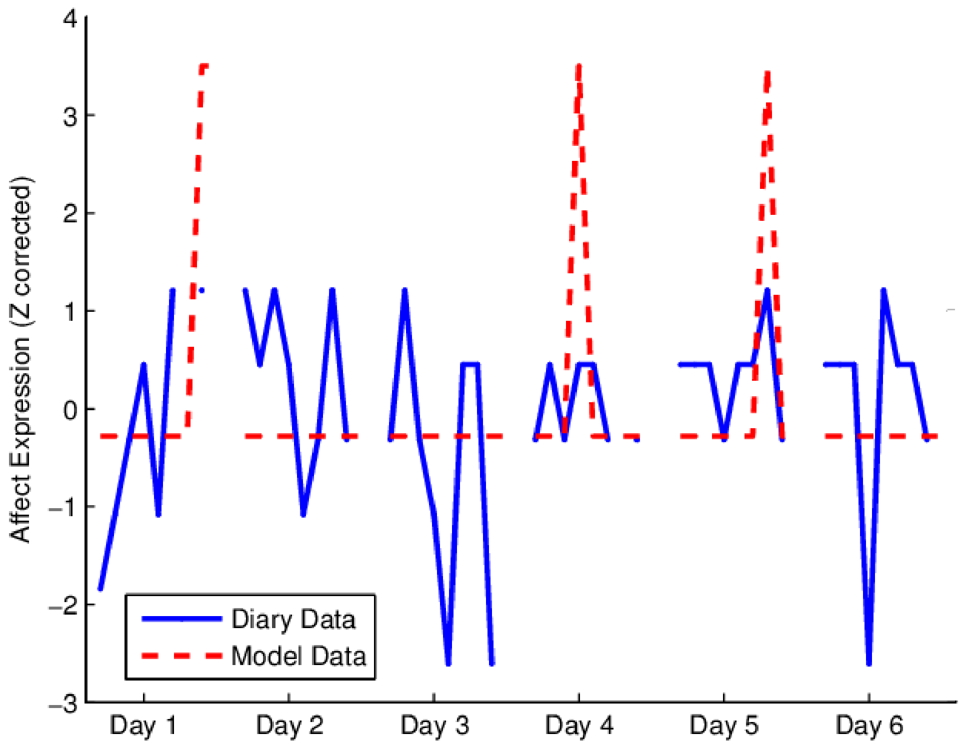

Figure 7.4 Affect-Expression results for Model 3 and Diary 3

Results for diary data are taken from the 46 diary recordings made in Diary 3; all 54 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

Affect-Expression Goals

The last correlation matrix presented is that of affect-expression goals (Table 7.10); correlations between diaries and their respective models are highlighted in bold font, while all other correlations between diaries and models are shown in the same table in plain font. As with the table for felt-affect goals (Table 7.7), Diary 3 was excluded from the analysis because of the limited number of data points for analysis in the series; a dummy column for the excluded diary data is, again, included. Results indicate that two of the five models significantly correlate with their respective diaries at the defined statistical significance of $p < 0.0017$ after the Bonferroni correction for multiple comparisons (30 comparisons). Further to this, four of the five models represent their respective diaries closer than they do any others, with Models 4 representing another diary closer than its counterpart. Finally, three of the five diaries are best represented by their respective models, with Diaries 4 and 6 being better represented by a model other than their counterparts.

Table 7.10 Correlations for affect-expression goals between all diaries and models

	Diary 1	Diary 2	Diary 3	Diary 4	Diary 5	Diary 6
Model 1	**.56****	-.02	--	-.09	-.14	-.13
Model 2	-.14	**.46**	--	-.01	.07	-.51**
Model 3	.05	-.15	--	-.01	-.07	-.08
Model 4	.27	-.45	--	**.01**	-.01	.59**
Model 5	.06	-.10	--	.20	**.47***	-.07
Model 6	.01	-.10	--	.11	.05	**.29**

** = p < 0.0003, * = p < 0.0017

Table 7.10 reports correlation strengths for model fits against their respective diary data ranging from .01 to .56; to offer a representation of the models' fit to diary data, results for felt affect for both Model 2 and Diary 2 are presented in Figure 7.5. This data fit is chosen as it is the median strength correlation between model data and its matched diary data in Table 7.10. The model data captures the changes throughout Day 3 and the end of Day 4 seen in the diary data.

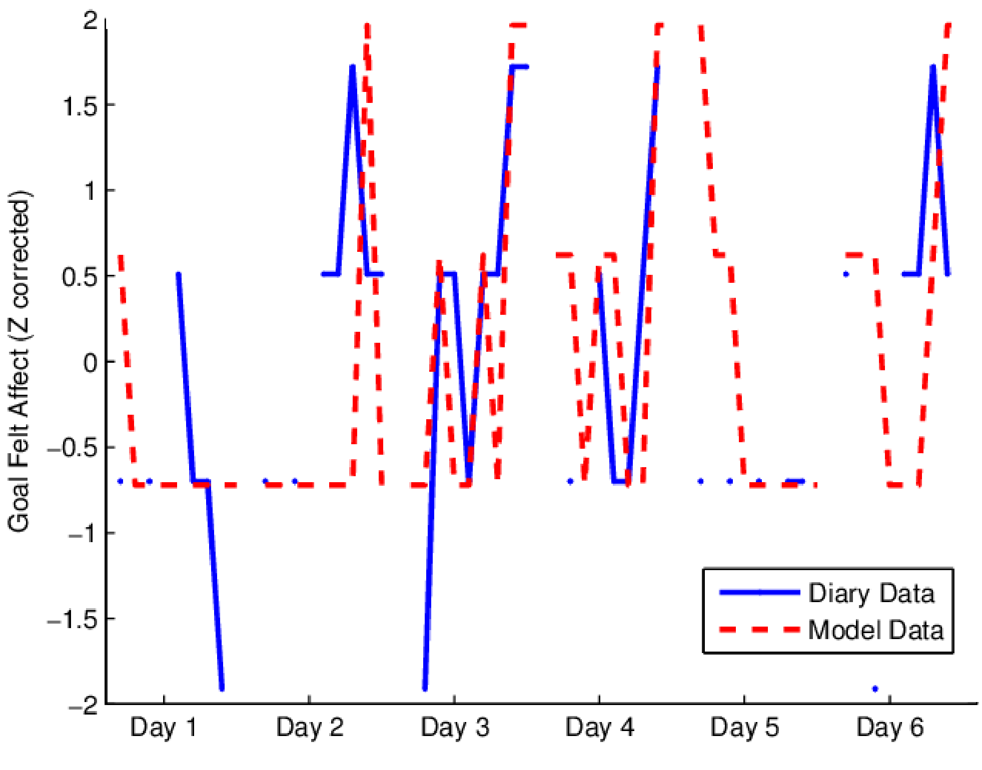

Figure 7.5 Affect-Expression goal results for Model 2 and Diary 2

Results for diary data are taken from the 38 diary recordings made in Diary 2; all 54 modelled results are shown. Discontinuities in the model data indicate start and end of daily data recording schedules.

7.3.2 Temporal Specificity

Continuing the repetition of the previous chapter's validation process of the model against diary data, trends within the diaries and models are again examined. As before, both the diary data and the model data are divided into three sections. The sections within each diary are correlated with each other; this process is repeated for each of the models. Also, model data sections are correlated against their respective diary data sections. Mean correlations between each section of the diary data are taken across results from all diaries; this process is again repeated for the models. On average there are 15 time points completed in each diary section for all measures.

Felt-Affect

Table 7.11 indicates that there is little correlation within the diaries on average across the three sections. This is reflected in the similar pattern within the models on average across the three model sections, although overall correlations sizes appear slightly larger. The table further points towards correlations between the model and respective diary section, particularly section B. These outcomes partially support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 7.11 Average correlations for felt-affect within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	-.06				
Diary Section C	.14	.01			
Model Section A	**.33**	.23	.22		
Model Section B	.06	**.63**	-.01	.11	
Model Section C	.06	.11	**.39**	.31	.24

Felt-Affect Goals

Results in Table 7.12 show a similar pattern to that seen in Table 7.11; the correlations shown are averages from five of the six diaries for felt-affect goals, with Diary 3 omitted due to the limited number of data points. There is little indication of correlation within the diaries on average across the three sections, although section A and C do appear to show a stronger correlation than that of the more temporally closer sections.

This outcome is not seen within the model correlations. The table does point towards correlations between the model and respective diary sections, particularly section B. These outcomes partially support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 7.12 Average correlations for felt-affect goals within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	-.11				
Diary Section C	.32	-.15			
Model Section A	**.37**	.17	.09		
Model Section B	-.18	**.66**	-.04	.28	
Model Section C	.09	.04	**.41**	.27	.29

Regulatory Resource

Table 7.13 indicates that there is little correlation within the diaries on average across the three sections. This is not reflected in a similar pattern within the models on average across the three model sections, in which correlations appear substantially larger. Results further indicate moderate correlations between the model and respective diary section, although correlations of similar strength between diaries and models are seen across sections. These outcomes offer limited support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 7.13 Average correlations for feeling drained within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	.19				
Diary Section C	-.08	-.03			
Model Section A	**.14**	.38	.21		
Model Section B	.23	**.49**	.39	.88	
Model Section C	.33	.48	**.31**	.73	.89

Affect-Expression

Results in Table 7.14 closely resemble those of the results in Table 7.12. There is little indication of correlation within the diaries on average across the three sections, although section A and C do appear to show a stronger correlation than that of the more temporally closer sections. This outcome is not seen within the model correlations, which appear to show stronger correlations between sections, although the strongest correlation seen does reflect that in the diary data. The table does point towards correlations between the model and respective diary sections, particularly section C. These outcomes partially support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 7.14 Average correlations for affect-expression within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	-.10				
Diary Section C	.21	-.01			
Model Section A	**.24**	.07	.20		
Model Section B	.06	**.36**	-.23	.23	
Model Section C	.24	.05	**.43**	.39	.24

Affect-Expression Goals

The correlations shown in Table 7.15 are averages from five of the six diaries for affect-expression goals, with Diary 3 omitted due to the limited number of data points. The results within the diaries appear to show a conventional decrease in the correlation strength between sections as the temporal distance increases. However, this outcome is not seen within the model correlations. The table does point towards correlations between the model and respective diary sections, particularly sections A and C. These outcomes partially support the model as a successful representation of the diaries according to the criteria specified for temporal specificity.

Table 7.15 Average correlations for affect-expression goals within diaries and models

	Diary Section A	Diary Section B	Diary Section C	Model Section A	Model Section B
Diary Section B	.24				
Diary Section C	.17	.19			
Model Section A	**.51**	.33	.26		
Model Section B	.07	**.32**	-.12	.24	
Model Section C	.52	.10	**.50**	.52	.34

7.3.3 Relational Representation

The final approach for identifying the capacity for the model to represent the diary is the replication of correlations between variables recorded. If two variables show a significant correlation within the diaries' recorded data, a model that aims to simulate both of these variables well ought to also represent the existing correlations.

Three comparisons between variables are made in this test for each of the diaries. Three of these are drawn from the testing conducted in Chapter 6; these correlations are: felt-affect and perceived self-regulatory capacity, felt-affect goals and perceived self-regulatory capacity, and felt-affect and felt-affect goals. An additional three are considered in this chapter, given the availability of affect-expression data; these correlations are: felt-affect and affect-expression, affect-expression and affect-expression goals, and felt-affect goals and affect-expression goals. It is anticipated that there is a positive correlation between felt-affect and affect-expression, given the known coherency between the two states (e.g., Mauss et al., 2005). Although this may not necessarily be the case as affect-expression could be regulated away from current felt-affect in order to meet display rule requirements (e.g., Grandey, 2000) and instead show positive correlation with affect expression goals.

Table 7.16 overviews the correlations between core concepts described above for each of the diaries. Firstly, just one diary shows correlation between felt-affect and self-regulatory capacity at the defined statistical significance of $p < 0.008$ after the Bonferroni correction for multiple comparisons (6 comparisons). Second, no diaries show correlation between felt-affect goals and self-regulatory capacity; Diary 5 is again excluded from analysis due to limited data points for affect goals. Third, four of the five diaries examined show positive strong correlations between felt-affect and felt-affect goals. Fourth, all six diaries show strong correlations between felt-affect and affect-expression. Fifth, four of the five diaries examined show correlation between affect-expression and affect-expression goals. Finally, four of the five diaries examined show strong positive correlations between felt-affect goals and affect-expression goals.

Table 7.16 Correlations of core concepts in each diary

	Diary1	Diary2	Diary3	Diary4	Diary5	Diary6
Felt-Affect & Regulatory Capacity	.32	.17	.68**	.31	-.35	.37
Felt-Affect Goals & Regulatory Capacity	.17	.01	--	-.06	-.32	.32
Felt-Affect & Felt-Affect Goals	.71**	.73**	--	.03	.95**	.60**
Felt-Affect & Affect-Expression	.84**	.70**	.82**	.93**	.92**	.77**
Affect-Expression & Affect-Expression Goals	.69**	.60**	--	.40	.84**	.54**
Felt-Affect Goals & Affect-Expression Goals	.73**	.68**	--	.21	.85**	.91**

** = $p < 0.0016$, * = $p < 0.008$

The results in Table 7.17 for the correlations between core concepts within the models show some similarities with the diary results seen in Table 7.16. First, just one of the models shows a positive correlation between felt-affect and self-regulatory capacity at the defined statistical significance of $p < 0.01$ after the Bonferroni correction for multiple comparisons (5 comparisons); although, this does not correspond to the positive correlation seen in the diary data. Second, unlike the diary data, two models show a positive correlation between felt-affect goals and self-regulatory capacity. Third, all models show a correlation between felt-affect and felt-affect goals, reflecting that seen in the diary data, although one model does show correlation while its diary counterpart does not. Fourth, felt-affect and affect-expression show correlation across all models, representing the trend seen in the diary data. Fifth, all models show correlations between affect-expression and affect-expression goals, although one model does show correlation while its diary counterpart does not. Finally, all models show correlations between felt-affect goals and affect-expression goals, although one model does show correlation while its diary counterpart does not.

Table 7.17 Correlations of core concepts in each model

	Model1	Model2	Model3	Model4	Model5	Model6
Felt-Affect & Resource Capacity	.11	-.19	.26	.66*	.27	.20
Felt-Affect Goals & Resource Capacity	.13	-.06	--	.68**	.45**	.26
Felt-Affect & Felt-Affect Goals	.94**	.92**	--	.90**	.40*	.78**
Felt-Affect & Affect-Expression	.72**	.74**	.54**	.74**	.90**	.60**
Affect-Expression & Affect-Expression Goals	.97**	1.00**	--	1.00**	.42**	.81**
Felt-Affect Goals & Affect-Expression Goals	.68**	.76**	--	.77**	.69**	.61**

** = $p < 0.0016$, * = $p < 0.008$

7.4 Summary and Discussion

Over the course of this chapter, a number of tests have shown the degrees to which the model can represent the novel diary data. One of the key issues in this chapter is the differences in capacity for the model to represent the diary data across different parameter sets. Results indicate that the initial parameter set used in Chapter 6 was not the best fit for this current chapter's results, although this is perhaps unsurprising, given the substantial differences between the participant groups. Variation of a restricted number of parameters, accounting for the differences between the participant groups, substantially improved the overall fit of the model in this chapter, even though the parameters fixed were not tailored to fit the current data set. Further room for investigation could come from the collection of data from a similar workplace population to that of the teachers in this study. It would be anticipated that the parameter set for a fit of the model for this population would more closely resemble that of the current parameter set over that of the previous chapter's.

Differences between the two participant groups can be seen if the correlations between variables recorded in the diaries are considered. In the first study, felt-affect is seen to strongly correlate with self-regulatory capacity in four of the five diaries, while only one diary in the current study shows a correlation between the two variables. Further differences between the participant groups are seen for correlations between felt-affect goals and self-regulatory capacity, and also felt-affect and felt-affect goals. These differences may arise from the affect-expression demands associated with teaching (Näring et al., 2006) and could offer a partial account as to why the model trained on the first data set showed less capacity to represent affect dynamics for the second data set.

In general, the *individual specificity* approach indicated limited support for the model. In comparison to the eight out of 17 correlations found significant in the first study, just nine of 28 were significant in this study, using the conservative Bonferroni correction for determining a threshold for significance. Alongside this, the models show highest degree of correlation with their respective diaries ahead of any other diaries 18 times out of the 28 comparisons made. Finally, the diaries show highest degree of correlation with their respective models ahead of any other models 18 times out of the 28 comparisons made. A recurring limitation in the models' capacity to represent the diary data is seen in the representations of affect-expression and the few positive signs of models matching the diary data there, while the other variables show more positive results. Affect-expression is the only variable tested in this chapter which is not considered in the previous chapter.

Some supporting evidence for the model's capacity to represent the diary data is seen in the *temporal specificity* approach. There appears to be a partial reflection of the correlations strengths between sections within the diaries by the correlations between sections within the models. This is particularly apparent in results for affect-expression goals. Alongside this, the models regularly show medium strength positive correlations with diaries, when the data for each is subdivided into the three sections.

The third means of the validation process for the model was the representation of correlations between variables in the diary data. In all cases in which a significant correlation was found in the diary data, the direction was positive, as anticipated; this overall direction in trends was represented in the model data. The diary data shows 19 significant correlations between core variables across the diaries; of these 19 significant correlations, 18 are repeated in the model data. However, an additional six significant correlations are seen in the model data, which are not found in the diary data. The strong correlations between affect and affect goals for both felt-affect and affect-expression exceed that seen in the diary data. This further reinforces the suggestion in the previous chapter that felt-affect dynamics and felt-affect goal dynamics are too closely related in the model. Further developments of the model could introduce different influences of depletion on regulation for the lower and higher tiers so that they may show a greater independence in dynamics.

Overall, the results in this chapter indicate that some of the success seen in the previous chapter may be attributed to the fitting of a particular set of data from one sample, rather than the development of a parameter set suitable across a range of samples. While testing of the model has extended across a wide range of parameters and parameter values, the factorial increase in tests required to examine parameter ranges at narrower intervals or alternative parameter variations (such as differences between regulatory momentum for affect-expression and felt-affect) currently limits capacity to do so. Future directions for the testing of this model would include the testing of further participant groups experiencing similar affective demands to those currently examined.

Chapter 8: Modelling Affect Regulation in Dyads

This chapter outlines the process of expanding the model beyond the representation of a single individual to that of agents in a network. In this chapter, the simplest network, that of a dyad, is constructed and within it, simulations of plausible interactions are investigated. Alongside this, representations of dyadic interaction in the current literature are examined and contrasted with the process that unfolds in model simulations of dyadic interactions.

8.1 Affect in a Dyad

Affect experience and affect regulation are not just limited, intrapersonal processes; affect is also considered a social phenomenon, in which, the affective experiences of individuals can shape and be shaped by those of others (e.g., Parkinson, Fischer, & Manstead, 2005). The sharing of affect through social expressions and communication (e.g., Keltner & Haidt, 1999), the recounting of experiences (e.g., Rimé, 2007), or even just being in the presence of others (e.g., Friedman & Riggio, 1981), is a common human experience. Individuals can seek to directly influence how others are feeling (Niven, Totterdell, & Holman, 2009) and can be unconsciously affected by other's expressions (Hatfield et al., 1994). A person's affect state may impact on people's feelings across dyadic relationships (e.g., Joiner, 1994) and across broad networks (Totterdell, Wall, Holman, Diamond, & Epitropaki, 2004), including networks spanning hundreds of individuals (e.g., Fowler & Christakis, 2008). This chapter examines the transmission of affect across a dyad.

Affect is known to converge between individuals who spend time together (e.g., Hatfield et al., 1994). Groups are considered to, at times, exhibit a shared mood across individuals working together (e.g., Bartel & Saavedra, 2000; Totterdell, Kellet, Teucmann, & Briner, 1998) and shared positive mood has been demonstrated to foster a range of positive outcomes such as cooperation (Barsade, 2002) and invested effort (Sy, Côté, & Saavedra, 2005). The process by which affective states can appear to spread from one individual to another in social circumstances is regarded as that of affective convergence. It has been elicited in experimental conditions (e.g., Howard & Gengler, 2001; Hsee, Hatfield, Carlson, & Chemtob, 1990; Neumann & Strack, 2000) and observed across a broad range of close dyadic relationships such as married couples (Hicks & Diamond, 2008), dating couples (Katz, Beach, & Joiner, 1999; Levenson &

Ruef, 1994), and roommates (e.g., Anderson, Keltner, & John, 2003; Gonzaga, Campos, & Bradbury, 2007; Howes, Hokanson, & Loewenstein, 1985; Joiner, 1994). In this chapter, affective convergence is examined primarily from the position of primitive contagion and a basic appraisal of expressions, although it is acknowledged that affect convergence can arise through other means, such as shared affective events (Thompson & Fine, 1999) and interpersonal affect regulation (Niven et al., 2009).

Although there are many studies in the literature examining affect regulation in a dyad, there are two problematic aspects of how dyadic interaction is represented. Firstly, in traditional, static models of affect, dyadic interaction is often considered in terms of an active agent engaging in affect regulation and a passive target, receiving affect-expression from the agent (e.g., Grandey, 2000). Secondly, attempts to better reflect two active individuals with their own affect regulation processes has characterised affect experience as alternating between individuals (Hareli & Rafaeli, 2008), rather than being continuous in both. These issues are further explored below as problems termed *agent-target designation* and *back-and-forth exchange*. It is necessary to examine these issues and present an understanding of the dynamics in a dyadic interaction that accounts for these, in order to develop a functioning MARDy simulation of a dyad. Unlike static models, dynamic simulation offers means for representing two active agents in a dyad engaged in concurrent affective experiences.

8.1.1 Agent-Target Designation

In the traditional understanding of affect regulation in dyadic interaction, it is often considered that one individual has affect regulation aims and one person is the recipient of the affect regulation process (e.g., Côté, 2005). For the active member of the dyad, these regulation aims may be intrapersonal or interpersonal. For instance, a customer service agent may seek to regulate his or her own feelings to present a positive and enthusiastic outward impression in order to meet display rule standards; alternatively, he or she may seek to calm and reassure an irate customer in order to minimise any disturbance to others. In either case, discussion regarding the dyadic interaction places emphasis on one member of a dyad engaging in affect regulation, normally termed the *Agent*. The agent is an individual who is recognised as playing an active role in the affect regulation process; whereas, the counterpart, normally termed the *Target,* is seen as a relatively passive member of the affect regulation process. Recent arguments seek to expand this understanding of the agent-target relationship to acknowledge that the target also plays an active role in the affect regulation process (Niven, Totterdell, Holman, & Cameron, in press).

More broadly, an agent-target relationship may become ill-defined in a dynamically changing dyadic relationship. An agent is characterised in the emotional labour literature as an individual who undertakes affect regulation towards a held goal: either regulation of their own affect or the affect of others (e.g., Grandey, 2000, 2003; Niven et al., 2009). However, if the perspective of the *Target* is considered, it would be evident that the target can *also* hold affective and broader goals. The customer in the earlier example may be expressing irritation as a means of seeking compensation or sympathy or possibly attempting to regulate their own frustration through the process of venting. In either case, the individual nominally referred to as the *Target* is engaging in active affective regulation processes in the dyad, activities that would be regarded as an *Agent's* behaviour. From this, it is evident that both members of the dyad can be regarded as active agents, shaping their own and each other's affective states.

This issue extends beyond that of just simply being one of terminology; overlooking the active role that both parties play in affect regulation in a dyad limits the scope for examining how affect may change over time. In a dyadic interaction, the assumption made that one member is a passive recipient of affect regulation and so not wholly studied results in potentially substantial gaps in understanding the dyad. It becomes necessary to approach the investigation of affect regulation in a dyad with the understanding that both individuals involved hold their own dynamically changing affect goals, which would impact on the course of affect exchange. In section 8.2, the design of an active affect regulation dyad is outlined with the principle that both members of the dyad are active affect regulating agents.

8.1.2 Back-and-Forth Exchange

Affect regulation in a dyad has been well described in terms of emotion cycles by Hareli and Rafaeli (2008) and similarly represented in what Côté (2005) terms an *affect cycle*. Hareli and Rafaeli (2008) argue that, alongside affect contagion, an agent's affect can change through the inferential processing of another's affective expression. They give the example of a cycle of emotions involving the expression of anger by Person A, which in turn elicits an expression of fear by Person B that then gives the response of embarrassment by Person A, with the cycle closing by Person B responding with relief.

This process is presented as a back-and-forth exchange of affective expressions, in which individuals perceive an expression of the other and then generate their own expression in response. The key implication is that, at any given point in a cycle, it is just one individual that is considered as processing and then expressing affect; the model remains silent on what affective processes the other individual is engaging in during this time. This presentation of a sequential nature of exchange in emotions omits the consideration that both agents have a continual and dynamically changing affective state (e.g., Russell 2003). Rather than using the representation that implies affect is passed back and forth from one agent to the other, it may be more useful to consider affect in a dyad as two parallel changing states which can impact on each other through affective expression.

This issue relates back to the first in that there is an added complexity in examining affect in a dyad rather than in an individual. This simplification in considering only one individual in a dyad as an active agent at any time does bring some clarity in describing affect cycles (e.g., Hareli & Rafaeli, 2008) and reduces the affective processes so that affect changes may be examined with traditional statistical models. However, it does mean that much of the affective dynamics of two individuals, each with their own on-going affect regulation and their own held affect goals, is not thoroughly examined. Reciprocal affect exchange in a dyad is necessarily a two way process, which forms a closed loop of each person engaging in affect-expression with the other. Complexities in affect dynamics may arise from this, which may not be considered if the more traditional perspectives for examining affect in a dyad (such as those described in this section) are used.

This chapter offers a means of representing both individuals in a dyad as active agents that seek to engage in affect regulation towards individual- held goals as a replacement for the more widely used ‘active agent’ and ‘passive target’ representation. It further offers representation of affect as a continually changing process in both agents, moving beyond the limited representation of affect being considered in only one individual at a time. To achieve this, the computational model developed in this thesis so far is considered as a representation of a single agent, which seeks to regulate affect towards known held goals. The development and expansion of the model to function within a dyadic framework is described in the following section.

8.2 Designing a MARDy Based Dyad

8.2.1 Overview

In Chapters 4 through to 7, the design of MARDy has been focused largely on the simulation of an individual. While there has also been the inclusion of influences external to the model of an individual that can shape the individual's affective and related states, these have so far been represented as just external impulses to the system. For simplicity in designing in the model, these have been considered as an affective event that just 'happens' and impacts on the dynamics of the system. The model cannot change the valence of these events, only how it reacts and "feels" in light of the situation and the event will continue on regardless. In some cases, this may be an appropriate characterisation of a situation: a film's sad plot will not change and become more light-hearted, if we express sadness; heavy traffic will not disperse just so that our frustration can be eased; and no matter how angry we become with a computer, its performance will not improve to appease us. However, there are many more situations in which affective expression can directly or indirectly change affective situations, such as interpersonal interaction.

As described in section 8.1, affect is often characterised as serving a social function with the purpose of shaping the social environment through impacting on others' behaviours, thoughts, and even affective states (e.g., Parkinson, 1996; Sy et al., 2005; Van Kleef, 2009). This characterisation of affect differs substantially from the simple 'external events' design used in the model because an individual's affect-expressions could influence the intensity, duration and onset of affective events that the individual perceives. The simulations in this chapter have been constructed to examine the influence of affect-expressions by agents in a dyad on the intensities of experienced affect of each agent. The development of a dyad in which affect is communicated between agents therefore allows for an agent's outputs (its affective expression) to be used to influence the intensity of inputs it receives (the affective events it experiences). This process is one described in the perceptual control theory literature (e.g., Powers, 1974) in which actions on the external world are used to control inputs in order to reduce their discrepancies with personal goals.

The development of a dynamic computational simulation of dyad offers a means of representing the active and dynamic processes involved in shaping affective states of both individuals. Simulations of independent, active agents such as those outlined later in this chapter can meet the challenges outlined in section 8.1 when attempting to understand affect dynamics in a dyad. Figure 8.1 offers a drawn representation of the continuous and concurrent use of affect regulation of two agents in a dyad.

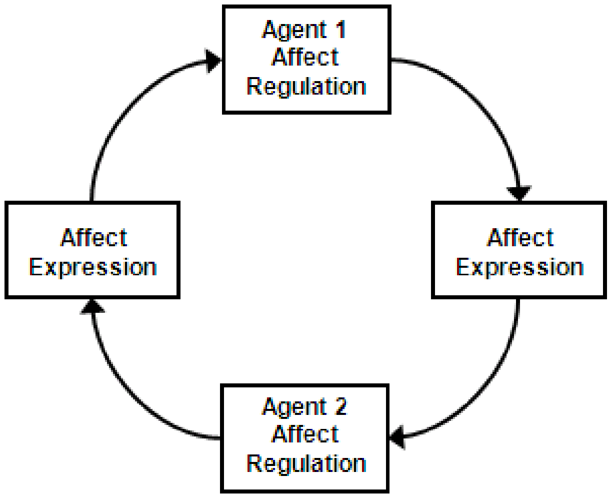

Figure 8.1 Closed loop formed by each agent's expressions influencing the other's affective states

This representation of affect-expression ultimately shaping the affective input received, through influencing the other agent's own states contrasts with Gross's (1998a) and later (e.g., Gross & Thompson, 2007) representations of affect regulation. Gross (1998a) describes the changing of affective events to regulate one's affect as situation modification and places this early in the linear chain of affect regulation strategies for an affective episode. However, within the model design, this process could be on-going through an affective episode and even concurrent with both cognitive change (felt-affect regulation in the model) and response modulation (affect-expression regulation in the model). Moreover, situation modification may arise *from* later regulatory processes used by Agent 1 because these may shape Agent 2's expressive state, modifying the affective situation Agent 1 faces. Given the evolving nature of regulation during dyadic interactions and potential for overlap in strategy use, Gross' (1998a) division of the process model into distinct emotional episodes in order to delineate 'earlier' regulation strategies that may occur after 'later' regulation strategies seems somewhat arbitrary.

8.2.2 Implementing a MARDy Dyad

In order to create simulations of the process shown in Figure 8.1, it is useful to consider the MARDy simulation from a more holistic perspective. Alongside this, an additional component needs to be added to the MARDy simulation.

Firstly, for examining the model in a dyadic network design it is of greater interest to view the model as a whole unit rather than a collection of regulatory mechanisms. The completed model of an individual (Figure 4.9) is grouped as a single system, with a singular input point (to receive affect-expressions) and output point (expression of affect) for other MARDy units to interact with. This grouped system makes up each individual agent and the internal operations (i.e. the higher and lower level control loops and the central resource) are functionally no different from those in the original, stand-alone model used in simulations in earlier chapters. This naming of the complete unit as an *Agent* refers both to the commonly-used name for an active figure in an affect regulation context and as recognition that this is the first step towards an agent based model of independent units interacting across a network.

Secondly, an additional block in the simulation is necessary to control the interactions between multiple MARDy agents. This additional block exists between each agent's output of affective expression and the affective input of another agent in the simulation; it is independent of agent models and does not alter operations within agents. This block controls the timing, frequency, and duration of the periods in which two agents are in contact with each other and so able to influence each other's affective states. Affect-expression is considered in the model as a continuous changing state and so the expressed output of each agent is always active, while both agents are in the awake state. Without this additional meeting block limiting the times that agents contact each other, each agent would be continuously engaging in affect-expression towards the other so the meeting block determines when the agents can receive each other's outputs and when they cannot. A schematic of the whole dyadic system is shown in Figure 8.2.

The model block that determines meeting times is a simple gate that opens and closes at predetermined times. These times are specified before running a simulation, using the same entry procedure in Matlab as the means for determining the agents' sleeping and waking times. While the sleeping and waking times for each agent can be set independently, the meeting times for both models are required to match in order to form a closed loop as a dyad. In addition to this, there exists a validation check before the stimulation begins to ensure that meeting times for the dyad do not overlap with either agent being asleep.

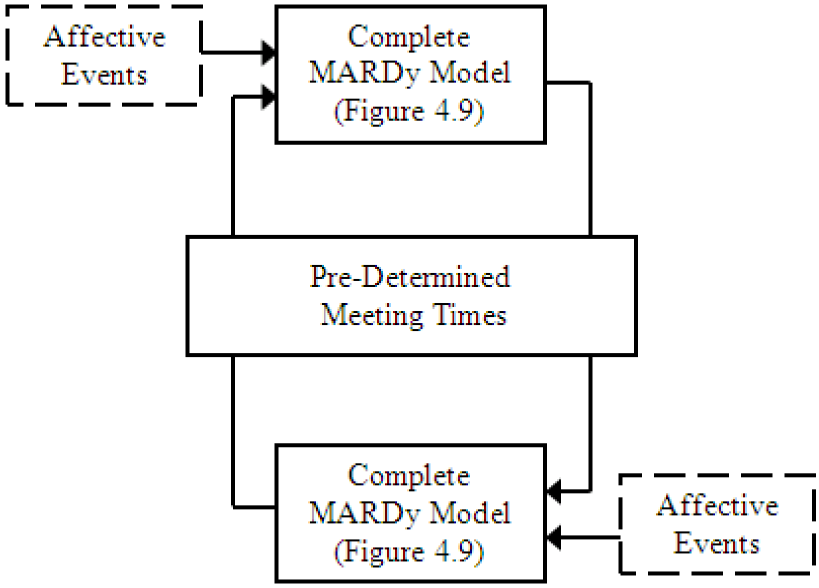

Figure 8.2 Schematic of two complete MARDy simulations connected through a model component that determines meeting times

Affect expression from each agent is a continuous output; its influence as an input to the other agent is determined by an intermediate block in Simulink acting as a 'gate' that allows affect expression to pass through at pre-determined time points for pre-determined durations. Dashed blocks represent affect events eternal to the dyad that may influence agents' felt states.

In this design, affect-expression in the dyad serves as the primary input to each agent, which acts in the felt-affect control loop as the destabilising influence, impacting on the felt-affect state (see section 3.2 for a description of a control loop's component parts). In previous chapters, this destabilising influence has been assigned as the widely encompassing term *affective events*, which typically incorporates affective expressions from others; from here on in this chapter, affective events is used to describe any affective input to the model that *does not* involve expressions in the dyad.

Affect-expression from one agent as an affective input to the other directly acts as an influence on the recipient's felt-affect state. A positive expression from one agent serves to improve the affective state of the other, while a negative expression serves to worsen the partner's affect. This process is a substantial simplification of affect exchange, especially compared to the range of possible responses to specific affective expressions (e.g., Hareli & Rafaeli, 2008; Keltner & Haidt, 1999). However, to include a range of possible responses to the affective expression of the other in a dyad would require the inclusion of a complex affect appraisal system that interprets others' expressions in terms of broader social goals. For example, in a competitive sports game an expression of anger from an individual due to poor performance may elicit happiness in another agent that stands to benefit from this. The broad range of possible evaluations to each expression cannot be successfully captured, even in a wide ranging model, such as the one in this thesis, and so a simpler representation of responses is chosen.

Affective expressions, alongside influencing the felt-affect state directly (e.g., Hareli & Rafaelli, 2008), can indirectly influence the felt-affect state through influencing the affect-expression state. As described earlier, affect contagion is regarded to include the process of expression mimicry (Hatfield et al., 1994), indicating a convergence of two people's affect-expression states. In order to achieve this in the simulation, the difference between the affect-expression state as an input to each agent and the agent's current affect-expression state is calculated. This difference is then fed directly to the affect-expression block (Figure 4.5) so that the current affect-expression begins to converge with the other agent's expression. Over time these two expressed states from each agent would fully converge in the absence of any successful deliberate intrapersonal expression regulation. The felt-affect state is in turn influenced by this convergence of expression through the feedback link from expression to the felt-affect state representing expressive feedback, such as that described by Hatfield et al. (1994).

This dyad-model design is not intended to examine deliberate interpersonal affect regulation. Deliberate interpersonal affect regulation is characterised as intentional actions or expressions with the goal of changing another individual's feelings or expressions (Niven et al., 2009). While an agent, as it stands, can regulate his or her own expressions towards a held goal, this does not occur within the broader framework of using that action to meet wider goals of changing another agent's felt-affect state. For this to be possible, each agent would need redesigning to include more goal states, such as a goal for what it wants the other agent to feel, and means for achieving these goals, such as selection mechanisms to switch focus from intrapersonal regulation to interpersonal regulation. For this reason of the required added complexity necessary to introduce deliberate interpersonal regulation, it is not considered in the model at present.

8.3 Simulating Dyadic Interaction

In order to test some of the expected outcomes of two agents interacting, it is necessary to both test a dyadic design of the model and to make comparisons with that of independent agents, existing alone. This contrasts the influence of affect-expression on agent's felt-affect states in the dyad with agents that do not receive such affective input. Further to this, isolated agents' affective expressions do not shape the affective environment (i.e. the affect states of other agents) as agents would in a dyad design. The outcome of any constructed scenario in a model of dyadic interaction does not alone highlight how the dyad has influenced an agent's affective states. A simulation of an individual agent can serve as a control condition for the dyad condition: if parameter values are kept consistent between the two conditions, the influence of the dyad on an agent's affective states can be determined.

In this chapter, three broad scenarios are simulated to show the range of influences a dyadic network can have on an agent's affective states. These scenarios have been selected to reflect broad classes of affect influence in a dyad. Firstly, two normative agents, with parameters derived from Chapters 6 and 7, are arranged as a dyad to determine the influence of the dyad arrangement on regulation towards shared typically positive affect goals. Second, the effects of dysfunctional affect regulation in the dyad are examined and contrasted with both isolated agents and the results from the first test. This scenario focuses on representing one agent in the dyad as experiencing symptoms of mild to moderate depression, with the aim of recreating aspects of affect convergence seen in Joiner (1994). The last scenario looks at interactions typified in the work psychology literature: presentation of inauthentic affect-expressions (surface acting) and their influence on a) customer/client interaction quality and b) the felt-affect state of the employee.

To create each scenario, a number of parameters require specification beforehand, such as the goal for felt-affect states, and the home-bases for felt-affect in each agent. Each parameter specification and the ranges used for them are outlined in this section. Ranges of values are used for all other parameters not specifically determined in the scenario creation. This allows for an overall range of plausible predicted behaviour of the models rather than an overly specified proscriptive outcome of the simulation. This further offers a broader representation of the outcomes of the model and reduces the potential of reporting artefacts of specific parameter configurations as definitive results for each agent. The values and ranges used for all of the parameters used throughout the simulations are detailed in Appendix 6; key parameters, specified to form each scenario design are mentioned in each section in this chapter.

For each scenario, the simulations are run 100 times with random values in a fixed range for all parameters to offer an example of the expected outcomes of dyadic interaction. The influences of affective events, outside the dyadic interaction, for each agent are represented by random values input to the felt-affect block, a procedure used by Oravecz et al. (2009) to represent the ups and downs of daily life. Dyadic interaction occurs between the models for a period lasting from 11am until 2pm and then again from 5pm to 8pm simulation time each day. In the model's representation of regultory resource, these times coincide with higher and lower levels of self-regulatory capacity so influences of resource on affect convergence can be explored. The maximum and minimum outcomes over a period of 6 simulated days are presented as simulation results; this simulation duration matches that of the data fitting period from Chapters 6 and 7. Agents are differentiated by the terms *Agent 1* and *Agent 2*.

8.3.1 Scenario 1: Supportive Interaction

The first dyad scenario is a simple connection of two normative agents. Results from Chapter 7 indicate that, almost without exception, individuals report having a goal affective state that is equal than or more positive than their current felt-affective state. In most cases, this exists as a high positive valence affect goal. To reflect this, for the purposes of this scenario, each agent is considered to regulate their affective states towards a high positive felt-affect goal and a congruent positive affect-expression goal so that their expressed state is likely to be a genuine representation of their felt-affect state. Two agents in a dyad may be considered as a representation of a typical romantically attached couple, two housemates, or mutual friends who share time with each other.

It is anticipated that this design will result in more positive affect experienced within the dyad in comparison with agents on their own. In empirical studies, it is indicated that positive affect can be shared through positive affect communication within the dyad (e.g., Rimé, 2009; Rimé, Mesquitab, Bocaa, & Philippot, 1991). Further to this, Hicks and Diamond (2008) highlight that, in romantically attached couples, one person recounting their most positive experience of the day to the partner would result in both individuals experiencing greater positive affect. Positive expression from each agent will encourage positive affect in the other, likely to ensure that reciprocal expression is, again, positive.

Proposition 1.1: *Agents holding equivalent positive affect goals in a dyad will both experience greater positive affect than they would alone.*

It is expected that each agent's positive affect-expression would result in their counterpart's felt-affect state being brought closer to the held positive felt-affect goals. Additional outcomes of this apparent support in reaching a held goal would be a reduction in regulatory efforts expended to meet goals and an overall greater conservation of self-regulatory capacity throughout the day. These processes could be considered to reflect results found by Fitzsimons and Finkel (2011) in which thoughts of a partner's assistance in reaching a variety of self-regulatory goals diminished their own regulatory efforts towards these goals. Support from a partner in reaching affect goals may diminish the necessary effort expended in reaching these.

Proposition 1.2: *Agents holding equivalent goals in a dyad will be less depleted in reaching the goal together than either will alone.*

Building on ***P1.1*** and ***P1.2***, it is anticipated that the arrangement of agents in this supportive dyad will influence the states of affect goals. With the predicted greater self-regulatory capacity, affect goals are more likely to be met and so less likely to be altered to more amenable levels. Further to this, if affect goals are likely to change, the affect states they will tend towards are anticipated to be close to the state intensities.

Proposition 1.3: *Agents holding equivalent goals in a dyad will maintain these closer to the goal 'home-base' and show less variation in affect goal intensities than isolated agents.*

In order to examine the propositions arising from this scenario, it is necessary to specify some agent parameters. Firstly, as previously described, both agents have positive felt-affect goals and so are set to hold a positive felt-affect goal of +5 on the simulation's affect scale from +5 to -5. Affect-expression goals are specified as +5, congruent with the felt-affect goals. In addition to this, the agents' home-base for affect is set at a slightly positive value of 1 to ensure that across the simulation the agents would generally experience a positive felt-affect state. Further parameter values, and ranges for each of these, are outlined in Appendix 6.

8.3.2 Scenario 2: Depressed Agent

The second dyad scenario is a representation of affect contagion seen in studies examining depression. Research on the affect states of college roommates indicates that if one member of the dyad shows persistent signs of mild depression, then the other member of the dyad may show an increase in negative affect. This outcome of a contagious negative mood reportedly increases over a period of months (Howes et al., 1985) and occurs early on in the dyad formation (Joiner, 1994). It is expected that representing symptoms of depression in Agent 2 (*Depressed Agent*) through the manipulation of parameters for affect regulation mechanisms can be sufficient in inducing depressive symptoms in Agent 1 (*Non-Depressed Agent*). It is not only expected that felt-affect will become more negative in the Non-depressed Agent, but also that felt-affect goals will be lowered and also regulatory fatigue will be greater in comparison with a control agent simulation.

Proposition 2.1: *The Non-Depressed Agent will display similar depressive symptoms to that of Depressed Agent, without the presence of underlying affect regulation dysfunction.*

The expected influence on the Non-Depressed Agent might be mitigated under certain circumstances. As described in section 8.2, parameter values for a wide array of the parameters used are not fixed across simulations but vary a small degree (Appendix 6). Parameter variations for the Non-Depressed Agent which improve upon the capacity to change affect (such as a greater regulatory momentum) or a more general positive disposition (such as a more positive home-base), may limit the influence of Non-Depressed Agent. As a result, the Non-Depressed Agent might not always show affect convergence in this scenario.

Proposition 2.2: *The Non-Depressed Agent may show 'immunity' to contagion of depressive symptoms, under specific parameter configurations enhancing positive affect, resource conservation, and/or regulatory momentum.*

Parameter specifications for the Non-Depressed Agent are kept from Agent 1 in the first scenario. Three parameter values are altered in the Depressed Agent to create the depressive symptoms of a stable and enduring negative felt-affect state and a feeling of depletion. First, the home-base for the Depressed Agent is specified at -3 on the ±5 scale used, resulting in a tendency for mild to moderate negative affect. Second, a gain of 0.5 is placed just before the felt-affect block (Figure 4.2.), which weakens the influence of affective input to change the felt-affect state from both felt-affect regulation and expression from the Non-Depressed Agent. Third, a similar gain is placed at the equivalent point in the affect-expression regulation loop. The inclusion of the gains restricts the degree of change to the affective states over time and can be considered analogous to the proposed *affective inertia* associated with depression (e.g., Kuppens et al., 2010). It is expected that as a product of the restricted capacity for affect regulation, the depressed agent will both experience goal adjustment towards a more manageable affective goal (as such, possibly wanting to feel less negative rather than an unattainable positive affect goal) and experience high regulatory fatigue through persistent unsuccessful efforts at improving felt-affect.

8.3.3 Scenario 3: Surface Acting

The third scenario looks at the effects of inauthentic expression by an agent in the dyad. This is considered in terms of a person engaging in surface acting at work to express a more positive affective state than their genuinely experienced affect (Hochschild, 1983). This process of surface acting is considered to be fatiguing (e.g., Goldberg & Grandey, 2007), and of limited success in shaping the other agent's feelings (e.g., Grandey, 2003). For this scenario, Agent 1 is considered as an *Employee* working in customer service and Agent 2 is considered the *Customer*. The scenario is divided into two sub-tests: the Customer's felt-affect state is manipulated so that it experiences positive affect in the first test and negative affect in the second, representing a happy or unhappy Customer, respectively. The deleterious effects of the Employee using surface acting on both the Employee's self-regulatory capacity and the quality of interaction between agents are expected to be modified by the affective states of the Customer. Positive affect states of the Customer are anticipated to improve felt-affect of the Employee, limiting dissonance and potentially self-regulatory fatigue; whereas negative affect states of the Customer are anticipated to worsen felt-affect of the Employee, increasing dissonance and potentially self-regulatory fatigue. This is analogous to Côté's (2005) mechanism of interpersonal feedback.

Proposition 3.1: *Dissonance between felt-affect and affect-expression in the Employee will be reduced, if the Customer's felt-affect reflects the Employee's affect-expressions.*

Proposition 3.2: *Dissonance between felt-affect and affect-expression in the Employee will be enhanced, if the Customer's felt-affect contrasts the Employee's affect-expressions.*

Proposition 3.3: *Regulatory resource depletion in the Employee will be reduced, if the Customer's felt-affect reflects the Employee's affect-expressions.*

Proposition 3.4: *Regulatory resource depletion in the Employee will be enhanced, if the Customer's felt-affect contrasts the Employee's affect-expressions.*

In order to simulate an individual engaging in surface acting towards a positive state, the Employee agent must create a discrepancy between felt-affect and affect-expression (such as Grandey's, 2003, example of a hotel clerk who displays sympathy but feels irritation towards a customer). To simulate an individual who displays a positive expression but feels otherwise, the held goal for the Employee's affect-expression is retained at 5, while the typically positive affect home-base and felt-affect goal for the Employee are reduced from 1 and 5 to -1 and 2 respectively. This maintains the Employee's felt-affect state at approximately neutral levels and could represent an employee who is not pursuing a company's display rules through deep acting.

For the first dyadic interaction test, the Customer's parameters are kept from Agent 2 in Scenario 1; the agent regulates towards high intensity positive affect goals. In the second test, the Customer's parameters for affect home-base, felt-affect goal and affect-expression goal are set to -2, -1 and -1, respectively; this is considered to represent a mildly negative affect state for the Customer. Results from these two tests are further compared against a control state of the Agents in isolation from each other.

8.4 Results

Results are gathered from both agents through the process of artificial diary data collection, outlined in chapter 7. Recordings are taken from the agents across a range of different variables: current felt-affect, current affect-expression, current felt-affect goal state, and current self-regulatory capacity. These recordings are taken every two hours in the simulation timeframe while agents are in the 'awake' state. Results are collected over a period of seven simulated days with the first day's results discarded as that day is used to specify the agents' desired starting states so the last six days of simulation are reported.

For each agent, in both their dyad design, in which affect is transferred, and in their control design, in which no affect can be transferred between agents, the range of results are reported. The highest and lowest average outcomes are taken from the 100 simulations used for each scenario, in which key parameter values were randomly altered in a small fixed range around the values used to give the best fit of data in chapter 7. This outlines the overall range of recorded states across all simulations, offering a general representation of plausible projected state intensities. In terms of felt-affect, affect-expression, and felt-affect goals, range consists of the most positive valence recording on average over the six days and the most negative (or least positive) valence recording averaged across the six days. In terms of self-regulatory capacity, the highest and lowest average self-regulatory capacity over the period of six days are reported. Results are scored on a scale of +5 to -5 for affect reports and on a scale of 0 to 10 for self-regulatory capacity, to mimic the scales used in the diary studies.

Results are presented by scenario; comparisons are made between the outcomes of the simulations of the agents affect regulatory behaviour in an isolated control design and the dyad design. Further to this, comparisons can be made from the outcomes of one scenario with the outcomes of the same agent in a similar scenario.

8.4.1 Results 1: Supportive Interaction

In this scenario, both agents are seeking to regulate their felt-affect towards a held positive goal, initially set at +5 on the ±5 scales used. It was predicted (**P1.1**) that the positive affect by each agent displayed during time spent together would serve to collectively increase the intensity of positive affect in comparison with agents alone. Results in Figure 8.3 indicate that both agents experience on average an overall higher felt-affective state when part of a dyad when compared to regulating towards the held goals alone. Figure 8.3 displays results in the convention used for the remainder of this chapter, unless otherwise specified: Agents as isolated individuals (Control) are on the left side and Agents as the dyad network (Dyad) are on the right; Agent 1 is represented in the upper graphs and Agent 2 in the lower graphs.

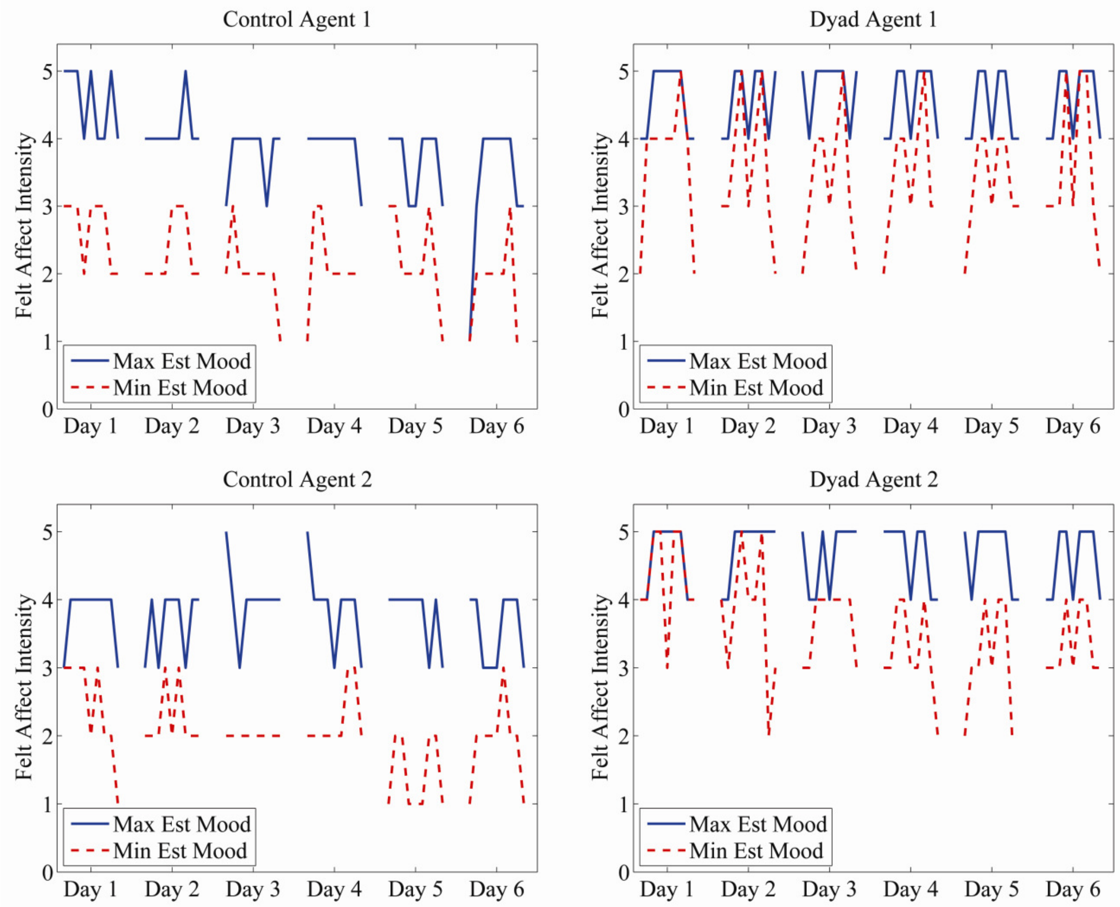

Figure 8.3 Ranges of felt-affective states for Agents 1 (top) and 2 (bottom), both as isolated models (left) and together in a dyad design (right).

A further predicted consequence (**P1.2**) of dyadic interaction in which both agents share mutual positive goals was the reduced effort required to regulate affect. It was anticipated that the mutual positive expression would assist both agents in reaching a high positive affect goal whereas agents alone would not have this available support. Results in Figure 8.4 indicate that depletion is slightly reduced throughout the day for both agents if they are connected in a dyad in comparison to regulating without contact with the other. This supports the expected outcome that regulation is less effortful with a supportive partner and suggests that this leads to a conservation of resource (see Hobfoll, 1989) rather than an actual boost to resource capacity (supporting strength-model theories, e.g., Muraven et al., 2006). As such, individuals are less likely to experience depletion when with a partner and perhaps likely to associate their partner with resource conservation, echoing the results found by Fitzsimons and Finkel (2011).

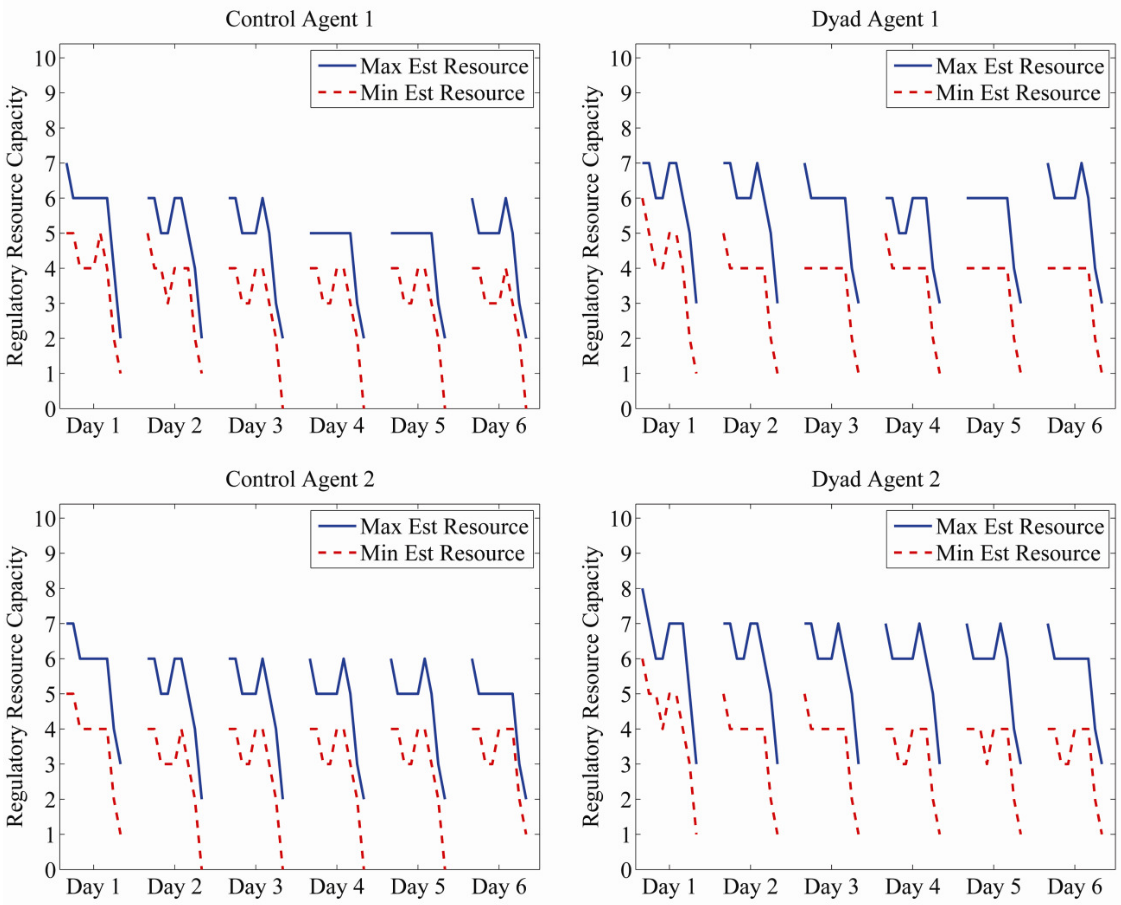

Figure 8.4 Ranges of self-regulatory capacity for Agents 1 (top) and 2 (bottom), both as isolated models (left) and together in a dyad design (right)

The final proposition (**P1.3**) considered the positive influence of the dyad would have on maintaining affect goals at high intensities. Given that agents in a dyad show less depletion in regulating towards affect goals (Figure 8.4), it is plausible that affect goals are less likely to deviate away from the affect goal home-base in a dyad. Figure 8.5 shows that the dynamics of affect goals in the dyad design are slightly more complex than this prediction of stability about a high initial intensity. While the results generally indicate that affect goals are held at a higher intensity in agents in a dyad than they are in either agent in isolation, they do not necessarily show greater stability. Maximum estimates in both the control and dyad design show stability at high affect goal intensities, with goals in the dyad design being slightly more positive. However, the lowest estimates show greater variability in affect goals, with affect goals in the dyad design appearing to centre on a more positive affect state than those in the control.

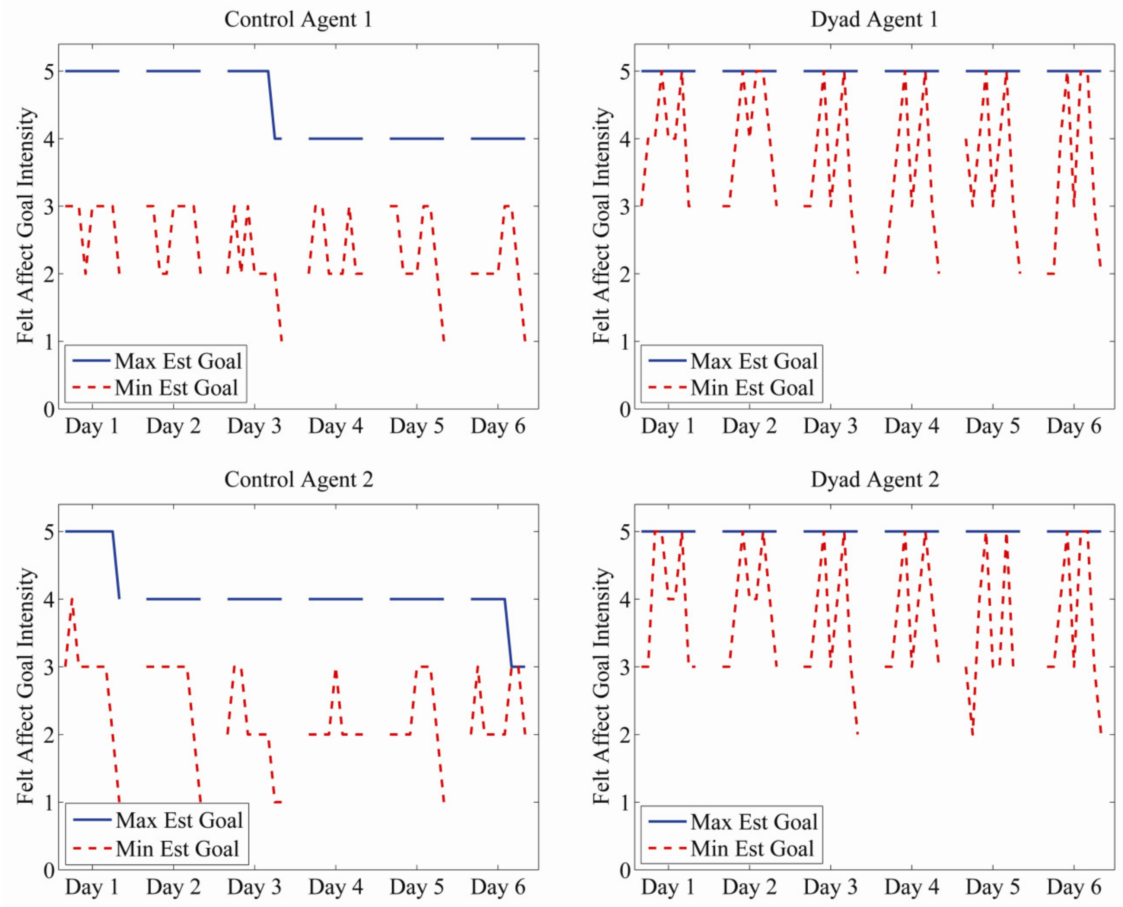

Figure 8.5 Ranges of felt-affective goal states for Agents 1 (top) and 2 (bottom), both as isolated models (left) and together in a dyad design (right)

8.4.2 Results 2: Depressed Agent

In the second scenario it was predicted that negative affect would transfer from the Depressed Agent to the Non-Depressed Agent (**P2.1**), in line with established results (e.g., Joiner, 1994). Figure 8.6 indicates that in a comparison between the non-depressed agent existing alone and existing as part of a dyad, the influence of a depressed agent can cause a decrease in positive affect to the extent that, at times, both agents experience negative affect. The moderately negative affect state of the Depressed Agent is reflected in lower bound estimates of felt-affect states of the Non-Depressed Agent. However, Figure 8.6 indicates that not every trial results in the Non-Depressed Agent's affect shifting to a negative state; some parameter configurations 'immunise' Agent 1 from substantial affect convergence, as was predicted (**P2.2**). Inspection of the parameter space indicates that felt-affect home-base and regulatory momentum are particularly high in 'immune' agents, while depletion cost of felt-affect regulation is particularly low. This is further discussed in section 8.5.

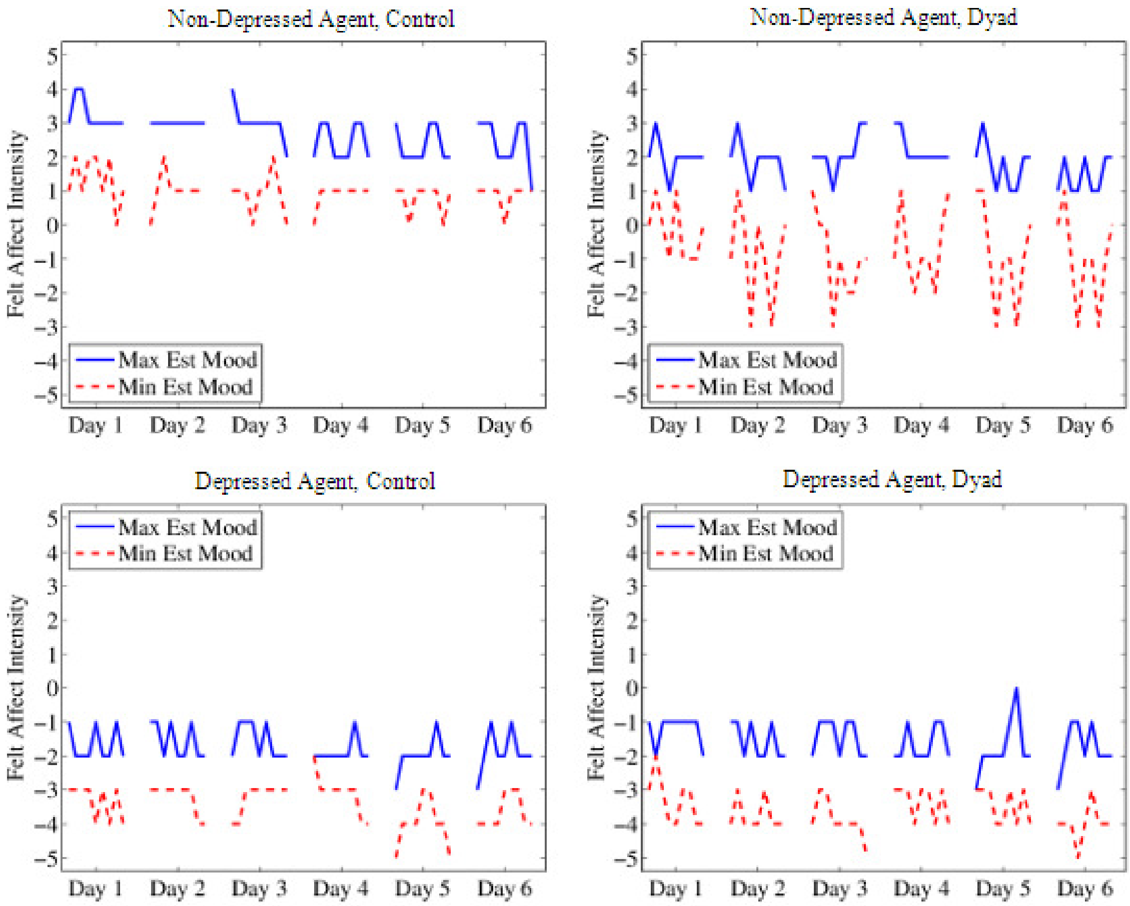

Figure 8.6 Ranges of felt-affective states for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right)

The second key influence seen in the 'depressed agent' dyadic interaction is the change in self-regulatory capacity in the non-depressed agent. Figure 8.7 indicates that depletion increases in the Non-Depressed Agent, if it is paired in a dyad with a Depressed Agent, further supporting propositions made (**P2.1**). Results further show that this occurs across all simulations run. Parameter configurations which enabled 'immunity' from affect convergence do not also enable 'immunity' of contagion of depletion, which does not support the proposition made (**P2.2**). These results point towards a mechanism for the apparent immunity to affect convergence: the Non-Depressed Agent may be expending more effort in engaging in regulation to conserve positive affect, depleting self-regulatory capacity.

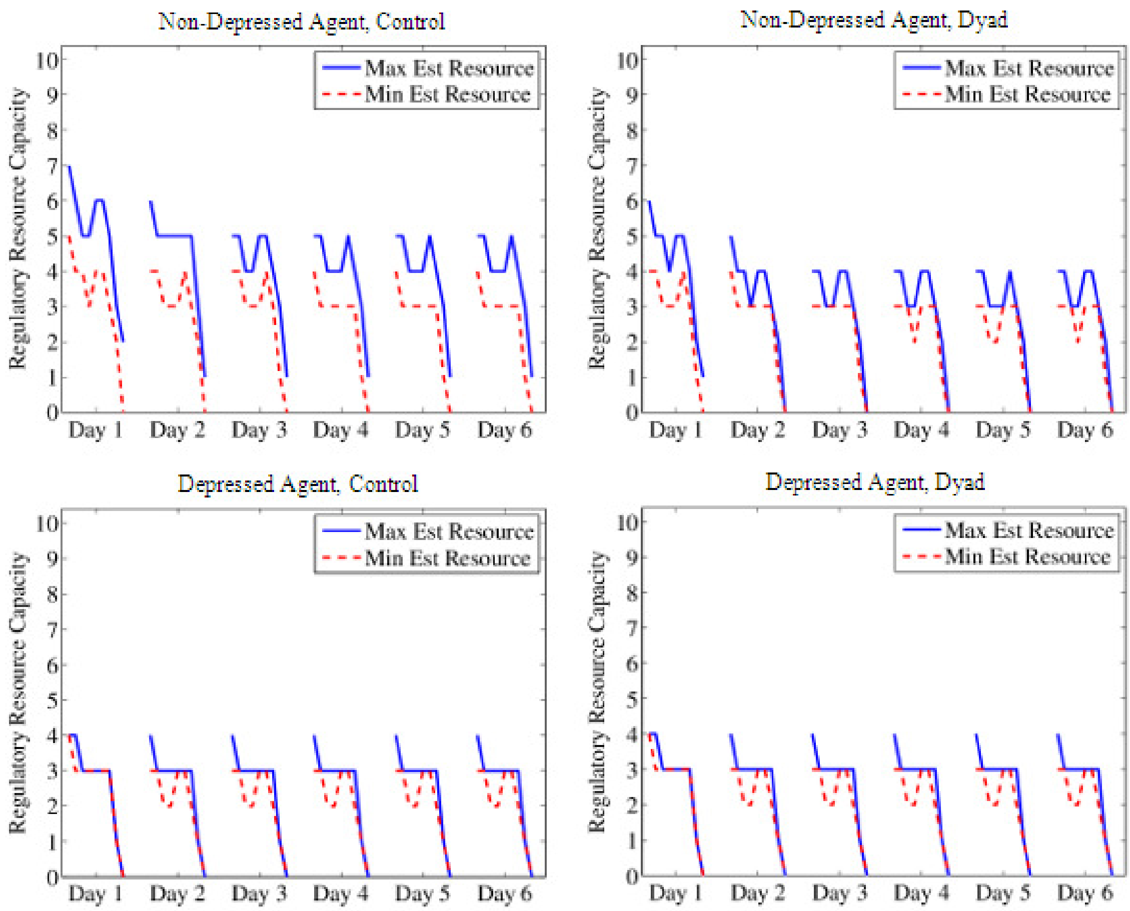

Figure 8.7 Ranges of self-regulatory capacity for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right)

A further outcome of the simulations is the change to the Non-Depressed Agent's affect goal states when in the dyad design in comparison with the control design. As seen in both the diary data and predictions from the literature (e.g., Lord & Hanges, 1987), affect goals tend towards current affect states in individuals that are depleted. This process is evident in the Depressed Agent's goal states under both conditions (Figure 8.8), which substantially differ from the value of the felt-affect goal home-base (+5). The Non-Depressed Agent shows slightly less positive felt-affect goals, in the dyad condition in comparison to the control condition, which can be regarded as some support for proposition **P2.1.** Support for this proposition is further seen in the resemblance of the Non-Depressed Agent's felt-affect goals in the dyad condition with the Depressed Agent's felt-affect goals (Figure 8.8), particularly for the minimum estimates made.

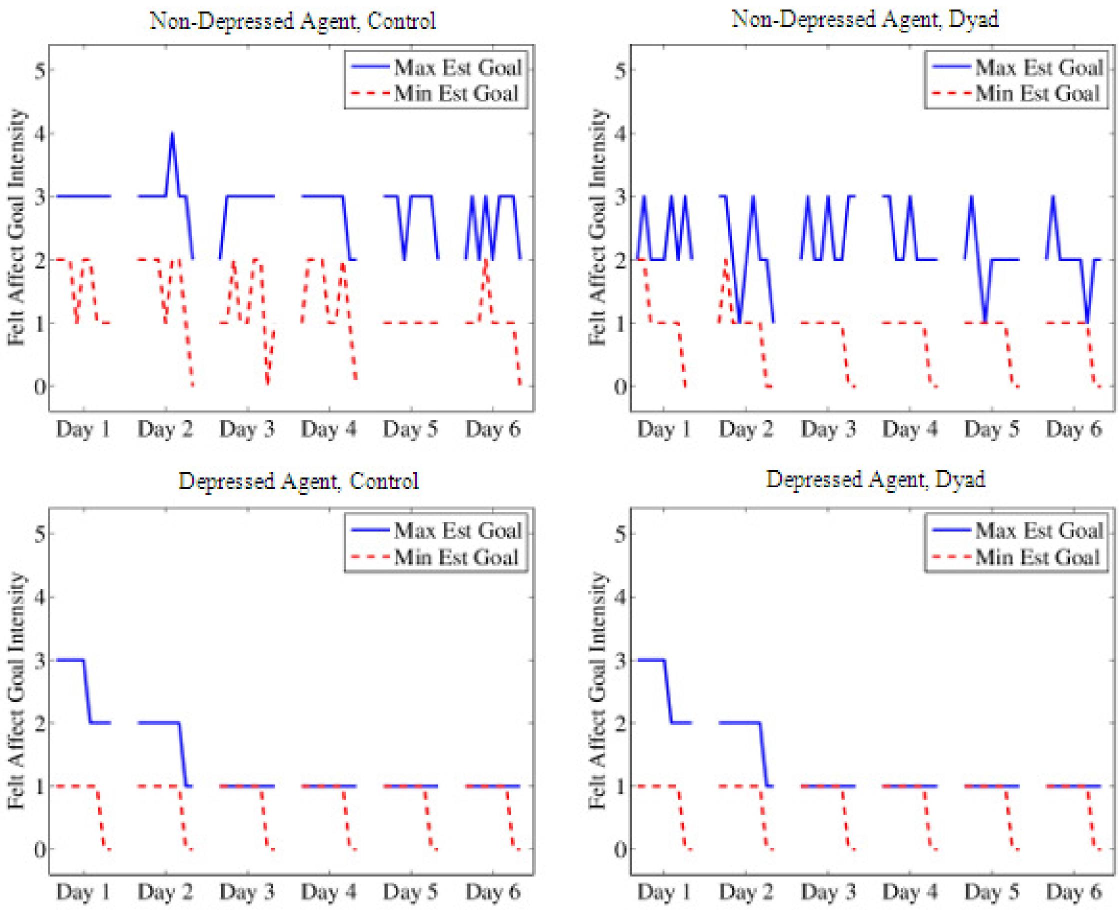

Figure 8.8 Ranges of felt-affect goal states for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right)

Lastly, convergence is seen in the dyad in terms of affect-expression (Figure 8.9). As with felt-affect, the Non-Depressed Agent shows a great variety in the degree of convergence, suggesting that certain parameter values and thus aspects of self-regulation can limit the likelihood of being influenced by other's affective and expressive states. Although this is not explicitly referred to in propositions, the pattern of results in figure 8.9 does reflect those seen earlier in this section.

Alongside this, there is some evidence of convergence in the Depressed Agent towards the more positive expressive states of the Non-Depressed Agent, even though although the depressed agent shows a dampened response to affective input. The parameters for the Depressed Agent restrict the capacity for regulatory efforts of both felt-affect regulation and affect-expression regulation. While the Depressed Agent has (initially) positive affect-expression goals, it does not have the means to successfully reach them; similarly, the felt-affective state does not change to such a degree and so cannot be solely driving the changes to the expressed state. Therefore, the overall positive changes in expression throughout the simulation largely appear to come from the process representing emotional contagion.

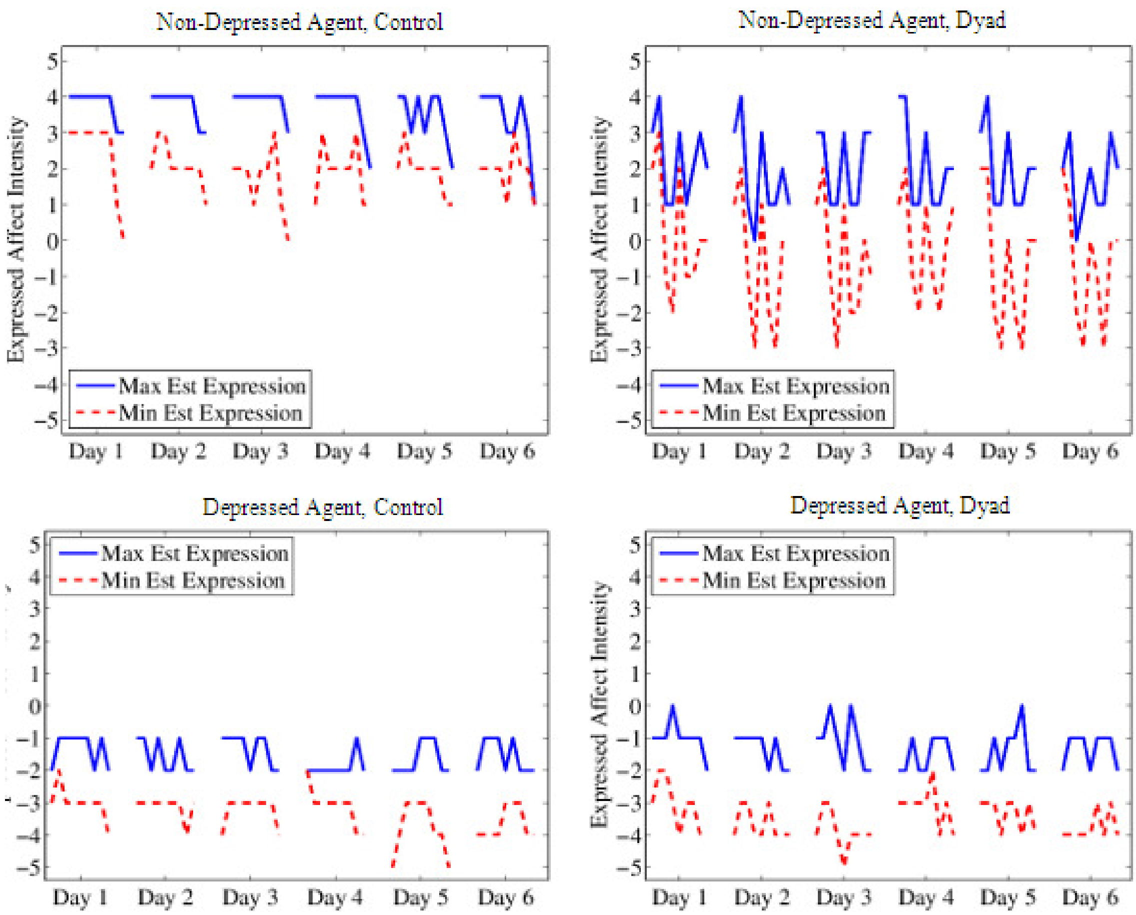

Figure 8.9 Ranges of affect-expression states for Non-Depressed Agent (top) and Depressed Agent (bottom), both as isolated models (left) and together in a dyad design (right)

8.4.3 Results 3: Surface Acting

The final scenario aims to represent an affect regulation process typically used by customer service agents when engaging with customers, which is surface acting. This scenario examines the influences that the Customer's (Agent 2) affective states may have upon the dissonance experienced by the Employee (Agent 1), which is presenting a more positive affective display than it feels (i.e., surface acting). To examine this, two dyads were used, in which the affective states of the Customer were manipulated: one with positive affect and one negative affect. Results indicate that the Employee shows affect-expressions substantially closer to its original affect goal home-base (+5), when in contact with a positive affect the Customer, in comparison to both a control agent and in a dyad with a negative affect Customer (Figure 8.10). Like the two agents in Scenario 1 (section 8.4.1), both agents appear to support each other in working towards their positive goals, resulting in more positive affect-expressions by the Employee. In contrast, when the Employee interacts with the Customer that aims to express a somewhat negative state, there is no support available to use to work towards the more positive state.

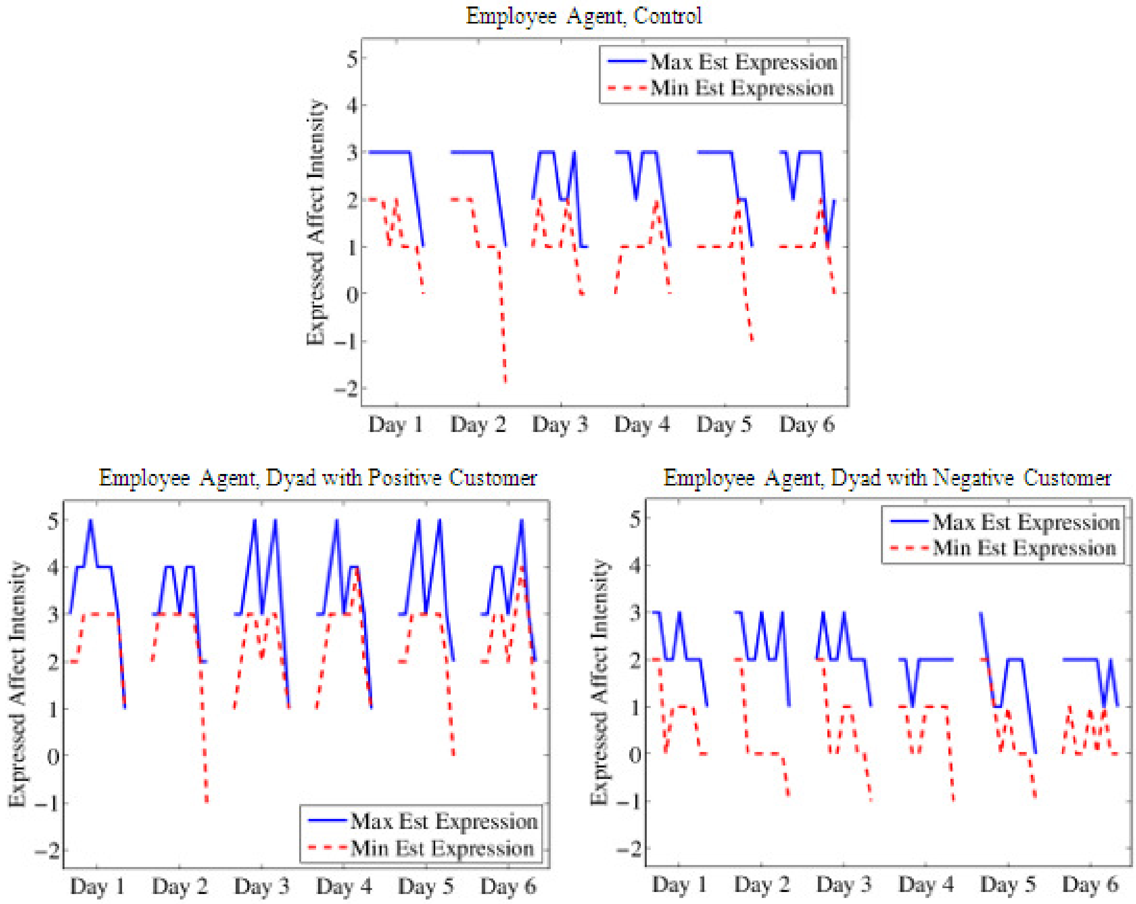

Figure 8.10 Ranges of affect-expression for the Employee as an isolated model (top), interaction with a positive affect Customer (bottom-left) and interaction with a negative affect Customer (bottom-right)

Further to this, the Employee's felt-affect is seen to become more positive, when in contact with a positive affect Customer, even though the Employee's felt-affect goal is specified at a marginally positive state. In contrast, felt-affect for the Employee in both the control simulations and in the dyad with a negative affect Customer shows maintenance of affect about a mildly positive state only. Figure 8.11 shows the felt-affect states for the Employee across all three tests.

Felt-affect and affect-expression can be considered together to give an indication of the dissonance between states experienced by the Employee, while engaging in surface acting. The proposed influence of a positive affect Customer, which has affect states reflecting the Employee's expression goals, in reducing the Employee's dissonance (**P3.1**) is only marginally present. While felt-affect in the Employee shifts towards the affect-expression goal, affect-expression also shifts to more positive states, preserving some dissonance. Alongside this, the proposed influence of a negative affect Customer, which has affect states contrasting the Employee's expression goals, in increasing the Employee's dissonance (**P3.2**) is not present. Explanations for these findings and their relation to emotional labour theory are considered in section 8.5.

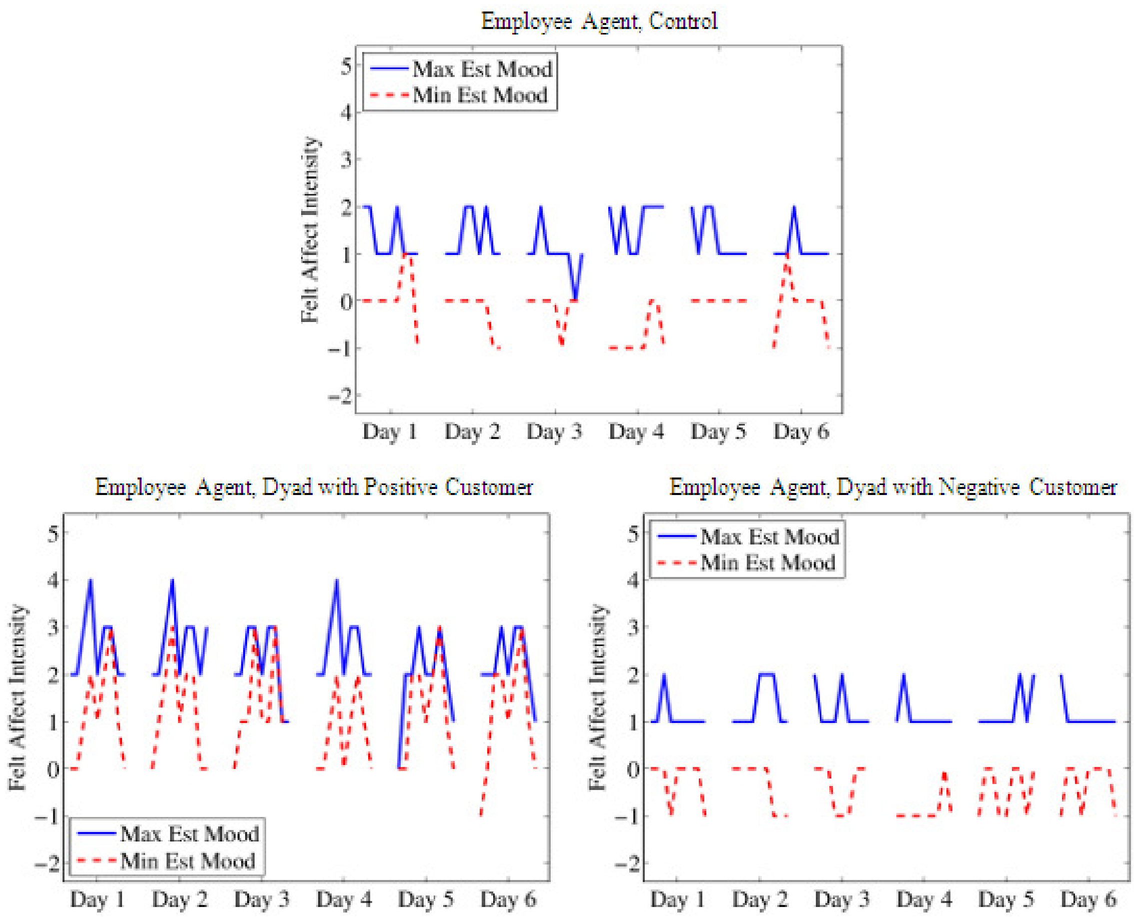

Figure 8.11 Ranges of felt-affect for the Employee as an isolated model (top), interaction with a positive affect Customer (bottom-left) and interaction with a negative affect Customer (bottom-right)

Results indicate that The Customer's affective states do have an influence on the depletion of self-regulatory capacity in the Employee. Figure 8.12 shows a slight increase in self-regulatory capacity in the Employee, if the Agent is paired with a positive affect Customer, in comparison to both a pairing with a negative affect

Customer or as an isolated Agent. This supports an earlier proposition (**P3.3**) that resource depletion may be mitigated by interaction with an Agent with affect states congruent with expression goals. However, Figure 8.12 does not show that interaction with a negative affect Customer does further deplete the Employee, in comparison with the Employee acting in isolation. As a result, this does not offer support for proposition **P3.4**, which suggests that resource depletion may be enhanced by interaction with an Agent with affect states contrasting with expression goals. These simulation results are further discussed in section 8.5.

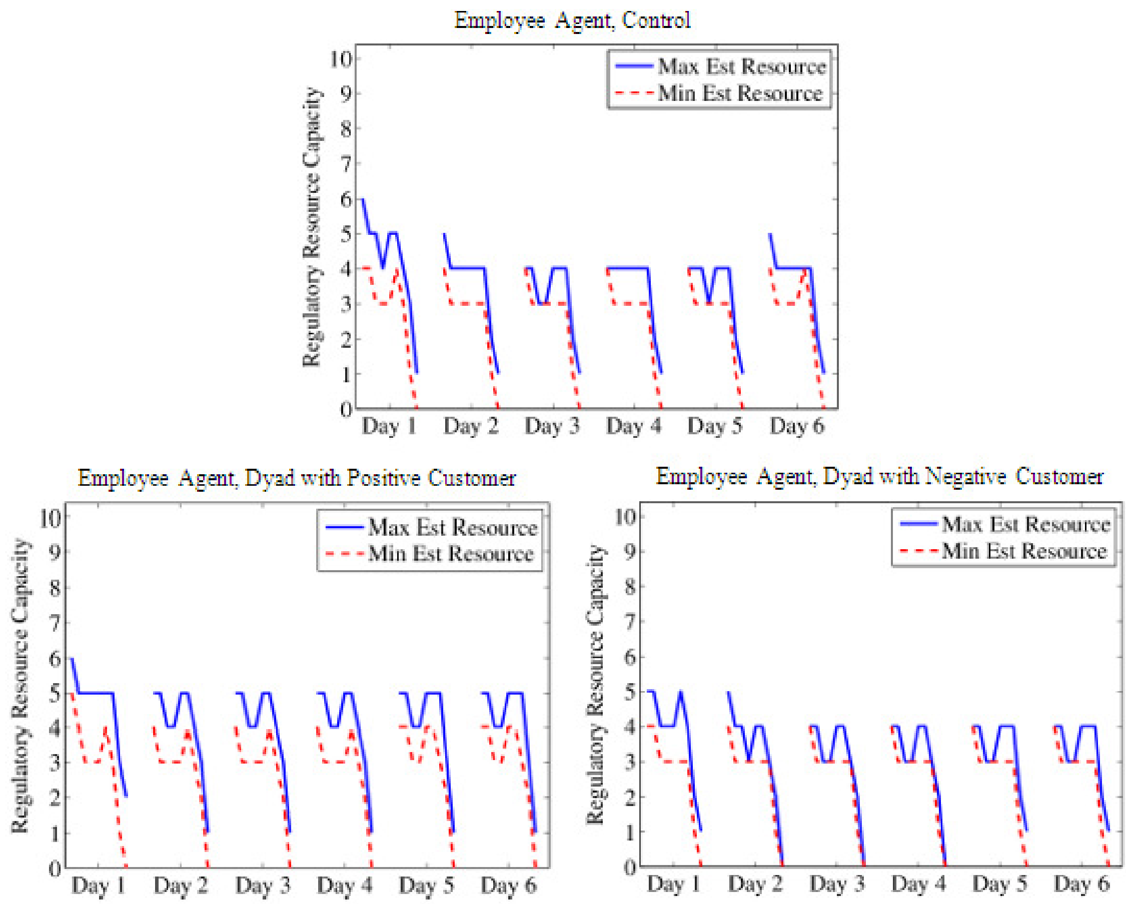

Figure 8.12 Ranges of perceived regulatory resource capacity for the Employee as an isolated model (top), interaction with a positive affect Customer (bottom-left) and interaction with a negative affect Customer (bottom-right)

8.5 Summary

This chapter offers representation of affect dynamics in dyadic interactions through computational simulation, which can overcome issues faced by more traditional investigation methods. Examining affect in a dyad from the perspective of one p as an active agent and one as a passive target (e.g., Côté, 2005) faces limitations in representing individuals as capable of being active in controlling their own affect and affect goals. Also, representing affect change in a dyad through static associations in traditional models (e.g., Hareli & Rafaeli, 2008) faces limitations in capturing the dynamics of both individuals concurrently. The use of computational simulation allows for both dyad members to be represented as complex individuals, concurrently pursuing their own affect goals, shaping the affect dynamics of themselves and their counterpart.

The simulations in this chapter offer support for the MARDy model as an effective representation of agents in a dyad, especially considering that the model has not been previously tested or fitted to data (Chapters 5 to 7) with dyadic interaction in mind. For the most part, propositions offered for affect dynamics in a dyad are matched by the simulations, which can further offer representations of plausible mechanisms for the affect dynamics seen. Propositions matched by the simulations are reviewed here and explanations are offered for cases in which propositions were not matched.

In the first scenario, the simulations indicate that two agents working towards mutually held positive affect goals experience more positive affect, less depletion, and maintain higher affect goals, than if either regulates towards these goals alone. These findings closely resemble propositions made and indicate the model's potential for representing affect dynamics in a dyad. The simulations suggest regulatory outsourcing, in which both agents co-regulating towards a held goal can reach it, even if they were unable to on their own and, in doing so, reduce the overall regulatory demands on themselves.

The second scenario sought to represent affect convergence between two agents, one of which experienced symptoms of depression, simulating previous research of Joiner (1994). The results indicated the simulated symptoms of depression identified in Agent 2 (negative affect and depletion) can be 'caught' by the Employee. Moreover, these symptoms occur within the Employee, even without any underlying change to its parameter values corresponding to those responsible for inducing the depressive symptoms in The Customer. As a caveat to **P2.1**, it was argued that not every simulation run in the second scenario would result in affect convergence and the experience of depressive symptoms in the Employee. Given the parameter ranges used to generate an array of outcomes across 100 trials, it was anticipated that some configurations would enable sufficient positive affect regulation to be 'immune' from depressive symptom contagion. Results indicated that a more positive felt-affect home-base, greater regulatory momentum, and a lower cost for felt-affect regulation than average each contributed to the Employee's immunity from depressive symptom contagion. Identification of psychological analogues in individuals could offer means of limiting processes of depressive contagion in situations such as that studied by Joiner (1994). It should, however, be noted, that such 'immune' agents were not also immunised from associated costs to their self-regulatory capacity, indicating that positive affect was maintained in such agents via regulatory efforts.

In the third scenario, results are mixed in terms of the simulations adhering to propositions offered. Interaction with the positive affect Customer does result in the Employee's affect becoming more positive; however, this process does not substantially result in a discrepancy reduction between felt-affect and affect-expression, contrary to the proposed outcome. This is because affect-expression also becomes more positive, in comparison to an isolated Employee. However, results indicate that depletion does decrease as proposed in **P3.3**, despite the discrepancy being maintained across conditions. This is considered to be a result of the more positive felt-affect state, which reaches the felt-affect goal state, limits the upward regulation necessary and reduces resource depletion. Despite the affect-expression state also increasing, results from Chapter 5 indicate that it is not the raw score of the affect-expression goal that influence cost but rather the discrepancy between felt-affect and affect-expression, leaving resource depletion unaffected in this regard.

Further results in the third scenario indicate that the negative affect Customer does not substantially impede the Employee's expression regulation or make the Employee's felt-affect state more negative, in comparison to the isolation condition. The results from this test may be due to a floor effect, in which the Employee engaging in affect-expression regulation that induces a large discrepancy between felt-affect and affect-expression is already maximally depleting. As a result, no further detrimental influences can be seen, in comparisons between to the dyad and isolation condition. While this test was not specifically designed to comment on the emotional labour experiments reported in Goldberg and Grandey (2007), it does offer an explanation for why they found a lack of interaction effects between use of surface acting and customer mood on employee experience of emotional fatigue. Results from their study indicated that a scenario involving an angry customer was not more detrimental to employee fatigue than one involving a calm customer; the current simulated scenario suggests that use of surface acting alone is sufficiently depleting to wash out any effects seen due to customer mood. The simulation results indicate that if an agent would habitually use expression regulation as a primary means of affect regulation, they are unlikely to see any substantial positive outcomes unless the other agent is already engaging in affect regulation towards a similar goal. This may be further influenced by individuals reacting negatively to surface acting in others, which can be perceived as being inauthentic (e.g., Martínez-Iñigo et al., 2007), although such effects extend beyond the current remit of the dyad model.

In summary, this chapter offers comment on existing means of conceptualising dyadic interaction and alternative means to further examine the affect dynamics within a dyad. Development of the model from representation of a single individual to that of multiple agents allows for novel predictions to be made regarding affect dynamics, which may not arise from use of static representations of affect in a dyad.

Chapter 9: General Discussion

9.1 Thesis Overview

In this thesis, I set out to examine the dynamics of affect regulation as a function of changes in self-regulatory capacity and dynamic goal states for affect. Affect regulation is regarded as a process for enacting change to affect states, such as heightening or dampening the intensity of an affective experience, and extending or reducing an affect experience's duration (Gross, 1999; Parkinson & Totterdell, 1999). Affect regulation can be broadly considered as consisting of two main processes: the regulation of feelings and the regulation of expressions. Gross (1998a) divides his model of affect regulation into approximations of these two categories, terming them *antecedent focused regulation*, processes which serve to moderate affect events and one's feelings, and *response focused regulation,* processes which serve to just moderate one's expressions. A similar distinction is made in the emotional labour literature, in which employees are expected to meet affective requirements at the workplace as part of their job, such as maintaining a calm and cheerful appearance when dealing with customers. Traditionally, research has examined emotional labour as comprising of two key processes: *deep acting*, regulating one's feelings, and *surface acting*, regulating one's expressions (Grandey, 2000; Hochschild, 1983; Totterdell & Holman, 2003). Despite the distinction made, these processes are considered to influence each other over time through the forward link from felt-affect shaping affect-expression (e.g., Mauss & Robinson, 2009), through the feedback link from affect-expression to felt-affect (e.g., Hatfield et al., 1994) and through their shared influence on one's capacity for engaging in affect regulation.

Affect regulation is a process that falls within the more general topic of self-regulation, which also encompasses the topics of regulation of behaviour and regulation of cognition. Commonalities seen across the subsets for regulation are the attention to one's states, be those feelings, actions or thoughts, the comparison with goal states, namely what one wants or ought to feel, act or think, and then changes undertaken to ensure that differences between the current and goal states are reduced (e.g., Carver & Scheier, 2001; Powers, 1974). One of the key, applied aspects self-regulation theories is the attempt to understand why individuals may often fail to engage in changes to their feelings, actions or thoughts even if they know that their current states do not meet their goals (e.g., Alberts et al., 2011; Gailliot & Baumeister, 2007; Muraven & Baumeister 2000). The strength-model of self-regulation posits that attempts at regulation drain from a limited shared self-regulatory resource, which fuels the process of self-regulation (Muraven & Baumeister 2000). Diminished self-regulatory capacity and failure of self-regulation may arise from a depletion of self-regulatory resource and subsequent attempts to conserve that which remains (Muraven et al., 2006). Deliberate or controlled processes of affect regulation are considered to both require the presence of this shared resource and to deplete it (e.g., Hagger et al., 2010; Muraven et al., 1998). A limited resource capacity for affect regulation therefore presents restrictions on one's capacity to continuously meet affect goals: one cannot always feel or express what one aims to. As a result, it requires examination to understand how individuals allocate resource and pursue affect goals in ways which might ensure a balance so that, over time, affect goals can be met within the restrictions placed on self-regulatory capacity through the process of resource conservation. The broad aim of this thesis is the investigation of these how these processes of affect goal pursuit and resource allocation unfold over time, in order to offer new insights into the dynamics of affect regulation.

In Part 1 of this thesis, Chapters 2 to 5, I examined the literature regarding the dynamics of affect regulation, self-regulatory capacity and goal adjustment and then explored means of representing these in a computational model. The literature review, in Chapter 2, covered four identifiable aspects of affect regulation dynamics, related in a single overarching model: felt-affect regulation, affect-expression regulation, limited self-regulatory capacity, and affect regulation goals. I then sought to identify a framework and method for which to explore the conceptual model derived from the literature review, in Chapter 3. A control theory framework was chosen to suitably represent the ubiquitous presence of closed-loop processes described in the literature review and a computational modelling method was outlined, which could capture dynamics described in the literature review and represent underlying interactions between the distinct processes of affect regulation. In Chapter 4, I subsequently outlined and constructed an operational model of affect regulation dynamics based on principles described in Chapter 3 so that the informally described processes and interactions in the model outlined in Chapter 2 were specified. At the close of Chapter 4, a computational model and a list of parameters used in the model to represent aspects of affect regulation were presented, alongside ranges for these parameters in which the model would prove functional. In Chapter 5, I presented a variety of tests on the model's behaviour and examined these against known data. This served to identify limits on the ranges of parameters so that the model may represent known affect regulation dynamics and ultimately make predictions for this area of research.

The first part of the thesis offered a new means of examining affect regulation dynamics as a part of the growing field of computational simulations of affect. Existing computational simulations of affect and affect regulation were considered and the need for a new overarching model of affect, self-regulatory capacity and affect goals was put forward. The outcomes, questions and aims from the literature review all pointed towards a need for an understanding of the dynamic processes associated with affect regulation and that this was not met by current computational simulations of affect. The proposed model in this section and method of investigation offered new insights to aspects of affect regulation, which require further investigation.

In Part 2 of the thesis, Chapters 6 to 8, I sought to evaluate the model's capacity for representing and making predictions regarding the 'real world' dynamics of affect, affect goals and self-regulatory capacity. In Chapter 6, I conducted a study in which five students recorded their felt-affect state, their affect goals, perceived self-regulatory capacity and felt-affective events over the period of six days. Variables in the model, such as simulated affective events and sleeping patterns, were adjusted to reflect each of the five participants' experiences and then parameters in the model were fit to best capture the affective dynamics observed across the diaries as a whole. These parameter values recorded were then used as a reference point for a second round of data fitting, in Chapter 7. In this chapter, I conducted a second, similar study in which six teachers recorded the same measures as used in the previous study, alongside their affect-expression states and affect-expression goals. Again, variable values were adjusted to reflect the experience of the participants in this study and parameters were varied for the new data series. The capacity for variants of the model from Chapter 6 to reflect the diary data in Chapter 7 was regarded as an indication for the model's validation and as a starting point for future model development. Lastly, in this section, in Chapter 8 I explored predictions made from simulations of two models' affect regulation dynamics, constructed so that they interacted as a dyad. Three scenarios were devised to examine changes in affect, affect goals, and resource capacity and test predictions derived from the design of the models and from existing theories for affect convergence, such as affect contagion. The outcomes of these simulations, in Chapter 8, were compared against control simulations, in which a single model had been implemented. The differences between the two simulation outcomes were considered in terms of current theory regarding controlled affect regulation and affect contagion.

The second part of this thesis offered a means for examining the model's capacity for representing the affect regulation dynamics seen in the real world. Strength of fit between the model data and collected diary data offered an initial step in the process of developing a model that can determine trends and reflect changes in people's regulation of affect. Further to this, the model forecasts affect to a closer degree than most individual's predictions could. At the end of the second part of the thesis, novel predictions regarding affect regulation were offered, in addition to arguments made for the importance of understanding affect regulation as a continuous and dynamic process, mirroring that of the considerations made in the beginning of the first section of the thesis.

This current chapter explores the predictions made by the model and the outcomes of the validation processes to draw some conclusions about the dynamic and interrelated nature of multiple aspects of affect regulation, self-regulatory capacity, and affect goals. To achieve this, the main predictions and findings from testing the model are summarised. The following themes are considered: predictions regarding self-regulatory resource depletion dynamics, predictions regarding affect regulation strategy choice dynamics, and predictions regarding the dynamics of affect regulation in a dyad. The findings across these themes are then discussed with regard to existing theories and models of affect. The methodological approach and current model's contributions to the research area are considered. Limitations of the model are then considered and avenues for further developments of the model, which may address these, are offered. Future research directions, based on the predictions made by the model's design and its behaviour during simulation, are suggested, wider and practical implications of this research are outlined, and conclusions are drawn.

9.2 Summary of Model Predictions and Findings

To begin this section, the model constructed as part of this thesis is reviewed and the parameters derived from its testing and the predictions which arise from its operation are summarised. These predictions, alongside the findings from the model simulations and parameter specifications, are then considered in terms of current affect regulation theory.

In the course of this thesis, I have developed, implemented and tested a computational model of affect regulation dynamics, which examines the interrelated processes of felt-affect regulation, affect-expression regulation, and the regulation of their respective goal states as a process for resource conservation (Figure 9.1). The model can be considered in terms of its five main component parts, which each represent a different aspect of affect regulation examined in the literature review. The components constituting different processes in affect regulation in the model are arranged to form a two-tiered structure. The lower tier of the model comprises of the processes of affect regulation, while the higher tier comprises of the processes of affect goal regulation. This chosen design is derived from the control theory literature (e.g., Carver & Scheier, 2001; Powers, 1974) that presents a structure for goal driven behaviour, in which lower tier goals are pursued in order to facilitate the pursuit of higher tier goals. Goals held at lower tiers are considered to be more concrete concepts changing over a short term; in contrast, higher goals are considered more abstract concepts that are more stable over time.

Alongside the distinction made by regulation processes into two tiers, affect regulation in the model is considered as two processes of felt-affect regulation and affect-expression regulation. This allows for the model to represent different states for felt and affect-expression and for the examination of the effects and dynamics of two related regulation processes interacting. Similarly, affect goals are divided by this distinction: the model can hold separate, changeable goals for the processes of felt-affect regulation and affect-expression regulation. This allows for the model to represent different degrees of conflict between two held affect goals and for the examination of the effects on affect that this could produce. The two sides of the model are primarily linked through the reciprocal influence of the two regulation processes in the lower tier. Just as the felt-affect state moves towards a stable point of valence termed the *home-base* (unless regulation efforts are sufficient to push it towards a goal state), affect-expression moves towards the moving point of valence that is the current experienced felt-affect state (unless regulation efforts push it towards a distinct goal state).

Each of the four component parts of the model described above are further linked through their shared dependence and influence on the central component representing self-regulatory capacity. In this model, resource is considered to be depleted through use of affect regulation, with affect goals more distal from the home-base requiring a greater degree of regulatory effort and so self-regulatory resource to reach. Self-regulatory resource is considered central to the processes of both affect regulation and affect goal regulation on felt-affect (left side of Figure 9.1) and affect-expression (right side of Figure 9.1) sides of the model. Resource fuels the capacity for the processes of felt-affect and affect-expression regulation, while depleted resource signals that goals require regulation in order to limit further resource depletion. Modelled self-regulatory capacity varies throughout the day as a combined function of circadian processes, time since sleep, and depletion from exertion of regulatory efforts. Self-regulatory capacity is restored to the model through regular and sufficient periods of sleep.

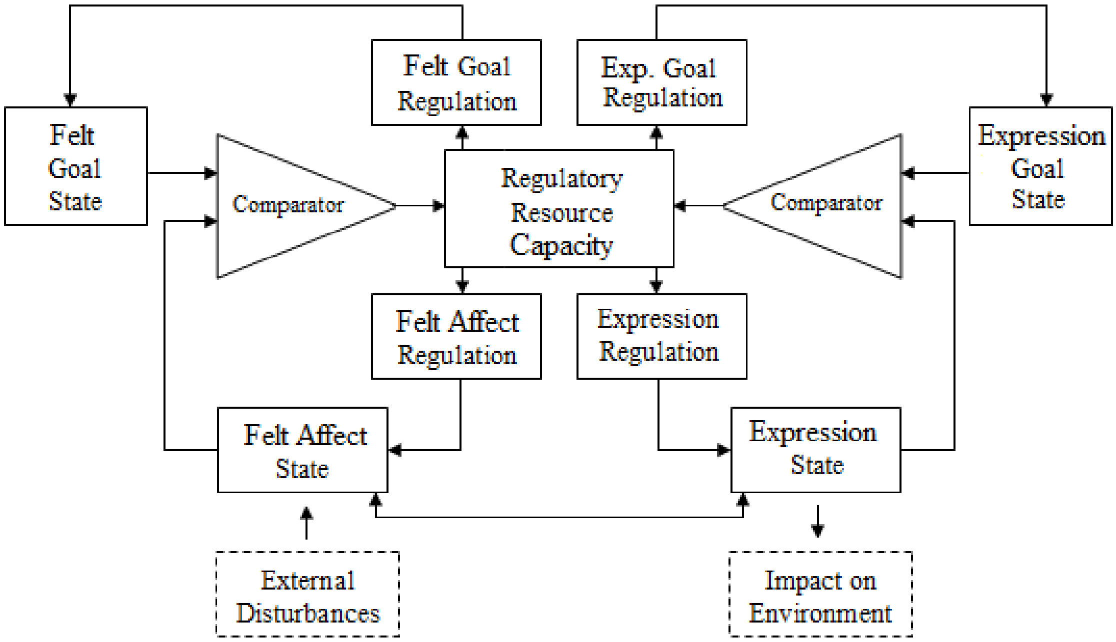

Figure 9.1 Schematic of the complete model of affect regulation dynamics
Representations of felt-affect regulation, affect-expression regulation, self-regulatory capacity (resource), felt goal regulation, and expression goal regulation are shown as two competing primary and secondary control loops. Solid boxes denote intra-individual processes; dashed boxes denote environmental or inter-individual processes; arrows denote proposed direct effects from one process to another.

The development of a computational simulation requires the specification of parameter values representing aspects of affect regulation processes. While in a simple, drawn sketch of a model, two concepts may be indicated to have a causal relationship, influence between them, or other indicated connection (such as reappraisal occurring earlier in the course of affect regulation than expression suppression in Gross' 1998a process model of affect regulation), this is not necessarily expanded upon and specified. In contrast, a computational simulation necessarily requires precise specification of the nature of the relationships between concepts in the form of parameter values (Epstein, 2008). The final parameter ranges for the model, based on the fitting of collected diary data in Chapters 6 and 7 are given in Table 9.1, alongside a description in terms of affect regulation. Parameters shown in italics were varied in the process of fitting the data collected from the two diary studies; parameters in plain font were derived from investigations in Chapter 5 and subsequently kept constant.

Table 9.1 Details of the final parameter ranges and the values specified in the model

Parameter Name	Description	Symbol	Plausible Range of Values	Value(s) used for data fit
Felt-Affect Change Rate	The rate at which felt-affect changes over time.	k	0.001 to 0.1	0.02
Regulatory Momentum	*The rate at which a detected discrepancy between affect and affect goals increases regulation efforts.*	*k2*	*0.0025 to 0.05*	*0.02*
Affect-Expression Change Rate	The rate at which affect-expression changes over time.	k3	0.004 to 0.4	0.08
Affect Goal Adjustment Rate	*The rate at which affect goals adjust over time.*	*k4*	*0.0025 to 0.05*	*0.02*
Feedback Link	The strength of influence affect-expression has on felt-affect	F	0 to 0.2	0.2
Felt-Affect Home-Base	Felt-affect resting point in absence of affect events or regulation.	H	0 to 0.4	0.2
Felt-Affect Goal Home-Base	Felt-affect goal resting point in absence of regulation.	*Felt_goal*	*0.2 to 1.0*	*0.8*
Felt-Affect Regulation Cost	*Depletion of resource due to felt-affect regulation.*	*Da*	*1 to 5*	*Study one: 2* *Study two: 5*
Affect-Expression Home-Base	Affect-expression goal resting point in absence of regulation.	*Exp_goal*	*0.2 to 1.0*	*Study one: 0.8* *Study two: 0.6*
Expression Regulation Cost	*Depletion of resource due to affect-expression regulation.*	*Sa*	*2 to 10*	*Study one: 2* *Study two: 6*

The process of testing the model in this thesis and deriving the parameter values has been achieved through three stages. The first stage, reported in Chapter 5, examined the model in terms of known data and existing studies. In the course of the chapter, the simpler constituent parts of model were examined in relation to narrow studies exploring more base phenomena before expanding testing to the whole model itself against wider reaching studies. The results of these tests led to a series of parameter ranges and specified parameter values, which shape the model's behaviour and constrict the ranges of its output values. Following on from this, in Chapters 6 and 7, the second stage for testing the model first comprised of collecting diary data in two studies of affect change and then varying parameters to fit the model to the data collected. Initial parameter values were determined through a best fit of the results from the first study and then validated through comparison of its capacity to fit the results from the second study. The results of this data fitting process refine the parameter values to that of more specific propositions than those offered initially through the first stage of testing, offering support to initial predictions made in the first stage of testing. Finally, in Chapter 8, the parameters derived from the previous stages of testing were implemented in two models arranged as agents in a dyad so that the model could be examined in relation to theories of affect contagion and offer further propositions to be tested in the future. Key predictions offered by the model as a part of the process of its testing are listed below:

- Affect-expression regulation depletes self-regulatory capacity at a marginally greater rate than felt-affect regulation.

  This prediction may be explored through the standard two-task paradigm for self-control studies (e.g., Muraven et al., 1998). In their meta-analysis, Hagger et al. (2010) report that there is a differentiation in depletion tasks effectiveness in depleting individuals. Two affect regulation strategies, such as reappraisal and suppression may then be contrasted in their effectiveness in inducing depletion and impairing performance in subsequent self-control tasks. Suppression of affect expression is anticipated to be more depleting than reappraisal.

- Affect goals show a shift in valence towards the current affect states during periods of high depletion at rates substantially faster than previously considered.

  Although the current thesis indicates that affect goals change with depletion over an extended period of time, these findings can be expanded upon. Results are based on diary data of between hourly and three hourly intervals and could be enhanced with more intensive recording protocols (e.g., every 15 minutes, Oravecz et al., 2009). Induced fatigue through sleep deprivation studies could further enable understanding of affect goal change during periods of exhaustion and potentially indicate that, like impaired affect regulation (Franzen et al., 2008; Scott et al., 2006), affect goal regulation (i.e. maintenance of consistent, typically held affect goals) is adversely affected.

- Affect regulatory strategy selection is influenced by an individual's perceived self-regulatory capacity – depleted resource prompts the increased use of affect-expression regulation.

  Again, the influence of depletion may be explored through the two-task paradigm for self-regulation. Depleted individuals in the second task would be anticipated to be more likely to use suppression strategies over strategies such as reappraisal. Should self-reporting of strategies prove problematic, such as individuals being better able to recall certain strategies over others, functional imaging may potentially be useful in differentiating strategies used (e.g. Goldin, McRae, Ramel, & Gross, 2008).

- Felt-affect regulation and affect-expression regulation co-occur; the concurrent use of strategies affords closer fits of modelled results to collected data.

Affect regulation tasks typically focus on exploring one regulation strategy at a time (Webb, Miles, & Sheeran, 2012); often, these strategies will be compared against another. However, concurrent use of affect regulation strategies is not examined experimentally (Webb et al., 2012). To test model predictions that difference regulation strategies can be, and are, used concurrently requires development of tasks in which participants are required to hold to contrasting goals for affect regulation. Demonstration of simultaneous use of multiple strategies may be achieved by requiring participants to regulate expression in order to display one emotion (such as excitement or enthusiasm) while regulating feelings in order to experience another (such as calmness). Self-report measures are unlikely to be suitable for examining this prediction so observer ratings of expression and physiological measures such as heart rate variability (Appelhans & Luecken, 2006) may be used to measure affect-expression and felt-affect states.

- The degree of conflict between felt-affect goals and affect-expression goals predicts the rate of depletion of self-regulatory resource, the convergence of felt and expression goals over time, and valence of felt-affect.

This may be explored through adaptation of Goldberg & Grandey's (2007) call centre simulation study. Rather than comparing a display goal for individuals to regulate towards against naturalistic expression, a variety of display goal intensities may be used. Participants acting in a customer service role could report perceptions of emotional exhaustion across the study and their perceived affective states, indicating whether convergence occurs throughout the study. Alternatively participant's affect state may be manipulated ahead of the customer service task design, again manipulating the discrepancy required between felt and expressed affect.

- Conflict between felt-affect goals and/or affect-expression goals across individuals interacting in a dyad results in a greater rate of depletion of self-regulatory capacity, and the convergence of affect goal states.

  Chapter 8 offers simulations of dyad interaction and predictions of affect dynamics that arise in dyads in which individuals share affective goals and have contrasting affective goals. Experimental studies in which individuals are paired in emotive conversations (e.g., Carrere & Gottman, 1999) with others who hold similar or contrasting affect goals could offer a means to test the predictions offered. Dyads in which individuals hold contrasting affect goals would be anticipated to show greater emotional exhaustion after interaction in comparison to those with similar affect goals; self-reports of individuals affect goals through duration of paired interactions. Alternatively, longer-term studies may take advantage of created dyadic interaction using similar sampling practices as Joiner (1994); diary studies of roommate interactions may show convergence of affective goals and reports of greater emotional exhaustion in individuals in dyads with contrasting affect goals in comparison to those in dyads with congruent affect goals.

These predictions are now grouped according to common themes and are examined in terms of their place within, and contribution to, current theory. The first theme, examining self-regulatory capacity change over time as a mechanism for affect change, is outlined in section 9.2.1. After this, in section 9.2.2, the representation of affect regulation as an unfolding and changing process and the predictions that arose from this are considered. Finally, in section 9.2.3, predictions arising from the development of the model as agents in a dyad and the resulting contrast with current views on the representation of agents are discussed.

9.2.1 Predictions Regarding Self-Regulatory Capacity

For the purpose of this developed model, self-regulation of affect was largely considered from the perspective of the strength-model of self-control (Baumeister et al., 2007). A limited resource for regulation of affect was used as a mechanism for fuelling the processes of affect regulation to work towards specific held affect goals. Regulatory efforts depleted this resource and rest, in the form of sleep, restored it. While there is an extensive literature on the nature of self-regulatory capacity as being limited (e.g., Hagger et al., 2010), there is little available in terms of the dynamics underlying self-regulatory capacity change or the mechanics of long term restoration of resource (Gailliot, 2008; Hagger, 2010). The model of self-regulatory capacity contained within the complete model of affect regulation dynamics afforded opportunity to make and test predictions regarding self-regulatory dynamics in terms of affect regulation.

Firstly, the model affords a means to test a specific prediction regarding the regulatory costs associated with effortful processes of felt-affect regulation and affect-expression regulation. In the emotional labour literature the process of affect-expression regulation is considered to be more closely associated with feeling emotionally drained than that of the process of felt-affect regulation (Holman et al., 2008, Grandey, 2003; Goldberg & Grandey, 2007; Martínez-Iñigo et al., 2007). In emotional labour terms, surface acting is routinely found to be more closely associated with feeling emotionally drained than deep acting is. There may be a number of underlying reasons for this, one of which will be examined in section 9.2.2, but for now just the relative costs of each regulatory process are considered.

A strength of the computational simulation approach is the necessity to outline underlying assumptions in a theory and to then specify how these are represented (Epstein, 2008). In the model, the relationship between affect regulation processes and feeling emotionally drained was first outlined as a causal one: both felt-affect regulation and affect-expression regulation deplete the capacity to manage affect (the limited self-regulatory resource). This causal relationship, while not explicitly shown in current results, is formative in structural model design, in which causal influence is assumed. Parameter ranges were specified to test the predictions outlined in the preceding paragraph regarding the relative cost of affect-expression regulation and whether it is a more depleting exercise than felt-affect regulation (*Da*, *Sa*, Table 9.1).

Results from fitting model parameters to the diary data indicate that closer representations of the diary data occur if affect-expression regulation is marginally more costly than felt-affect regulation. This extends beyond the testing in Chapter 5, which only indicates that concurrent regulation of affect-expression and felt-affect could be more effortful than either alone. The parameter configuration from representing diary data indicates that the association between affect-expression regulation and perceptions of depletion is not just the influence of concurrent regulation but that the affect-expression regulation process is itself more resource intensive than felt-affect regulation. This proposition does raise issues regarding individuals' choice of regulatory processes because it presents affect-expression regulation as being more costly and, potentially, less adaptive than felt-affect regulation. The implications of this are discussed in section 9.4.3.

Secondly, the model highlights one area of self-regulation that is underrepresented in the strength-model of self-control, which is goal-setting. Depletion of resource in the strength-model is associated with the reduction in persistence towards held goals and the conservation of remaining resource (e.g., Muraven et al., 2006). In terms of resource conservation, the model in this thesis predicts that alongside a reduction in efforts put towards reaching an affect goal or maintenance of affect at an affect goal, an individual may also aim to bring goals to a more achievable and less draining level. This concept of changing goals draws from the alternative view of self-regulation that is motivational intensity theory. A goal perceived to be sufficiently difficult will not be pursued unless there is a satisfactory incentive to do so (e.g., Alberts et al., 2011). This approach for goal pursuit is considered in the informal model by Diefendorff and Gosserand (2003) as a means of selecting which goal is pursued at each level. For the purposes of this thesis' model, the aspect of motivation intensity theory examined is the perceived effort required to regulate towards affect goals.

In the control theory literature, it is argued that while control is engaged to regulate a particular state towards a goal, goal states themselves are regulated (e.g. Powers, 1974). This process is argued to result in the goal changing very slowly in comparison to the regulated state (e.g., Carver & Scheier, 2001). Over time, goals that consistently exist out of reach of regulatory efforts would be expected to gradually shift towards a more achievable state, whereas goals which are frequently reached through regulation are unlikely to show any substantial change.

The above proposition was examined in the process of fitting the model parameters to the diary data in Chapters 7 and 8. In both studies, the best fit of the model data to that of the diary data required affect goal adjustment rate (*k4*, Table 9.1) to be specified at a comparable rate to that of the fixed parameter value for affect change rate (*k*, Table 9.1). This means that during the times of resource depletion at which affect goals were most strongly regulated towards the current affect states, goal adjustment would occur at approximately the same speed as affect change would. This prediction argues that, contrary to Carver and Scheier's (2001) assertions, individuals could rapidly change an untenably high goal to one which is more achievable, exhibiting flexible control towards dynamic goals. Furthermore, the high valence goals the model specifies for felt-affect do not automatically imply a persistent overarching aim in the model for high valence affect. Contrary to assumptions made based on hedonic theories of affect (e.g., Larsen, 2000), the model does not always seek to 'feel' good; rather, in many cases, when experiencing negative affect sufficient goal adjustment occurs so that the model sets a goal of feeling neutral or less negative.

Further to this, the model offers a specific prediction regarding affect goal-change, which contrasts with a proposition by Diefendorff and Gosserand (2003). It is proposed in their model that a specific, narrow range for an affect goal would restrict variability in affect states in comparison to a wider range for an affect goal. It is further proposed that this maintenance of affect at this narrow range would lead to greater emotional exhaustion because of the greater degree of control required. However, in contrast to this, the current model indicates that, over time, a broader range for an affect goal (as represented by a capability to regulate the affect goal level) could lead to a *reduced* variability in affect, when compared to a narrow range for an affect goal (as represented by a restriction on regulating the affect goal level), providing that this goal is sufficiently distant from the home-base. This is due to the increase in regulatory fatigue associated with reaching higher affect goals and as a result a diminished capability in reaching these held goals. A variable affect goal would, of course, result in some variability in affect but potentially within a narrower band due to the reduced occurrence of depletion. This prediction highlights a significant strength of a dynamic model over a descriptive and unspecified model. While a descriptive model such as Diefendorff and Gosserand's (2003) design relies on assumption and at times even an intuitive understanding of how phenomena examined might change over time, a dynamic model such the one in this thesis affords the ability to specify and test predictions made.

9.2.2 Predictions Regarding Affect Regulation Dynamics

In the course of testing this thesis' model, a number of specific predictions regarding the nature of affect dynamics and the dynamics of undertaking affect regulation have been produced. This has allowed for propositions to be made at the level of individual model components, such as the nature of the home-base that affect tends towards, and at high levels of the model's working, integrating multiple aspects of the model to examine emergent trends, such as the change over time in affect regulation strategy choice. This section examines three of these predictions made by the model. It further considers their implications for current affect regulation theories, including the implications of these predictions being derived from a dynamic perspective of affect regulation.

Firstly, the integration of related aspects of affect regulation, self-regulatory capacity and affect regulation goals in this computational model point towards specific predictions and propositions of affect regulation strategy selection. An important prediction made by the model is the circumstances required for the model to engage in transition from one dominant affect regulatory strategy to another and the process by which this occurs. If the goals for felt-affect and affect-expression are congruent then, as self-regulatory resource depletes, the model indicates a switch from the use of regulation of primarily felt-affect to that of the regulation of affect-expression.

At higher levels of self-regulatory resource, capacity for felt-affect regulation would be sufficient in its control to maintain felt-affect at the goal state and affect-expression at a congruent goal state. This is due to the coupling between felt-affect and affect-expression: unless affect-expression is regulated towards its own distinct goal, affect-expression tends towards its moving home-base of felt-affect, a process which is regarded as necessary for a means of representing authentic expression. However, once self-regulatory resource depletes and there is insufficient capacity to maintain felt-affect at the goal level, a discrepancy would begin to form between affect-expression and its goal as its home-base of felt-affect drifts away from the expression goal state. This discrepancy engages affect-expression regulation as a required means of controlling the affect-expression state: felt-affect regulation is no longer enough to maintain control of expression and use of affect-expression regulation increases to maintain affect-expression control. As a result, there exists a transition in the model from felt-affect regulation being the primary means of controlling both felt-affect and affect-expression to that of an increase in affect-expression regulation as resource depletes.

This prediction regarding strategy change poses an apparent contradiction with another made in the previous section, which outlined that the model indicates that expression regulation is more costly, in terms of self-regulatory resource, than felt-affect regulation. It would not be expected that this strategy would then come in to use when self-regulatory resource is low and attempts to conserve remaining resource ought to be made. Nevertheless, this switch between dominant regulatory strategies from felt-affect regulation to affect-expression regulation is an observed outcome in the model, seen when felt-affect and affect-expression goals are congruent. Paradoxically, diminished resource appears to prompt the use of a more costly regulation strategy (see section 9.2.1). A caveat for this prediction is the current model assigns equal value to the pursuit of felt-affect and affect-expression goals. Alternative models, such as the informal model by Diefendorff and Gosserand (2003), which vary the motivation to pursue particular goals might show different regulation selection dynamics.

This prediction presents important considerations for current affect regulation research. While the previous section highlights that affect-expression regulation is associated with a greater feeling of being emotionally drained, this is universally assumed to be an indication of the depleting nature of affect-expression regulation and its higher costs compared with felt-affect regulation (e.g., Richards & Gross 2000). The specific prediction in this section does not challenge that assumption, and indeed is a product of a model that forwards such a position; however, it does suggest that there exists an additional pathway in the relationship between affect-expression regulation and emotional exhaustion. Not only does use of affect-expression regulation lead to outcomes of feeling emotionally drained, feeling emotionally drained leads to use of affect-expression regulation strategies. This may present a confound or complication for studies that simply present an association between affect-expression regulation and feeling emotionally drained. This prediction by the model poses implications for field studies of affect regulation and for experimental studies alike (see section 9.4.3).

Secondly, the model puts forward a directly contrasting approach to understanding affect regulation episodes to that of the dominant approach in affect regulation research, the process model (Gross, 1998a, 1999, 2001). In the process model, affect regulatory strategies are described as being distinct, sequential and linear. Regulation strategies are considered to have their specific place in time during an emotion regulation episode and are not thought to generally show overlap in their use (Gross & Thompson, 2007). In contrast to this inflexible, procedural approach, the model constructed in this thesis presents affect regulation strategies as flexible, with the potential to overlap and influence each other. Moreover, this approach as an investigation of the proposed dynamics of affect regulation highlights that regulation strategies can show continuous operation across what Gross (1998a) terms affective episodes (complete cycles from affect experiences' beginning to end until the next begins). This seamless transition of affect regulation use from one point in time to the next potentially indicates that attempts to categorise and define individual episodes of affect are somewhat arbitrary.

A strength of the control theory framework is its representation of graded change, allowing for conceptualisation of overlapping processes while in transition from one to another, or balancing the allocation of resource to the execution of multiple processes (e.g., Carver & Scheier, 1986). Use of this framework enables the examination of modern theories of affect existing as a continuous, changing state (Russell, 2003) and affect regulation as a similarly changing process (Kuppens et al., 2010; Oravecz et al., 2009). The model developed in this thesis follows such a tradition and, as a consequence, is successful in representing the dynamics of affect in terms of both felt-affect and affect-expression seen in collected diary data (Chapters 6 & 7).

In the two diary studies, the model's quality of fit with the data was assessed through three means and within these assessments subject to three criteria before being considered an appropriate fit of the data. The data collected in Chapter 7, of which both felt-affect and affect-expression states were recorded, afforded for the dual processes of felt-affect regulation and affect-expression regulation to be examined in the model. Across a majority of correlations examined, the model met the criteria specified for a successful representation of affect regulation dynamics. These criteria were: a) the presence of a significant correlation between model results and the represented individual's diary data, b) the correlation between the model and the diary was greater than correlations between the model and any other diary, and c) the correlation between the model and the diary was greater than correlations between the diary and any other model. The parameter values for the model meeting these criteria (Table 9.1) indicated that the model engages in regulation towards distinct goal intensities for felt-affect and affect-expression, which necessitated the use of two concurrent regulatory strategies in the model. This outcome reinforces the argument that individuals may not just be capable of using concurrent regulation strategies but that they also seem to engage with regulation in this way this when necessary. For example, individuals might choose to regulate affect-expression in order to display a negative emotion, while still engaging in felt-affect regulation strategies to maintain a positive felt state.

Thirdly, the model challenges assumptions made by other dynamic representations of affect regulation. The diffusion model of affect (DynAffect) outlined by Oravecz et al. (2009) and Kuppens et al. (2010) suggests that affect can be represented as variable fluctuating values about a single attractor point of affect state, termed the home-base. This echoes theoretical accounts of affect, such as the representations of affect change in terms of homeostatic control (e.g., Larsen, 2000; Larsen & Prizmic, 2004) and as a model itself, is drawn from aspects of the self-regulation literature (e.g., Carver & Scheier, 1990; Chow et al., 2005). Arguments made by the DynAffect model, such as the presence of an attractor point for affect have inspired aspects of the model designed in this thesis, and terms such as home-base have been adopted. However, it is the nature of the home-base described by Oravecz et al. (2009) that is contested by this current thesis' model.

For the purposes of clarity in writing, only the felt-affect state is considered in this argument because the DynAffect model (Kuppens et al., 2010; Oravecz et al., 2009) does not represent affect-expression. The DynAffect model proposes that a single attractor state exists, which affect regulation works towards and affect, as a result, tends towards (Oravecz et al., 2009). However, in the process of reducing affect change to this simple representation, a necessary complexity in affect change is lost through the unification of affect regulation and the general trend of affect change to a single point. The current model's proposed representation of affect regulation and general trend of affect change is of two distinct attractor points: the stable home-base*,* situated at a marginally positive valence, and the variable affect goal state, generally situated at a more positive valence. This dual attractor point design can represent specific trends seen in the affect literature that are not reflected in the DynAffect model, particularly the association of sleep deprivation with the impairment of affect regulation and positive affect maintenance (e.g., Franzen et al., 2008; Scott et al., 2006; Tempesta et al., 2010). Unlike the DynAffect model, the current model offers account for such trends; regulation towards a positive held goal becomes limited with regulatory fatigue during sleep deprivation in the model and so at theses times felt-affect can drift away from the positive held goal towards less positive affect states.

One implication from this current thesis' proposal is that the home-base that affect tends towards, against positive regulation processes, is lower than Oravecz et al. (2009) suggest. Their model of affect tending towards a central point might accurately represent at a surface level the observed recordings of affect as it moves approximately about two points either side but the current model offers this representation and further offers explanation and integration with theory as to the underlying process involved. One of the many reasons offered by Epstein (2008) for using computational models is their potential for indication that apparently simple phenomena are in fact more complex. The approach taken by the current thesis' model offers accounts of affect regulation processes beyond that of just descriptions of data seen (e.g., Oravecz et al., 2009) and instead accounts for data in terms of wider theory.

9.2.3 Predictions Regarding Affect Regulation in a Dyad

While the model was primarily designed, constructed, and tested around the representation of affect regulation in an individual, the model as representation of agents in a dyad was one of the more fruitful areas of investigation for prediction generation. Known phenomena, such as affect contagion (e.g., Barsade, 2002; Neuman & Strack, 2000; Totterdell et al., 2004) were represented in simulations in Chapter 8, alongside the generation of predictions regarding other phenomena such as goal contagion and contagion of self-regulatory capacity. More broadly, the necessity for understanding affect as a continual and dynamic process in social interaction was put forward and current issues with representing affect regulation in dyads were considered. This section discusses predictions for affect regulation processes arising from simulating two interacting, dynamic, affect regulation agents.

The first prediction offered by the simulation of the models as a dyad concerns the influence one agent's affect goal states can have on the other and argues that goal contagion could occur between persons. More specifically, the model predicts that agents with shared affect goals (e.g., both agents have a goal for high positive valence felt-affect) can result in maintenance of these high affect goals, rather than the observed change in goal states to typically lower levels in simulations of just a single agent. In addition to this, conflicting affect goals result in a convergence of goals between agents.

This process was found to be mediated through the convergent affect experienced by agents. As each agent attempts to regulate their own felt-affect, while in the presence of an individual expressing an opposing affect state, affect states between agents begin to converge (as argued would occur by the affect contagion literature, e.g., Barsade, 2002). This convergence of affect determines the valence that affect goals will be regulated towards during periods of depletion to conserve energy and so affect states trending towards each other will inevitably result in affect goals trending towards each other in the model. The finding is further supported through the simulation of a dyad in which one individual is represented as experiencing depression. The limited capacity for engaging in affect regulation and enduring negative felt states serve to draw the non-depressed partner in the dyad's felt state towards a more negative state (e.g., Joiner, 1994) and also the non-depressed partner's affect goals towards a lower valence.

This investigation with the model as a dyad offers a unique contribution to the understanding of both affect regulation and to the processes of contagion between individuals because the research of contagion of affect goals is still underrepresented in the literature. In prior studies of goal contagion, affect change has only been considered as a consequence of goals changing (e.g., Chartrand, Dalton, & Cheng, 2008), whereas these simulations examine the potential for affect change to influence goal adjustment. Further consideration of this proposed occurrence of goal contagion could be taken up by the emotional labour literature. In the reciprocal regulation of affect while in a dyad, each agent's affective states and affect goals influence the other's. The model demonstrates that a cycle may be entered of unsuccessful affect regulation by an 'employee' agent, if it solely serves to engage in surface acting regulation strategies. If both employee and customer agents hold positive affect goals, interaction is predicted to remain positive, while surface acting. However, if a customer agent holds less positive or negative affect goals these can influence the employee agent to experience similarly negative affect states and limit the employee agent's capacity to successfully present positive affect, forming cyclical patterns of negative affect-expression between agents. These simulations point to contextual dependence on the relative success of surface acting as a regulation strategy, indicating that it might not *necessarily* be associated with poorer dyadic interaction.

However, there are wider considerations for such interactions not addressed by the model, such as the perception of authenticity in affect-expression, influencing agents' response (e.g., Grandey, Fisk, Matilla, Jansen, & Sideman, 2005). In the emotional labour literature, surface acting is positively associated with both inauthentic expression and emotional exhaustion, in contrast to deep acting, which is not (e.g., Martínez-Iñigo et al., 2007). A customer could hold negative affect-expression goals as a result of perceiving a customer-service agent's expressions to be inauthentic (e.g., hostility in response to perceived inauthenticity), which could contribute to the negative effects of the customer-service agent using surface acting (i.e. emotional exhaustion). In contrast, a customer-service agent using deep acting does not show inauthentic expression and fatigue effects could be limited through positive social feedback (e.g., Côté, 2005). The protective or deleterious effects of social interaction might offer explanation why differences between associated costs of affect-expression regulation and felt-affect regulation are seen in the emotional labour literature and yet show similar costs in simulations. Such effects could be explored in development of dyad simulations to include perceptions of authenticity in others' expressions.

The model further offers a series of predictions regarding the influence an agent's affect states can have on the other's self-regulatory capacity and argues that contagion of self-regulatory fatigue could occur between persons. In the first scenario tested, in which both agents share positive affect goals, it was found that both agents showed a reduced degree of resource depletion. A positive cycle is seen in which affect-expression from each agent supports the process of affect regulation towards the held affect goal by the other, reducing the demand on each agent and degree to which resource depletes. This process reflects Côté's (2005) model of social feedback.

Self-regulatory capacity is further seen to be influenced by an agent's partner in the dyad in the presence of conflicting affect goals across individuals. Affect-expression from each individual, which draws the other's felt state away from their respective held affect goals, promotes the further use of regulation in the other agent. Conflict between the agents gradually resolves through the continual depletion of self-regulatory capacity and the shift of affect goals towards the other's in the attempt to limit resource depletion. Contagion of depletion is seen in a similar scenario to that of the conflicting goals in the simulation of a depressed individual in a dyad. An outcome of the representation of the continual negative input to the depressed agent coupled with a restricted capacity for affect regulation is substantial depletion. Affect regulation appears to generate a change in the non-depressed agent's resource, given the extra regulatory effort required in working towards affect goals as felt-affect tends towards that of the depressed agent.

Again, this investigation with the model as a dyad offers a novel contribution to the understanding of both affect regulation and to the processes of contagion between individuals because the research of contagion of self-regulatory capacity is only a recent consideration in the literature (e.g., VanDellen & Hoyle, 2010). Recent studies report conflicting accounts of contagion of regulatory fatigue (e.g., Ackerman, Goldstein, Shapiro, & Bargh, 2009) and improvement of self-regulatory capacity through contagion (e.g., VanDellen & Hoyle, 2010). This model offers an account for a specific instance of regulatory fatigue in one individual influencing another due to processes of contagion. Affect regulation between individuals in workplace environments has been reported to induce depletion in others observing this take place (Totterdell, Hershcovis, Niven, Reich, & Stride, 2012), indicating that contagion of self-regulatory fatigue may extend to wider networks.

9.3 Limitations

9.3.1 Limitations of the Model

The approach taken of computational modelling for examining affect regulation dynamics offers many unique means of examining and explaining mechanisms underlying relationships within affect regulation. However, the approach does have limitations that impact upon the degree to which outcomes of the model can be considered alongside existing means of understanding affect regulation. This model sought to draw together a range of related concepts regarding affect regulation and, as a result, required a high number of parameters to represent these processes and their interactions. In terms of testing and specifying parameters, a large number of parameters to be tested present complications for developing clear and specific predictions (e.g., Roberts & Pashler, 2000). This is particularly evident in models such as this one, which exhibit a high degree of recurrent relationships, such as the depletion of self-regulatory resource by affect regulation processes and also their dependence on the presence of resource (e.g., Muraven et al., 1998). As a result of the non-linear structure of the model, changes to a parameter value in one area of the model could influence the behaviours of the model at other areas and such a result might not be anticipated. This means that controlled parameter changes require intensive investigation across the model to determine the overall influence of parameter specification in the model dynamics. This model presents recurrent relationships across two different levels, the first being each individual control loop and the second being the relationships between each of the control loops.

The development of non-linear process within the model is an unavoidable consequence of examining affect regulation as conceptualised in the current theories founded upon control theory principles. Control theory as a framework rejects the simple feed-forward process from stimulus to response, emphasising that feedback from response to stimulus in order to shape perceptions of the stimulus is an essential component of behaviour (Powers, 1974). Moreover, there are non-linear aspects in the theory contributing to the development of the model. While not often presented explicitly in the strength-model, there is a recurrent relationship between regulation that depletes resource and a reliance on resource for successful regulation. More broadly, the strength-model argues for a further recurrent relationship in the training of self-regulatory capacity over time: building strength and resistance to regulatory fatigue requires the regular use of self-regulation and occurrence of fatigue (Muraven, 2010). Recurrent loops, such as those described, may necessarily require a more complex recurrent model to capture trends and offer explanations.

An additional effect of a large number of parameters in the model is the dramatic increase in the number of tests required for the effects of parameter variations. As mentioned earlier, the influence of a change in parameter may be seen across values in the model dependent on other parameters, also subject to change. As a result, a comprehensive investigation in the nature of how each parameter change can influence all others becomes a prohibitively time consuming task. To reduce the time taken in testing parameter variation, a two stage process was used in testing and validating the model. First, components of the model that can be considered in isolation as a functional unit were tested using the restricted parameter bases this produces. From this, six key influential parameters were identified as having a substantial influence on model behaviour and a clearly identifiable analogue in the emotion regulation literature. This allowed for a limited range of parameters to be examined and used as a means for fitting data gathered from the diary studies

Despite the large number of parameters specified and prior assumptions made explicit in this model, there are still assumptions regarding the nature of affect regulation left implicit. Indeed, the very choice in including representation of some phenomena as parameter values and not others is itself reliant on implicit assumptions (Ragan, 2010).

The use of computational models as a tool for examining expansive research areas, such as affect regulation, necessarily requires a simplification and reduction of the real world (Bosse et al., 2010), and a balance is to be struck in working towards a more complete representation while preserving simplicity in the model's design (Carley, 1999). As a result of this aim to reduce the model to a simple representation of the processes involved in affect regulation, areas considered by other computational models, such as affect appraisal (Gratch & Marsella, 2004), are not implemented in this model.

9.3.2 Limitations of the Diary Studies

Five aspects of the model's outputs were used as the measures for data collection in the diary studies. These were: felt-affect, affect-expression, perceived self-regulatory capacity, felt-affect goals, and affect-expression goals. These were chosen because they meet the criteria of representing each of the component parts of the model and because they were simple 'real world' measures, which could be collected through self-report. However, the collected data from the first diary study indicated that the means used to measure affect-expression, on an event sampling basis, did not yield sufficient data points to be of use in the data fitting procedure. This posed a challenge for the validation approach taken for the model because a revised representation of affect-expression was required, in order to be able to collect enough recordings of affect-expression for data fitting in the second study. To achieve this, affect-expression was recorded in the same manner as the other measures, on a time sampling basis. This necessitated the description of affect-expression as a continuous and changing process, similar to felt-affect, rather than a process that co-occurs with affective events.

As a result, a trade-off was made between the retrieval of more accurate but incomplete affect-expression results, to a more complete results set of general, affect expressive tone. A more general representation in the recordings for affect-expression could lead to issues regarding how individuals consider their expressed state. When considering affect-expression in general terms in the course of each diary entry, it may be plausible that individuals are likely to make a recording similar to that of their felt-affect state due to memory or cognitive biases such as a perception that they generally are a person who shows genuine or authentic expression of how they feel.

Alongside the issue regarding affect-expression recordings, there exists the limited potential for examining regulatory fatigue over time in a diary study. A measure of fatigue using a self-report scale would necessarily be recording subjective experience of regulatory fatigue, which may differ from self-regulatory resource fatigue. However, given the constraints placed upon the study due to the nature of requiring frequent repeated recordings, more objective means of measuring regulatory capacity are not suitable, particularly those which require persistence at tasks over an extended period of time or may be improved through practice (e.g., Muraven 2010). While subjective regulatory fatigue may be considered a less reliable measure because of the limitations of self-report, there is evidence to suggest that the perceptions of fatigue, alongside fatigue itself, influence self-regulatory capacity (Clarkson et al., 2010; Job et al., 2010). Further to this, the results from the diary studies indicate that perceptions of regulatory fatigue show just a moderate correlation with that of one's perceived alertness, which may also refer to subjective fatigue, suggesting a degree of distinction between the concepts.

9.3.3 Limitations of Using the Diary Studies as a Validation Tool

The primary limitation of using data fitting as a tool for validating a computational model is outlined by Roberts and Pashler (2000). They argue that the 'goodness of fit' between a model and a data set is not a sufficient means of presenting the quality of a model. Alongside any fit of data should be outlined the flexibility of the model, the variability of the data, and likelihood of other outcomes. Ultimately a model should be assessed on how constraints on theory are made by the model and determine if these are constraints seen in existing, empirical data. In the course of this thesis, specific constraints in the model are tested, such as the ratio in self-regulatory resource costs between felt-affect regulation and affect-expression regulation. This proposed imbalance between the costs of regulating affect is seen in the best fits of the diary data for both studies offering support for the model as plausible alternative costs of the two processes (see section 9.2.1) do not occur in the model best fits.

The use of data fitting as a validation tool has been argued as a suitable starting point (Rodgers & Rowe, 2002) for theory development and as a diagnostic tool for examining relationships within models (Humphries & Gurney, 2007). Data which falls outside the ranges that the model can predict lead researchers to re-examine assumptions made in the model and can point towards areas which require development. For example in this thesis, tailoring parameter values to offer best fits of individuals' data indicates that for participant 5 in study 2 affect goals may typically be lower than the affect home-base.

This points towards an inappropriately set goal home-base for the model to represent the diary contrary to the general assumption that the goal home-base state would be more positive than the home-base.

Results in Chapters 6 and 7 are a product of fitting a general model to the complete data sets. A limitation of this is that individual differences are not explored and as a result, fitting of the individual diary data is not as close as it can be. Optimising parameter fits to each individual's diary data enables better fit of the data sets and potentially improved predictive validity for extended modelling of individuals affect dynamics across longer periods of time. Differences between parameter values between individuals can be regarded as predictions of individual differences across key aspects of individuals' affective profiles or affect regulation use.

Fitting the model data to individual results may indicate that individuals differ in their depletion resulting from felt-affect regulation, which can be further explored and tested in experimental studies. Oravecz et al. (2009) use individual fitting of results to differential between individuals' affective variability and their home-bases for affect; these individual profiles are indicated to correlate with personality measures of neuroticism and extraversion respectively. Fitting individual results through variation in actuator gains in simple models of control (Rogers, Mansell, Ihenacho, & Gruber, in press) can offer specific predictions of individuals' behaviour in novel situations; interaction between two fitted control models of preferences for personal space predicts human behaviour in actual interactions. A data fitting procedure of this means applied to this thesis has implications for predictions of dyadic interaction; this is suggested in the ranges of affect in modelled interactions in Chapter 8, where individuals with high regulatory momentum (high actuator gain) are indicated to be comparatively immune to the observed effects of depression contagion.

9.4 Future Research Directions and Wider Implications

Taking the limitations described into consideration, this section examines some of the potential research avenues made available through the development of this simulation. These are organised by the themes of further research within the current model, further research expanding upon the current model, and further practical research. Wider implications are considered alongside the discussion of further practical research. Computer simulation offers a strong, alternative means of investigating observable phenomena such as emotion regulation because it requires the explicit specification of assumptions, predictions, and hypotheses. Models used to describe emotion regulation have traditionally existed as simple box-diagram representations of processes involved (e.g., Gross, 1998a) and, in this form, do little to offer specified, measurable, and testable predictions. In contrast, the requirements for specific representation in a simulation of concepts and explanations of the interactions between these concepts present new avenues to be pursued and new predictions about these concepts to be made (e.g., Thompson & Derr, 2009).

9.4.1 Further Parameter Testing

The thesis offers an overview of the parameter variation process used to best fit the diary data. The large number of parameters shaping the behaviour of the model, as it currently stands, presents a logistical challenge for a comprehensive overview of each parameter's influence with regards to variations in all of the remaining parameters. To best accommodate the process of parameter variation within the scope of the thesis, it was determined that six key parameters of interest would be varied in the process of data fitting (Table 9.1). The process used does offer a template for further means of testing and examining the model in the capacity of an extended study. This process of fitting further parameters could result in closer fits with diary data, given the additional degrees of freedom that further varied parameters afford, and could offer further insights into parameters already examined.

The use of further parameter variation could be extended to that of dividing a general parameter, which was initially created through the grouping of four individual parameters for the purpose of parsimony in the model. The parameter regarding the influence of regulation efforts (regulatory momentum, *k2*, Table 9.1) is used at each point of regulation in the model: felt-affect regulation, affect-expression regulation, felt-affect goal regulation and affect-expression goal regulation. However, with regards to the first two uses of this parameter, there is a distinction drawn in the literature between individuals who favour reappraisal (felt-affect regulation) and individuals who favour affect suppression (affect-expression regulation) as regulation strategies (reappraisers and suppressors, Gross & John 2003). Two distinct parameters at the lower tier of affect regulation, which determine the efficacy of regulation strategy, could be applied to examine this distinction.

Moreover, this distinction between those preferring felt-affect regulation and those preferring affect-expression regulation (Gross & John, 2003) could be applied at the higher tier as individuals could hypothetically prefer to limit goal conflict through adjusting either the felt-affect goal or the affect-expression goal. Further to this, a distinction could be made between individuals by the difference in their efficacy between enacting regulation at higher and lower levels. In this model both of these considerations would be represented by again dividing the overarching parameter *k2* into constituent parameters for each component of the model where *k2* is currently used. This design decision would further allow for the investigation, understanding, and possible explanation of the interaction of regulatory processes over the current description level of data trends in affect goal adjustment offered by the existing model. It should be noted that the data patterns described in section 9.2.1 regarding the reported rate of affect goal adjustment would not be altered by this adaptation of the model because at that point, the model serves just to reflect trends existing in the data.

The above examples, describing adaptations of the current model, both point towards the potential for the model to better capture changes in affect and affect regulation seen in data through the variation of parameters to represent individual differences. The examination of individual differences in the dynamics of affect has recently been described as an essential aspect of developing understanding of emotion in the future (Kuppens et al., 2010). In Chapters 6 and 7, considerations are made in the respective short discussions about the use of refining the data fitting process to individuals' diaries through the differentiation between parameter values across multiple instances of the model. It remains to be seen if differences in aspects of affect regulation processes such as individual's preference for one strategy over another or the perceived effort required to engage in such strategies can both be reflected in parameter variations of individual differences and result in closer representation of their affect dynamics.

9.4.2 Further Developments of the Model

In addition to the suggested developments within the model for further parameter testing, in Section 9.4.1, there are many further possibilities for expanding upon the current model and means to broaden its investigatory scope and its explanatory and predictive capacities. In this section, four general future directions for the model and specific aspects of these are suggested and considerations of the impact on the model are offered.

First, there are multiple alternative means of representing affective experience in the affect literature. Moreover, recent research in affective dynamics indicates that affect experience over time might vary from one form of affect to another (Verduyn et al., 2009). Building on work by Sonnemans and Frijda (1994), Verdun et al. (2009) indicate that diverse affective experiences, such as anger, joy, and sadness, may differ not just in their typical duration but also that their intensity profiles (how the experience changes over time). Representation of individual affect experience profiles in an adaptation of the current model could be achieved through the development of parallel control loops and the modification of affective event intensities to determine their capacity to influence each affective state. Such a development could allow for investigation of the dynamics of different regulation processes for each affect experience, to answer questions such as whether certain types of affect are easier to regulate than others. Should it be considered more prudent to maintain a 'core-affect' representation (e.g., Russell, 2003), the model could be expanded through the representation of affect as independent processes of valence and arousal, such as that shown by Oravecz et al. (2009). Affect could further be represented across different periods of time, drawing a distinction between moods and emotions (e.g., Beedie et al., 2005), testing the scalability of the operations conducted in the model; for example, this could be used to determine whether the successful representation of affect change over an extended period of days is transferable to representations of affect across minutes. Section 9.2 offers predictions of individuals' affect and affect regulation dynamics for both longer term and more immediate timeframes; the further development of the model to focus on modelling shorter time-frames could aid in further refining the experiments offered to test predictions for short-term affect regulation dynamics.

Second, the model could be developed through the inclusion of an appraisal system. A fundamental aspect of emotion regulation is the process of appraisal (e.g., Gross, 1998a; Scherer, 1999) and there are existing and proposed computational simulations aimed at representing how stimuli are appraised (Gratch & Marsella, 2004, 2005; Gratch, Marsella, & Petta, 2009; Sander, Grandjean, & Scherer, 2005). The dynamic process of reappraisal has not yet been investigated with computational models in terms of dynamics of self-regulatory capacity, expression regulation, or pursuit of dynamic affect goals. There remains much room for further investigation in these terms by extending this thesis' current model. Gratch et al.'s (2009) model is designed with the intention of demonstrating a detailed representation of the multiple steps required to appraise an event or occurrence in terms of interaction with and influence on beliefs and desires. In contrast, the current model described in this thesis has not been constructed with the intention to use this broad and complex approach in its representation of the influence of events or occurrences on affective states. As a result, the current model does not engage in a ‘true’ process of reappraisal when regulating felt-affect in the time an affective event acts on the model’s felt-affect state. In this existing representation, the model currently enacts a change to the felt-affect state but leaves the valence of the experienced event untouched.

A ‘true’ representation of reappraisal would consist of the more complex process of directly changing the magnitude of the interpreted valence of the event influencing the felt-affect state at a point in the system *before* influence reaches the felt state (e.g., Gross, 1998a). This process creates additional complexity in that appraisal parameter(s) would need inclusion and the capacity to be modified by the model itself. Alongside this, the representation of affective events could need restructuring because, as the current model stands, there is a single pathway from the broadly defined ‘events’ input to influence the felt-affect of the model. The model does not have any representation of what these events are, just that they have an affective valence value that influences the felt-affect state. Each event or influence on felt-affect would require identification as a distinct representation so that the model does not universally reappraise all stimuli including novel ones that may bear no relation to prior events reappraised. This would be a development which could require extensive change to the model through the use of a symbolic (e.g., Gratch & Marsella, 2004) neural network (Sander et al., 2005), or other non-linear (e.g., Mueleman, 2012) representation of distinct, identifiable events. Development of representation of the context in which events occur and are appraised could offer substantial improvements in fitting model outputs to empirical data. Affective events may be represented in terms of their influence on individual’s held goals (e.g., Gratch & Marsella, 2004) better allowing the model to capture enduring impact of brief but emotionally significant events that have a lasting impact on the individual.

A third means of developing the model consists of the provision for the choice of goal pursuit. Diefendorff and Gosserand (2003) refer to a means of selecting between goals to pursue and so shape behaviour. At each level of the model’s hierarchy, goals are considered to be in competition with each other: individuals cannot simultaneously pursue two incompatible goals. It is suggested that the particular goal to pursue at the time is chosen based on its *motivational force,* a value derived from the interaction of the perceived likelihood of reaching the goal (Vroom, 1964) and the contribution this goal makes in reaching other desired, higher goals (Austin & Vancouver, 1996). The goal with the highest motivational force is argued to be the one selected for pursuit, until a higher motivational force for another goal arises.

Revising the means of goal pursuit selection affords a step towards a more general framework for a multi-level control system for affect regulation. At present, affect goal pursuit is not considered in terms of how likely it would be to assist in higher level goal pursuit (which itself is only represented at a most basic degree of affect goals tending towards a fixed point of valence determined by an otherwise unspecified 'higher level of control'). Adaptation of the model at this point could present further opportunity to examine influences of dynamic parameter variation, such as learning or reorganisation of priorities as a means of reducing goal conflict. This design direction towards a more Perceptual Control Theory based approach (e.g., Powers, 1974) over the current self-regulation system approach (e.g., Carver & Scheier, 2001) would offer opportunity to further examine dynamic shifts in affect regulatory strategy use over both a short term (in the case of goal selection) and long term (in the case of reorganisation of priorities and learning effective strategies). Reorganisation of goals and adjustment of motivations to pursue each offers a rich potential for improving the quality of fitting model results to existing data, particularly in terms of reflecting affect goal dynamics. Inclusion of a motivational force to pursue affect goals, either alongside, or in replacement of, the existing 'resource model' offers means to compare and contrast conflicting accounts (e.g., Alberts et al., 2011; Baumeister et al., 2007) of the pursuit of held goals Experimentally induced affect goal conflicts, such as those offered in section 9.2 may further test model predictions of the capacity to pursue individual goals.

The final offered development of the model relates to that of the third suggested extension because it proposes the broadening of affect regulation use to include interpersonal affect regulation (e.g., Niven et al., 2009). Deliberate interpersonal affect regulation strategies would develop and expand upon the predictions generated in Chapter 8 from the formation of a dyad of models because it would enable a wider degree of affect-expression change according to agents' motivations. An individual agent may actively seek to improve their own affective state through regulating others' felt-affect states and affect-expressions as an alternative means to intrapersonal regulation. Two agents with dynamic aims and motivations would further emphasise the importance of regarding actors in a dyad as both active agents seeking to control their own affect, as outlined in Chapter 8.

Leading on from this, models may be assembled as agents in complex networks of individuals, forming a hybrid simulation of parameter driven and agent based model (e.g., Epstein & Axtell, 1996; Smith & Conrey, 2007). Activity of agents, governed by rules at a complete system level, such as the structure of organisational networks (Totterdell et al., 2004), degrees of susceptibility to affect contagion (Ilies, Wagner, & Morgeson, 2007), and influence of network changes or mergers (Franz & Carley, 2009), would develop the investigation of affect regulation processes and strategy selection for affect regulation at broader levels than just the individual. Such approaches would further enable the examination for network effects on individuals as part of the growing argument for the benefit of examining affect as a social process, embedded within social networks. It is possible that using multiple, connected agents to explore affect regulation within a network as a unit may offer closer fits to individual data than examining individuals alone. Networks with dynamic connections between individuals may then offer predictions of network formation's relationships with individuals' affect regulation styles; individual agents that tend to use more effective regulation strategies may be more influential in the network and so more likely to make and maintain connections.

9.4.3 Wider Implications and Research Directions

Expanding beyond developments for the model, this section considers the wider implications of the research in this thesis across five main areas. The first area that the thesis has implications for is the understanding of affect regulation. Within the context of affect research, it is still only relatively recently that affect has been really considered in terms of being a dynamic (Boker, 2002; Scherer, 2000a) and controllable process (Gross, 1998a; Gross & Thompson, 2007). Given the short history of affect being examined from these approaches, the development of explorative models can offer unique perspectives and novel implications, particularly at their intersection of affect regulation dynamics.

The model points towards two aspects of affect regulation that together have implications for the way affect regulation is commonly conceptualised. Firstly, representation of two agents interacting in a dyad highlights that an individual engaging in expression regulation can shape the emotional experiences and expressions of the other individual. Issues arise when examining this interaction through the lens of the process model (Gross, 1998a); the first agent's response modulation (expression regulation) modifies the affective situation it perceives (the second agents expression). This coinciding of processes contrasts the linear depiction of affect regulation in the process model. Secondly, the thesis suggests that both felt-affect regulation and affect-expression regulation can co-occur, particularly in the pursuit of two contrasting held affect goals. Individuals in the second diary study report distinctions both between their felt-affect and affect-expression states and between the felt and expression affect goal states. Representations of these differences are met by the model through specifying contrasting goal states and independent regulation of affect states. Again, this contrasts the representation of affect regulation in the process model.

Alongside the alternative representations of regulation dynamics, the occurrence of switching between dominant regulation strategy use in the model has implications for the representation of individuals as *reappraisers* or *suppressors* (e.g., Gross & John, 2003). Regulation strategy use is context dependent in the model, relying on the relative disparity or coherency between the two affect goals and current self-regulatory capacity. A change in circumstances the model faces, such as affective events, a change in affect goals, or depletion of resource can, for example, see the model switch from exerting control primarily through felt-affect regulation, to both strategies being used concurrently, to primarily affect-expression regulation. While there may be trait dependent influences on regulation strategy selection, the model indicates that situational context can play an important role. Experiments in which the context of regulation is altered could offer further insights into the dynamics of individuals' regulation strategy use.

The second area that the thesis has implications for is the understanding of self-control. In the literature on the strength-model of self-control, suggestions are made that self-regulatory capacity is depleted across a day (Baumeister et al., 1994; Baumeister et al., 1999; Baumeister and Heatherton, 1996) and restoration across the long term is associated with sleep (Barber et al., 2010; Gailliot, 2008; Hagger, 2010). However, there is a dearth of studies examining this proposition further and studies dedicated to exploring the strength-model over time focus primarily on building self-control (e.g., Muraven, 2010) or record too infrequently to examine changes within a day (Muraven, Collins, Shiffman, & Paty, 2005). This thesis develops the concept of resource depletion and restoration occurring across regular cycles and offers new insight into variation in resource capacity. Further exploration of self-regulatory capacity, such as controlled sleep-deprivation studies, could be conducted to better uncover any underlying rhythms and examine resource depletion's association with subjective fatigue (e.g., Hagger et al., 2010).

Given the strength-model's emphasis on the conservation of self-regulatory resource as a mechanism for abandoning self-regulation efforts, the indication that self-regulatory capacity varies within individuals across time has implications for testing protocols. Time-of-day effects may be seen between experimental studies as individuals might be more prepared to conserve resource in studies later on in the day after already experiencing everyday demands on self-regulation. So-called 'glucose-hypothesis' studies have been careful to monitor times in which self-regulation experiments are undertaken, particularly in repeated measures designs (Niven, Totterdell, Miles, Webb, & Sheeran, in press). However, there is no current indication that potential time-of-day effects have been considered in self-control experiments in general.

The third area that the thesis has implications for is the use of computational models for investigating affect. To the author's knowledge, there have not been previous attempts for integration of research across the diverse areas of: felt-affect regulation, affect-expression regulation, self-regulatory capacity and goal adjustment, to develop an overarching model of affect regulation dynamics. Previous attempts at modelling affect and affect regulation dynamics have been limited to changing felt states only (e.g., Bosse et al., 2010; Oravecz et al., 2009) and point towards developing models for expression regulation as a future direction for the field (Bosse et al., 2010). The current model draws together these multiple aspects of affect regulation to a single model in which these are presented as being interrelated processes. As a result, complex dynamics of affect can be explored and changes of affect considered in broader terms, including the influence on affect goals and self-regulatory capacity.

The use of computational models to represent dynamic processes offers alternative perspectives on affective processes and allows for exploration of plausible mechanisms underlying complex affect dynamics. Computational models, such as the one presented in this thesis, highlight current gaps in the literature that arise due to examining affect as a dynamic process trough using static models, such as that developed by Diefendorff and Gosserand, (2003). Propositions about the course of affect over time made using informal models offer limited scope for investigation because representations of dynamics cannot be specified. In contrast, the development of computational models requires the specification of propositions (e.g., Epstein, 2008) enabling these to be formally tested and hypotheses examined.

Practical implications arising from the development of predictive models of affect dynamics extend to the use of such models as 'virtual participants' for study. In experimental investigations where it becomes impractical or unethical to test propositions, such as the effects of extended sleep deprivation, a representation of plausible results derived from computational models offers possible alternatives to the use of human participants. This approach however, necessarily depends on accurate projections from simulations. Accurate and extended representation of an individual's affect states offers further direction for research; clinical interventions for mood disorders could be explored and contrasted against projections made by the model for an individual's affect states without intervention. Alternatively parameter change within a model representing an individual's affect history could offer estimates of the projected influence interventions may have; such work is preliminarily explored in the context of anger management therapy in Bosse et al. (2010) and could be explored in further models.

The fourth implication for research concerns hedonistic theories of affect. Traditionally the management of affect has been viewed with the assumption that individuals aim to maximise positive feelings (e.g., Khrone et al., 2002; Larsen, 2000; Tice & Bratslavsky, 2000). However, there has been a recent growth in the exploration of affect goals from an alternative, instrumental perspective (e.g., Tamir, 2009a). Exploring the utility of affect as a tool to facilitate goal pursuit has placed emphasis on the benefits of negative valence affective states, and critically, contested the perspective that individuals solely aim to feel good.

Even though the current model is built incorporating what is ultimately a hedonistic standpoint of affect regulation (i.e., the felt-affect goal home-base is more positive than the felt-affect home-base), the parameter set developed results in affect goals being as variable as felt-affect itself. Overall the model offers a representation of affect goals not just as single track as Larsen's (2000) representation of assuming individuals want to feel good, but rather the more diverse view that individuals typically want to feel better (i.e., more positive *or* less negative). This indication that positive affect goals can vary broadens the hedonistic perspective and implies that a 'weak hedonistic approach' of flexible goals, in contrast to the 'strong hedonistic approach' (e.g., Larsen, 2000), remains relevant alongside the development of instrumental theories of affect.

The final area that the thesis has implications for is the control theory perspective of self-regulation. Carver and Scheier's (2001) model of self-regulation offers an account of goal-directed behaviour, organised in a hierarchy of tiers of competing control loops. While their theory draws heavily from control in engineering (Clark, 1996) and perceptual control theory (Powers, 1974), one notable distinction is in their representation of affect. Positive and negative affect are considered as perceptions of the rate of progress towards or away from a goal and themselves argued to exist as states within their own control loops. These loops hold a fixed representation of how individuals would want to feel and in representations of their control model, are situated outside the main goal hierarchy.

As discussed in terms of implications for hedonistic theories of affect, this thesis indicates that affect goals (i.e. what individuals want to feel) are not static. Representation of variation within individuals of affect goals over time indicates that these changes can even occur at rates comparable to affect change. This is a substantial contrast to the model put forwards by Carver and Scheier (2001), which does not consider the implications of adjustment of affect goals. Variation in affect goals offers a wider role for affect within the control framework, pointing towards behaviour being shaped to achieve goal affect states, as argued by Baumeister, Vohs, DeWall, and Zang, (2007). Further to this, as affect goals can exist as something individuals specifically seek, this implies that an integration of affect regulation within the main hierarchy of goal driven self-regulation (Carver & Scheier; Powers, 1974) is appropriate. Again, this points towards the importance of examining self-regulation processes as being interrelated and the value of integrating related areas of research within overarching frameworks.

In terms of practical implications, the model offers new directions for tools in the growing field of affect tracking and affect management. Currently, individuals can self-monitor affect changes through a variety of smartphone applications or websites (e.g., *T2 MoodTracker*™, t2health.org/apps/t2-mood-tracker; *Moodscope*™, moodscope.com), which have potential use in terms of affect management and self-help. Development of a MARDy affect tracking tool could extend affect tracking to that of goal affect states, which, to the author's knowledge, no other tracking tool provides. Moreover, individuals can find it difficult to accurately forecast their affect (e.g., Ayton, Pott, & Elwakili, 2007) and yet current affect management tools do not explore individuals' prospective affect in aid of better forecasting feelings. MARDy simulation offers representation of affect dynamics based on affective events and model development as an affect management tool could offer forecasting of individuals' affect states based on individuals' anticipated affective events.

9.5 Summary and Conclusions

This chapter brings together findings from three means of testing the current model of affect regulation dynamics to explore propositions across three themes: self-regulatory capacity, affect regulation dynamics, and affect regulation in a dyad. The model discussed in this chapter represents the integration of five interrelated areas of self-regulation: felt-affect regulation, affect-expression regulation, self-regulatory capacity, felt-affect goal regulation and affect-expression goal regulation. Its implementation as a computational model offers the exploration of dynamics across each of these areas and mechanisms underlying these. Implications of the models propositions for research are considered, and limitations and future directions discussed.

Findings from model development and simulation indicate affect regulation dynamics can successfully be represented within a control theory framework of two levels of control. Moreover, within this framework, the higher tier, representing adjustments made to affect goals, shows comparable rates of change to that of the lower tier, representing affect states; this contrasts anticipated results and suggests flexibility in what individuals want to feel or express. Model representation of regulatory dynamics gathered from diary data is most successfully achieved with model parameter sets specified to reflect findings from emotional labour literature and a hedonistic conceptualisation of affect: specifically, affect-expression regulation is considered more effortful than felt-affect regulation and individuals typically regulate towards positive affect goals. Understanding both how affect changes across time and the mechanisms involved are current challenges for affect research; this thesis has offered a novel and viable way of moving that endeavour forward.

References

Abraham, R. (1998). Emotional dissonance in organizations: Antecedents, consequences, and moderators. *Genetic, Social, and General Psychology Monographs; Genetic, Social, and General Psychology Monographs*. *124*(2), 229-246.

Ackerman, J. M., Goldstein, N. J., Shapiro, J. R., and Bargh, J. A (2009). You wear me out: The vicarious depletion of self-control. *Psychological Science, 20*(3), 326-332.

Adolph, E. F. (1947). Urges to eat and drink in rats. *American Journal of Physiology, 151*, 110-125

Åkerstedt, T., & Folkard, S. (1995). Validation of the S and C components of the three-process model of alertness regulation. *Sleep: Journal of Sleep Research & Sleep Medicine, 18*(1), 1-6.

Åkerstedt, T., & Folkard, S. (1996). Predicting sleep latency from the three-process model of alertness regulation. *Psychophysiology, 33*(4), 385-389.

Åkerstedt, T., Folkard, S. & Portin, C. (2004). Predictions from the three-process model of alertness. *Aviation, Space, and Environmental Medicine, 75*(3), 75-83

Alberts, H. J. E. M., Martijn, C., & de Vries, N. K. (2011). Fighting self-control failure: Overcoming ego depletion by increasing self-awareness. *Journal of Experimental Social Psychology, 47*(1), 58-62.

Adelmann, P. K., & Zajonc, R. B. (1989). Facial efference and the experience of emotion. *Annual review of psychology, 40*(1), 249-280.

Anderson, C., Keltner, D., & John, O. P. (2003). Emotional convergence between people over time. *Journal of Personality and Social Psychology; Journal of Personality and Social Psychology, 84*(5), 1054-1068.

Anderson, J. R. (1976). *Language, memory, and thought. Hillsdale*, NJ: Erlbaum.

Appelhans, B. M., & Luecken, L. J. (2006). Heart rate variability as an index of regulated emotional responding. *Review of general psychology*, *10*(3), 229.

Ashby, W. R. (1961). An introduction to cybernetics. London: Chapman.

Ashkanasy, N. M., & Daus, C. S. (2002). Emotion in the workplace: The new challenge for managers. *The Academy of Management Executive (1993-2005)*, *16*(1), 76-86.

Austin, J. T., & Vancouver, J. B. (1996). Goal constructs in psychology: Structure, process, and content. *Psychological Bulletin, 120*(3), 338-375.

Ayton, P., Pott, A., & Elwakili, N. (2007). Affective forecasting: Why can't people predict their emotions? *Thinking & reasoning, 13*(1), 62-80.

Baddeley, A. (2007). *Working memory, thought, and action*: New York: Oxford University Press.

Barber, L. K., & Munz, D. C. (2011). Consistent-sufficient sleep predicts improvements in self-regulatory performance and psychological strain. *Stress and Health, 27*(4), 314-324.

Barber, L. K., Munz, D. C., Bagsby, P. G., & Powell, E. D. (2010). Sleep consistency and sufficiency: are both necessary for less psychological strain? *Stress and Health, 26*(3), 186-193.

Bard, P. (1939). Central nervous mechanisms for emotional behavior patterns in animals. *Research Publications of the Association for Research in Nervous & Mental Disease, 19*, 190-218.

Bargh, J. A. (1994). The four horsemen of automaticity: Awareness, efficiency, intention, and control in social cognition. In R. S. Wyer & T. K. Srull (Eds.), *Handbook of social cognition* (2nd ed., pp. 1-40). Hillsdale: Erlbaum.

Bargh, J. A., Gollwitzer, P. M., Lee-Chai, A., Barndollar, K., & Trötschel, R. (2001). The automated will: nonconscious activation and pursuit of behavioral goals. *Journal of Personality and Social Psychology, 81*(6), 1014-1027.

Bargh, J. A., & Williams, E. L. (2006). The automaticity of social life. *Current Directions in Psychological Science, 15*(1), 1-4.

Barone, D., Maddux, J. E., & Snyder, C. R. (1997). *Social cognitive psychology: History and current domains*. New York: Springer.

Barsade, S. G. (2002). The ripple effect: Emotional contagion and its influence on group behavior. *Administrative Science Quarterly, 47*(4), 644-675.

Bartel, C. A., & Saavedra, R. (2000). The collective construction of work group moods. *Administrative Science Quarterly, 45*(2), 197-231.

Baumeister, R. F. (2002). Ego depletion and self-control failure: An energy model of the self's executive function. *Self and Identity, 1*(2), 129-136.

Baumeister, R. F. (2008). Free will in scientific psychology. *Perspectives on Psychological Science, 3*(1), 14-19.

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology, 74*(5), 1252-1265.

Baumeister, R. F., DeWall, C. N., Ciarocco, N. J., & Twenge, J. M. (2005). Social exclusion impairs self-regulation. *Journal of Personality and Social Psychology, 88*(4), 589-604.

Baumeister, R. F., Faber, J. E., & Wallace, H. M. (1999). Coping and ego depletion. In C. R. Snyder (Ed.), *Coping: The psychology of what works* (pp. 50-69). New York, US: Oxford University Press

Baumeister, R. F., & Heatherton, T. F. (1996). Self-regulation failure: An overview. *Psychological inquiry, 7*(1), 1-15.

Baumeister, R. F., Heatherton, T. F., & Tice, D. M. (1994). *Losing control: How and why people fail at self-regulation*. San Diego, US: Academic Press.

Baumeister, R. F., Vohs, K. D., DeWall, C. N., & Zhang, L. (2007). How emotion shapes behavior: Feedback, anticipation, and reflection, rather than direct causation. *Personality and Social Psychology Review, 11*(2), 167-203.

Baumeister, R. F., Vohs, K. D., & Tice, D. M. (2007). The strength model of self-control. *Current Directions in Psychological Science, 16*(6), 351-355.

Bechara, A. (2004). The role of emotion in decision-making: Evidence from neurological patients with orbitofrontal damage. *Brain and cognition, 55*(1), 30-40.

Beedie, C. J., & Lane, A. M. (2012). The role of glucose in self-control: another look at the evidence and an alternative conceptualization. *Personality and Social Psychology Review, 16*(2), 143 –153.

Beedie, C., Terry, P., & Lane, A. (2005). Distinctions between emotion and mood. *Cognition & Emotion, 19*(6), 847-878.

Bennett, S. (1993). *A history of control engineering, 1930-1955*. Stevenage, UK: Peter Peregrinus Ltd.

Bennett, S. (n.d.). *Emotion model version 6*. Unpublished manuscript, Department of Psychology, The University of Sheffield, Sheffield, UK.

Benton, D., Owens, D. S., & Parker, P. Y. (1994). Blood glucose influences memory and attention in young adults. *Neuropsychologia, 32*(5), 595-607.

Biswas-Diener, R., Diener, E., & Tamir, M. (2004). The psychology of subjective well-being. *Daedalus, 133*(2), 18-25.

Boivin, D. B., Czeisler, C. A., Dijk, D. J., Duffy, J. F., Folkard, S., Minors, D. S., … Waterhouse, J. M. (1997). Complex interaction of the sleep-wake cycle and circadian phase modulates mood in healthy subjects. *Archives of General Psychiatry, 54*(2), 145-152.

Boker, S. M. (2002). Consequences of continuity: The hunt for intrinsic properties within parameters of dynamics in psychological processes. *Multivariate Behavioral Research, 37*(3), 405-422.

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual review of psychology, 54*(1), 579-616.

Bolger, N., DeLongis, A., Kessler, R. C., & Schilling, E. A. (1989). Effects of daily stress on negative mood. *Journal of Personality and Social Psychology, 57*(5), 808-818.

Bosse, T., Pontier, M., & Treur, J. (2010). A computational model based on Gross' emotion regulation theory. *Cognitive Systems Research, 11*(3), 211-230.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological review, 108*(3), 624-652.

Brandtstädter, J., & Rothermund, K. (2002). The life-course dynamics of goal pursuit and goal adjustment: A two-process framework. *Developmental Review, 22*(1), 117-150.

Breazeal, C. (2003). Emotion and sociable humanoid robots. *International Journal of Human-Computer Studies, 59*(1), 119-155.

Birchler-Pedross, A., Schröder, C. M., Münch, M., Knoblauch, V., Blatter, K., Schnitzler-Sack, C., … Cajochen, C. (2009). Subjective well-being is modulated by circadian phase, sleep pressure, age, and gender. *Journal of biological rhythms, 24*(3), 232-242.

Brotheridge, C. M., & Lee, R. T. (2002). Testing a conservation of resources model of the dynamics of emotional labor. *Journal of Occupational Health Psychology, 7*(1), 57-67.

Buck, R. (1980). Nonverbal behavior and the theory of emotion: The facial feedback hypothesis. *Journal of Personality and Social Psychology, 38*(5), 811-824.

Burke, R. J., & Greenglass, E. (1995). A longitudinal study of psychological burnout in teachers. *Human Relations, 48*(2), 187-202.

Butler, E. A., Lee, T. L., & Gross, J. J. (2007). Emotion regulation and culture: Are the social consequences of emotion suppression culture-specific? *Emotion, 7*(1), 30-48.

Cameron, D. & Webb, T. (in press a) Self-Regulatory capacity. In M. D. Gellman, & J. R. Turner (Eds.), *The Encyclopedia of behavioral medicine*. Springer.

Cameron, D. & Webb, T. (in press b) Self-Regulatory fatigue. In M. D. Gellman, & J. R. Turner (Eds.), *The Encyclopedia of behavioral medicine*. Springer.

Campos, J. J., Frankel, C. B., & Camras, L. (2004). On the nature of emotion regulation. *Child Development, 75*(2), 377-394.

Cannon, W. B. (1927). The James-Lange theory of emotions: A critical examination and an alternative theory. *The American Journal of Psychology, 39*(1), 106-124.

Carley, K. M. (1999). On generating hypotheses using computer simulations. *Systems Engineering*, 2(2), 69–77.

Carrere, S., & Gottman, J. M. (1999). Predicting divorce among newlyweds from the first three minutes of a marital conflict discussion. *Family Process*, *38*(3), 293-301.

Carver, (2004) Self-regulation of action and affect. In Baumeister, R. F. & Vohs, K. D. (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 13-39). New York, US: Guilford Press.

Carver, C. S., & Scheier, M. F. (1982). Control theory: A useful conceptual framework for personality–social, clinical, and health psychology. *Psychological Bulletin, 92*(1), 111-135.

Carver, C. S., & Scheier, M. (1990). Principles of self-regulation: Action and emotion. In E. T. Higgins & R. M. Sorrentino (Eds.), *Handbook of motivation and cognition: Foundations of social behavior* (pp. 3-52). New York, US: Guilford Press.

Carver, C. S., & Scheier, M. F. (2001). *On the self-regulation of behaviour.* Cambridge, UK: Cambridge University Press.

Carver, C. S., & Scheier, M. F. (2011). Self-regulation of action and affect. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of self-regulation*: *Research, theory, and applications* (2nd ed., pp. pp. 3-21). New York, US: Guilford.

Chaplin, D. J., & Rhalibi, A. E. (2004, June). *IPD for emotional NPC societies in games*. Paper presented at the 2004 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, Singapore.

Chartrand, T. L., Dalton, A. N., & Cheng, C. M. (2008). The antecedents and consequences of nonconscious goal pursuit. In J. Y. Shar & W. L. Gardener (Eds.), *Handbook of motivation science* (pp. 342-355). New York, US: Guilford Press.

Chow, S. M., Ram, N., Boker, S. M., Fujita, F., & Clore, G. (2005). Emotion as a thermostat: representing emotion regulation using a damped oscillator model. *Emotion, 5*(2), 208-225

Cialdini, R. B., Darby, B. L., & Vincent, J. E. (1973). Transgression and altruism: A case for hedonism. *Journal of Experimental Social Psychology, 9*(6), 502-516.

Clark, L. A., Watson, D., & Leeka, J. (1989). Diurnal variation in the positive affects. *Motivation and Emotion, 13*(3), 205-234.

Clarke, R. N. (1996). *Control system dynamics*. New York: Cambridge University Press.

Clarkson, J. J., Hirt, E. R., Jia, L., & Alexander, M. B. (2010). When perception is more than reality: the effects of perceived versus actual resource depletion on self-regulatory behavior. *Journal of Personality and Social Psychology, 98*(1), 29-46.

Colby, C. Z., Lanzetta, J. T., & Kleck, R. E. (1977). Effects of the expression of pain on autonomic and pain tolerance responses to subject-controlled pain. *Psychophysiology, 14*(6), 537-540.

Conati, C., & Maclaren, H. (2009). Empirically building and evaluating a probabilistic model of user affect. *User Modeling and User-Adapted Interaction, 19*(3), 267-303.

Côté, S. (2005). A social interaction model of the effects of emotion regulation on work strain. *Acadamy of Management Review, 30*, 509-530.

Cron, W. L., Slocum Jr, J. W., VandeWalle, D., & Fu, Q. (2005). The role of goal orientation on negative emotions and goal setting when initial performance falls short of one's performance goal. *Human Performance, 18*(1), 55-80.

Custers, R., & Aarts, H. (2005). Positive affect as implicit motivator: on the nonconscious operation of behavioral goals. *Journal of Personality and Social Psychology, 89*(2), 129-142.

Dalgleish, T. (2004). The emotional brain. *Nature Reviews Neuroscience, 5*(7), 583-589.

Davis, E. L., Levine, L. J., Lench, H. C., & Quas, J. A. (2010). Metacognitive emotion regulation: Children's awareness that changing thoughts and goals can alleviate negative emotions. *Emotion, 10*(4), 498-510.

Davis, J. I., Senghas, A., Brandt, F., & Ochsner, K. N. (2010). The effects of BOTOX injections on emotional experience. *Emotion, 10*(3), 433-440.

Davis, J. I., Senghas, A., & Ochsner, K. N. (2009). How does facial feedback modulate emotional experience? *Journal of research in personality, 43*(5), 822-829.

DeWall, C. N., Baumeister, R. F., Gailliot, M. T., & Maner, J. K. (2008). Depletion makes the heart grow less helpful: Helping as a function of self-regulatory energy and genetic relatedness. *Personality and Social Psychology Bulletin, 34*(12), 1653-1662.

Diefendorff, J. M., Croyle, M. H., & Gosserand, R. H. (2005). The dimensionality and antecedents of emotional labor strategies. *Journal of Vocational Behavior, 66*(2), 339-357.

Diefendorff, J. M., & Gosserand, R. H. (2003). Understanding the emotional labor process: A control theory perspective. *Journal of Organizational Behavior, 24*(8), 945-959.

Diener, E., & Diener, C. (1996). Most people are happy. *Psychological Science, 7*(3), 181-185.

Eaton, L. G., & Funder, D. C. (2001). Emotional experience in daily life: Valence, variability, and rate of change. *Emotion, 1*(4), 413-421.

Eftekhari, A., Zoellner, L. A., & Vigil, S. A. (2009). Patterns of emotion regulation and psychopathology. *Anxiety, Stress, & Coping, 22*(5), 571-586.

Ekman, P., & Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology, 17*(2), 124-129.

Ekman, P., Friesen, W. V., & O'Sullivan, M. (1988). Smiles when lying. *Journal of Personality and Social Psychology, 54*(3), 414-420.

Emmons, R. A., & King, L. A. (1988). Conflict among personal strivings: Immediate and long-term implications for psychological and physical well-being. *Journal of Personality and Social Psychology, 54*(6), 1040-1048.

Epstein, J. M. (2008). Why model? *Journal of Artificial Societies and Social Simulation, 11*(4), 12 <http://jasss.soc.surrey.ac.uk/11/4/12.html>.

Epstein, J. M., & Axtell, R. (1996). *Growing artificial societies: Social science from the bottom up.* Washington, D.C., US: MIT Press.

Erber, R., & Erber, M. W. (2000a). The self-regulation of moods: Second thoughts on the importance of happiness in everyday life. *Psychological inquiry, 11*(3), 142-148.

Erber, R., & Erber, M. W. (2000b). Mysteries of mood regulation, Part II: The case of the happy thermostat. *Psychological inquiry, 11*(3), 210-213.

Erber, R., Wegner, D. M., & Therriault, N. (1996). On being cool and collected: mood regulation in anticipation of social interaction. *Journal of Personality and Social Psychology, 70*(4), 757-766.

Farrell, S., & Lewandowsky, S. (2010a). Computational models as aids to better reasoning in psychology. *Current Directions in Psychological Science, 19*(5), 329-335.

Farrell, S., & Lewandowsky, S. (2010b). *Computational modeling in cognition: principles and practice*. Thousand Oaks, US: Sage.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations,* 7, 117-140

Finkel, E. J., Campbell, W. K., Brunell, A. B., Dalton, A. N., Scarbeck, S. J., & Chartrand, T. L. (2006). High-maintenance interaction: inefficient social coordination impairs self-regulation. *Journal of Personality and Social Psychology, 91*(3), 456-475.

Fisher, C. D. (2000). Mood and emotions while working: Missing pieces of job satisfaction? *Journal of Organisational Behaviour, 21*, 185-202.

Fitzsimons, G. M., and Bargh, J. A. (2004). Automatic self-regulation. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 151-170) New York, US: Guilford.

Fitzsimons, G. M., & Finkel, E. J. (2011). Outsourcing self-regulation. *Psychological Science, 22*(3), 369-375.

Forgas, J. P., & Ciarrochi, J. V. (2002). On managing moods: Evidence for the role of homeostatic cognitive strategies in affect regulation. *Personality and Social Psychology Bulletin, 28*(3), 336-345.

Fowler, J. H., & Christakis, N. A. (2008). The dynamic spread of happiness in a large social network. *BMJ: British Medical Journal, 337*, a2338.

Frank, M. G., & Ekman, P. (1993). Not all smiles are created equal: The differences between enjoyment and nonenjoyment smiles. *Humor: International Journal of Humor Research, 6*(1), 9-26

Frantz, T., & Carley, K. (2009). Computationally Modeling the Effect of Organizational Complexity on Post-merger Integration. In C. L. Cooper and S. Finkelstein (Eds.), *Advances in Mergers and Acquisitions*, (pp. 79-102). Oxford, UK: JAI Press,

Franzen, P. L., Siegle, G. J., & Buysse, D. J. (2008). Relationships between affect, vigilance, and sleepiness following sleep deprivation. *Journal of Sleep Research, 17*(1), 34-41.

Freud, S. (1927). The Ego and the Id, (J. Riviere, Trans.). London, UK: Hogarth Press and Institute of Psycho-analysis. (Original work published 1923)

Friedman, H. S., & Riggio, R. E. (1981). Effect of individual differences in nonverbal expressiveness on transmission of emotion. *Journal of Nonverbal Behavior, 6*(2), 96-104.

Frijda, N. H. (1993). Moods, emotion episodes, and emotions. In M. Lewis, & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 381-403). New York, NY, US: Guilford Press.

Frijda, N. H. (2007). *The laws of emotion*. Mahwah, US: Erlbaum.

Frijda, N. H., Mesquita, B., Sonnemans, J., & Van Goozen, S. (1991). The duration of affective phenomena or emotions, sentiments and passions. *International Review of Studies on Emotion, 1*, 187-225.

Fulford, D., Johnson, S. L., Llabre, M. M., & Carver, C. S. (2010). Pushing and Coasting in Dynamic Goal Pursuit. *Psychological Science, 21*(7), 1021-1027.

Fuller, J. A., Stanton, J. M., Fisher, G. G., Spitzmüller, C., Russell, S. S., & Smith, P. C. (2003). A Lengthy Look at the Daily Grind: Time Series Analysis of Events, Mood, Stress, and Satisfaction. *Journal of Applied Psychology, 88*(6), 1019-1033.

Gailliot, M. T. (2008). Unlocking the energy dynamics of executive functioning: Linking executive functioning to brain glycogen. *Perspectives on Psychological Science, 3*(4), 245-263.

Gailliot, M. T., & Baumeister, R. F. (2007). The physiology of willpower: Linking blood glucose to self-control. *Personality and Social Psychology Review, 11*(4), 303-327.

Gailliot, M. T., Baumeister, R. F., DeWall, C. N., Maner, J. K., Plant, E. A., Tice, D. M., … Schmeichel, B. J. (2007). Self-control relies on glucose as a limited energy source: willpower is more than a metaphor. *Journal of Personality and Social Psychology; Journal of Personality and Social Psychology, 92*(2), 325-336

Gailliot, M. T., Michelle Peruche, B., Plant, E. A., & Baumeister, R. F. (2009). Stereotypes and prejudice in the blood: Sucrose drinks reduce prejudice and stereotyping. *Journal of Experimental Social Psychology, 45*(1), 288-290.

Geen, R. G. (1995). *Human motivation: A social psychological approach.* Belmont, US: Wadsworth.

Goffman, E. (1990). *The presentation of self in everyday life*. London, UK: Penguin Books.

Goldberg, L. S., & Grandey, A. A. (2007). Display rules versus display autonomy: Emotion regulation, emotional exhaustion, and task performance in a call center simulation. *Journal of Occupational Health Psychology, 12*(3), 301-318.

Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: reappraisal and suppression of negative emotion. *Biological psychiatry, 63*(6), 577.

Gollwitzer, P. M., & Oettingen, G. (2011). Planning promotes goal striving. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of self-regulation*: *Research, theory, and applications* (2nd ed., pp. 162-185). New York, US: Guilford.

Gonzaga, G. C., Campos, B., & Bradbury, T. (2007). Similarity, convergence, and relationship satisfaction in dating and married couples. *Journal of Personality and Social Psychology, 93*(1), 34-48.

Govorun, O., & Payne, B. K. (2006). Ego-Depletion and Prejudice: Separating Automatic and Controlled Components. *Social Cognition, 24*(2), 111-136.

Grandey, A. A. (2000). Emotional regulation in the workplace: A new way to conceptualize emotional labor. *Journal of Occupational Health Psychology, 5*(1), 95-110.

Grandey, A. A. (2003). When" the show must go on": Surface acting and deep acting as determinants of emotional exhaustion and peer-rated service delivery. *Academy of management Journal, 46*(1), 86-96.

Grandey, A. A., Fisk, G. M., Mattila, A. S., Jansen, K. J., & Sideman, L. A. (2005). Is “service with a smile” enough? Authenticity of positive displays during service encounters. *Organizational Behavior and Human Decision Processes, 96*(1), 38-55.

Gratch, J., & Marsella, S. (2001, May). *Tears and fears: modeling emotions and emotional behaviors in synthetic agents*. Paper presented at the 5th International Conference on Autonomous Agents, Montreal, Canada.

Gratch, J., & Marsella, S. (2004). A domain-independent framework for modeling emotion. *Cognitive Systems Research, 5*(4), 269-306.

Gratch, J., & Marsella, S. (2005). Lessons from emotion psychology for the design of lifelike characters. *Applied Artificial Intelligence, 19*(3-4), 215-233.

Gratch, J., Marsella, S., & Petta, P. (2009). Modeling the cognitive antecedents and consequences of emotion. *Cognitive Systems Research, 10*(1), 1-5.

Gross, J. J. (1998a). The emerging field of emotion regulation: An integrative review. *Review of general psychology, 2*(3), 271-299

Gross, J. J. (1998b). Antecedent-and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology, 74*(1), 224-237.

Gross, J. J. (1999). Emotion regulation: Past, present, future. *Cognition & Emotion, 13*(5), 551-573.

Gross, J. J. (2001). Emotion regulation in adulthood: Timing is everything. *Current Directions in Psychological Science, 10*(6), 214-219.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology, 85*(2), 348-362.

Gross, J. J., & Thompson, R. A. (2007). Emotion regulation: Conceptual foundations. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 3-24). New York, US: Guilford Press.

Hackenbracht, J., & Tamir, M. (2010). Preferences for sadness when eliciting help: Instrumental motives in sadness regulation. *Motivation and Emotion, 34*(3), 306-315.

Hagger, M. S. (2010). Sleep, self-regulation, self-control and health. *Stress and Health, 26*(3), 181-185.

Hagger, M. S., Wood, C., Stiff, C., & Chatzisarantis, N. L. D. (2010). Ego depletion and the strength model of self-control: a meta-analysis. *Psychological Bulletin, 136*(4), 495-525.

Hareli, S., & Rafaeli, A. (2008). Emotion cycles: On the social influence of emotion in organizations. *Research in Organizational Behavior, 28*, 35-59.

Harrison, Y., & Horne, J. A. (2000). The impact of sleep deprivation on decision making: a review. *Journal of Experimental Psychology: Applied, 6*(3), 236-249

Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1992). Primitive emotional contagion. In M. S. Clark, (Ed), *Review of personality and social psychology: Vol. 14. Emotion and social behavior*. (pp. 151-177). Newbury Park, US: Sage.

Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1994). *Emotional contagion.* Cambridge: Cambridge University Press.

Hatfield, E., & Hsee, C. K. (1995). The impact of vocal feedback on emotional experience and expression. *Journal of Social Behavior and Personality*, *10*, 293-313.

Havas, D. A., Glenberg, A. M., & Rinck, M. (2007). Emotion simulation during language comprehension. *Psychonomic Bulletin & Review, 14*(3), 436-441.

Heatherton, T. F., & Ambady, N. (1993). Self-esteem, self-prediction, and living up to commitments. In R. F. Baumeister (Ed.), *Self-esteem: The puzzle of low self-regard* (pp. 131-145). New York, US: Plenum Press.

Heatherton, T. F., & Wagner, D. D. (2011). Cognitive neuroscience of self-regulation failure. *Trends in cognitive sciences*. *15*,(3), 132–139.

Hemenover, S. H. (2003). Individual differences in rate of affect change: studies in affective chronometry. *Journal of Personality and Social Psychology, 85*(1), 121-131.

Hennenlotter, A., Dresel, C., Castrop, F., Ceballos-Baumann, A. O., Wohlschläger, A. M., & Haslinger, B. (2009). The link between facial feedback and neural activity within central circuitries of emotion—New insights from botulinum toxin–induced denervation of frown muscles. *Cerebral Cortex, 19*(3), 537-542.

Hicks, A. M., & Diamond, L. M. (2008). How was your day? Couples' affect when telling and hearing daily events. *Personal Relationships, 15*(2), 205-228.

Hobfoll, S. E. (1989). Conservation of resources: A new attempt at conceptualizing stress. *American psychologist, 44*(3), 513-524.

Hobfoll, S. E. (2002). Social and psychological resources and adaptation. *Review of general psychology, 6*(4), 307-324.

Hochschild, A. R. (1983). *The managed heart*. Berkeley, US: University of California Press.

Hollenbeck, J. R., & Williams, C. R. (1987). Goal importance, self-focus, and the goal-setting process. *Journal of Applied Psychology, 72*(2), 204-211.

Holman, D., Martinez-Iñigo, D., & Totterdell, P. (2008). Emotional labour and employee well-being: An integrative review. In A. N. and C. L. Cooper (Eds.)

Research Companion to Emotion in Organizations (pp. 301-315). Cheltenham: Edward Elgar.

Holman, D., Totterdell, P., Rogelberg, S. G. (2005). A daily diary study of goal striving: The relationship between goal distance, goal velocity, affect, expectancies, and effort. In N. M. Ashkanasy, W. J. Zerbe, C. E. J. Härtel (Eds.), *The effect of affect in organizational settings, Volume 1 (Research on Emotion in Organizations)* (pp. 95-121). Emerald Group Publishing

Hui, S. A., Wright, R. A., Stewart, C. C., Simmons, A., Eaton, B., & Nolte, R. N. (2009). Performance, cardiovascular, and health behavior effects of an inhibitory strength training intervention. *Motivation and Emotion, 33*(4), 419-434.

Hülsheger, U. R., & Schewe, A. F. (2011). On the costs and benefits of emotional labor: A meta-analysis of three decades of research. *Journal of Occupational Health Psychology, 16*(3), 361-389

Humphries, M., & Gurney, K. (2007). A means to an end: validating models by fitting experimental data. *Neurocomputing, 70*(10), 1892-1896.

Hung, I. W., & Labroo, A. A. (2011). From firm muscles to firm willpower: Understanding the role of embodied cognition in self-regulation. *Journal of Consumer Research, 37*(6), 1046-1064.

Ilies, R., & Judge, T. A. (2005). Goal regulation across time: the effects of feedback and affect. *Journal of Applied Psychology, 90*(3), 453-467.

Ilies, R., Wagner, D. T., & Morgeson, F. P. (2007). Explaining affective linkages in teams: Individual differences in susceptibility to contagion and individualism-collectivism. *Journal of Applied Psychology, 92*(4), 1140-1148.

Jackson, D.C., Mueller, M.J., Dolski, I., Dalton, K.M., Nitschke, J.B., Urry, H.L., … Davidson, R.J., (2003). Now you feel it, now you don’t: Frontal brain electrical asymmetry and individual differences in emotion regulation. *Psychological Science 14*, 612–617

James, W. (1884). What is an Emotion? *Mind, 9*, 188-205.

James, W. (1892). Psychology: A Briefer Course. New York: Holt.

Jarrett, R.J. (1979). Rhythms in insulin and glucose. In T.T. Krieger (Ed.), *Endocrine rhythms* (p. 247–258). New York: Raven.

Job, V., Dweck, C. S., & Walton, G. M. (2010). Ego Depletion—Is It All in Your Head? *Psychological Science, 21*(11), 1686-1693.

Johnson, E. I., Husky, M., Grondin, O., Mazure, C. M., Doron, J., & Swendsen, J. (2008). Mood trajectories following daily life events. *Motivation and Emotion, 32*(4), 251-259.

Joiner, T. E. (1994). Contagious depression: Existence, specificity to depressed symptoms, and the role of reassurance seeking. *Journal of Personality and Social Psychology, 67*(2), 287-296.

Judge, T. A., Woolf, E. F., & Hurst, C. (2009). Is emotional labour more difficult from some than others? A multilevel, experience sampling survey. *Personnel Psychology, 62*(1), 57-88.

Kappas, A. (2011). Emotion and regulation are one! *Emotion Review, 3*(1), 17-25.

Karoly, P., & Kanfer, F. (1982). *Self-management and behaviour change.* Cambridge, UK: Cambridge University Press.

Keesey, R. E., & Powley, T. L. (1986). The regulation of body weight. *Annual review of psychology, 37*(1), 109-133.

Keillor, J. M., Barrett, A. M., Crucian, G. P., Kortenkamp, S., & Heilman, K. M. (2002). Emotional experience and perception in the absence of facial feedback. *Journal of the International Neuropsychological Society, 8*(1), 130-135.

Kelly, J. R., & Barsade, S. G. (2001). Mood and emotions in small groups and work teams. *Organizational Behavior and Human Decision Processes, 86*(1), 99-130.

Kelly, R. E., Mansell, W., & Wood, A. M. (2011). Goal conflict and ambivalence interact to predict depression. *Personality and Individual Differences, 50*(4), 531-534.

Keltner, D., & Haidt, J. (1999). Social functions of emotions at four levels of analysis. *Cognition & Emotion, 13*(5), 505-521.

Killgore, W. D. S., Balkin, T. J., & Wesensten, N. J. (2006). Impaired decision making following 49 h of sleep deprivation. *Journal of Sleep Research, 15*(1), 7-13.

King, L. A., & Emmons, R. A. (1991). Psychological, physical, and interpersonal correlates of emotional expressiveness, conflict, and control. *European Journal of Personality, 5*(2), 131-150.

Kirschenbaum, D. S. (1987). Self-regulatory failure: A review with clinical implications. *Clinical Psychology Review, 7*(1), 77-104.

Kirschenbaum, D. S., Malett, S. D., Humphrey, L. L., & Tomarken, A. J. (1982). Specificity of planning and the maintenance of self-control: 1 year follow-up of a study improvement program. *Behavior Therapy, 13*(2), 232-240.

Kirschenbaum, D. S., Tomarken, A. J., & Ordman, A. M. (1982). Specificity of planning and choice applied to adult self-control. *Journal of Personality and Social Psychology, 42*(3), 576-585.

Kleinke, C. L., Peterson, T. R., & Rutledge, T. R. (1998). Effects of self-generated facial expressions on mood. *Journal of Personality and Social Psychology, 74*(1), 272-279.

Koole, S. L. (2009). The psychology of emotion regulation: An integrative review. *Cognition and Emotion, 23*(1), 4-41.

Kraut, R. E., & Johnston, R. E. (1979). Social and emotional messages of smiling: An ethological approach. *Journal of Personality and Social Psychology, 37*(9), 1539-1553.

Krohne, H. W., Pieper, M., Knoll, N., & Breimer, N. (2002). The cognitive regulation of emotions: The role of success versus failure experience and coping dispositions. *Cognition & Emotion, 16*(2), 217-243.

Krueger, F., Barbey, A. K., McCabe, K., Strenziok, M., Zamboni, G., Solomon, J., … Grafman, J. (2009). The neural bases of key competencies of emotional intelligence. *Proceedings of the National Academy of Sciences, 106*(52), 22486-22491.

Krumhuber, E. G., & Manstead, A. S. R. (2009). Can Duchenne smiles be feigned? New evidence on felt and false smiles. *Emotion, 9*(6), 807-820

Kunkle, D. R., & Merrigan, C. (2002). Pulsed neural networks and their application. *Computer Science Dept., College of Computing and Information Sciences, Rochester Institute of Technology*.

Kuppens, P., Oravecz, Z., & Tuerlinckx, F. (2010). Feelings change: accounting for individual differences in the temporal dynamics of affect. *Journal of Personality and Social Psychology, 99*(6), 1042-1060.

Labouvie-Vief, G., & Medler, M. (2002). Affect optimization and affect complexity: Modes and styles of regulation in adulthood. *Psychology and aging, 17*(4), 571-587.

Laird, J. (1984). "The Real Role of Facial Response in the Experience of Emotion: A Reply to Tourangeau and Ellsworth and Others." *Journal of Personality and Social Psychology, 47,* 909-917

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). International affective picture system (IAPS): Technical manual and affective ratings: Gainesville, FL: The Center for Research in Psychophysiology, University of Florida.

Lange, C. G. (1922). The emotions: A psychophysiological study (I. A. Haupt, Trans.). In K. Dunlap (Ed.), *The emotions* (Vol. 1, pp. 33-90). Baltimore, US: Williams & Wilkins. (Original work published 1885)

Larsen, R. J. (2000). Toward a science of mood regulation. *Psychological inquiry, 11*(3), 129-141.

Larsen, R. J. (2005, July). *Affect regulation: Conceptual issues and application to organisations*. Paper presented at Rotterdam Conference on Emotions in Organisations, Rotterdam, Netherlands.

Larsen, R. J., Augustine, A. A., & Prizmic, Z. (2009). A process approach to emotion and personality: Using time as a facet of data. *Cognition and Emotion, 23*(7), 1407-1426.

Larsen, R. J., Diener, E., & Emmons, R. A. (1986). Affect intensity and reactions to daily life events. *Journal of Personality and Social Psychology, 51*(4), 803-814

Larsen, R. J., & Prizmic, Z. (2004). Affect regulation. In R. F. Baumeister, & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 40-61). New York, US: Guilford Press.

Latham, G. P., & Locke, E. A. (1991). Self-regulation through goal setting. *Organizational Behavior and Human Decision Processes, 50*(2), 212-247.

Lazarus, R.S. (1966). *Psychological stress and the coping process.* New York, US: McGraw-Hill.

Lazarus, R. S. (1968). Emotions and adaptation. In W. J. Arnold (Ed.), *Nebraska Symposium on Motivation* (Vol. 16). Lincoln: University of Nebraska Press.

Lazarus, R. S. (1991). *Emotion and Adaptation.* New York, US: Oxford University Press.

Leary, M. R. (1995). *Self-presentation: Impression management and interpersonal behavior. Social psychology series.* Madison, US: Brown and Benchmark.

Lewis, M. D. (2005). Bridging emotion theory and neurobiology through dynamic systems modeling. *Behavioral and Brain Sciences, 28*(2), 169-193.

Liu, Y., Prati, L. M., Perrewé, P. L., & Ferris, G. R. (2008). The relationship between emotional resources and emotional labor: An exploratory study. *Journal of Applied Social Psychology, 38*(10), 2410-2439.

Locke, E. A. (1996). Motivation through conscious goal setting. *Applied and Preventive Psychology, 5*(2), 117-124.

Locke, E. A., & Latham, G. P. (1990). *A theory of goal setting & task performance.* Englewood Cliffs, US: Prentice-Hall.

Lord, R. G., & Hanges, P. J. (1987). A control system model of organizational motivation: Theoretical development and applied implications. *Behavioral Science, 32*(3), 161-178.

Louie, M. A., & Carley, K. M. (2008). Balancing the criticisms: Validating multi-agent models of social systems. *Simulation Modelling Practice and Theory, 16*(2), 242-256.

Lucas, R. E. (2007). Adaptation and the Set-Point Model of Subjective Well-Being Does Happiness Change After Major Life Events? *Current Directions in Psychological Science, 16*(2), 75-79.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: an integrative review. *Psychological Bulletin, 109*(2), 163-203.

Magoun, H., Harrison, F., Brobeck, J., & Ranson, S. (1938). Activation of heat loss mechanisms by local heating of the brain. *Journal of Neurophysiology*, *1*, 101-114.

Mann, S., & Cowburn, J. (2005). Emotional labour and stress within mental health nursing. *Journal of Psychiatric and Mental Health Nursing, 12*(2), 154-162.

Maria, K. A., & Zitar, R. A. (2007). Emotional agents: A modeling and an application. *Information and Software Technology, 49*(7), 695-716.

Marr, D. (1982). *Vision*: *A Computational Investigation into the Human Representation and Processing of Visual Information.* San Francisco: Freeman.

Martínez-Iñigo, D., Totterdell, P., Alcover, C. M., & Holman, D. (2007). Emotional labour and emotional exhaustion: Interpersonal and intrapersonal mechanisms. *Work & Stress, 21*(1), 30-47.

Masicampo, E. J., & Baumeister, R. F. (2008). Toward a physiology of dual-process reasoning and judgment: Lemonade, willpower, and expensive rule-based analysis. *Psychological Science, 19*(3), 255-260.

Mauss, I. B., Bunge, S. A., & Gross, J. J. (2007). Automatic emotion regulation. *Social and Personality Psychology Compass, 1*(1), 146-167.

Mauss, I. B., Cook, C. L., & Gross, J. J. (2007). Automatic emotion regulation during anger provocation. *Journal of Experimental Social Psychology, 43*(5), 698-711.

Mauss, I. B., Levenson, R. W., McCarter, L., Wilhelm, F. H., & Gross, J. J. (2005). The tie that binds? Coherence among emotion experience, behavior, and physiology. *Emotion, 5*(2), 175-190.

Mauss, I. B., & Robinson, M. D. (2009). Measures of emotion: A review. *Cognition and Emotion, 23*(2), 209-237.

McIntosh, D. N. (1996). Facial feedback hypotheses: Evidence, implications, and directions. *Motivation and Emotion, 20*(2), 121-147.

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). *Plans and the Structure of Behavior*. New York: Holt, Rinehart & Winston

Miller, H. C., Pattison, K. F., DeWall, C. N., Rayburn-Reeves, R., & Zentall, T. R. (2010). Self-Control Without a "Self"? *Psychological Science, 21*(4), 534-538.

Miller, R. S., & Leary, M. R. (1992). Social sources and interactive functions of emotion: The case of embarrassment. In M. S. Clark (Ed), *Emotion and social behavior*. (*Review of personality and social psychology*) (Vol 14. pp. 202-221). Thousand Oaks, US: Sage.

Mischel, W. (1974). Processes in delay of gratification. *Advances in experimental social psychology, 7*, 249-292.

Moore, M., Kirchner, H. L., Drotar, D., Johnson, N., Rosen, C., Ancoli-Israel, S., & Redline, S. (2009). Relationships among sleepiness, sleep time, and psychological functioning in adolescents. *Journal of pediatric psychology, 34*(10), 1175-1183.

Morling, B., & Evered, S. (2006). Secondary control reviewed and defined. *Psychological Bulletin, 132*(2), 269- 296.

Morris, W. N. (2000). Some thoughts about mood and its regulation. *Psychological inquiry, 11*(3), 200-202.

Morris, J. A., & Feldman, D. C. (1996). The dimensions, antecedents, and consequences of emotional labor. *Academy of Management Review*, 986-1010.

Morris, J. A., & Feldman, D. C. (1997). Managing emotions in the workplace. *Journal of Managerial Issues*, 257-274.

Morris, W. N., & Reilly, N. P. (1987). Toward the self-regulation of mood: Theory and research. *Motivation and Emotion, 11*(3), 215-249.

Mueleman, B., & Scherer, K. (2012, May). *Is the relation between appraisal and emotion nonlinear?* Poster presented at CERE Fourth European Conference on Emotion, Canterbury, UK.

Muraven, M. (2010). Building self-control strength: Practicing self-control leads to improved self-control performance. *Journal of Experimental Social Psychology, 46*(2), 465-468.

Muraven, M., & Baumeister, R. F. (2000). Self-regulation and depletion of limited resources: Does self-control resemble a muscle? *Psychological Bulletin, 126*(2), 247-259.

Muraven, M., Collins, R. L., Shiffman, S., & Paty, J. A. (2005). Daily fluctuations in self-control demands and alcohol intake. *Psychology of Addictive Behaviors, 19*(2), 140-147.

Muraven, M., Shmueli, D., & Burkley, E. (2006). Conserving self-control strength. *Journal of Personality and Social Psychology, 91*(3), 524-537.

Muraven, M., & Slessareva, E. (2003). Mechanisms of self-control failure: Motivation and limited resources. *Personality and Social Psychology Bulletin, 29*(7), 894-906.

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as a limited resource: Regulatory depletion patterns. *Journal of Personality and Social Psychology, 74*(3), 774-789.

Murray, G., Allen, N. B., & Trinder, J. (2002). Mood and the circadian system: Investigation of a circadian component in positive affect. *Chronobiology International, 19*(6), 1151-1169.

Näring, G., Briët, M., & Brouwers, A. (2006). Beyond demand–control: Emotional labour and symptoms of burnout in teachers. *Work & Stress, 20*(4), 303-315.

Neumann, R., & Strack, F. (2000). " Mood contagion": the automatic transfer of mood between persons. *Journal of Personality and Social Psychology, 79*(2), 211-223.

Niedenthal, P. M. (2007). Embodying emotion. *Science, 316*(5827), 1002-1005.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review, 9*(3), 184-211.

Nilsson, J. P., Söderström, M., Karlsson, A. U., Lekander, M., Åkerstedt, T., Lindroth, N. E., & Axelsson, J. (2005). Less effective executive functioning after one night's sleep deprivation. *Journal of Sleep Research, 14*(1), 1-6.

Niven, K., Totterdell, P., & Holman, D. (2009). A classification of controlled interpersonal affect regulation strategies. *Emotion, 9*(4), 498-509

Niven, K.., Totterdell, P., Holman, D., & Cameron, D. (in press). Emotional Labor at the Unit-level In Grandey, A., Diefendorff, J., Rupp, D. (Eds.), *Emotional Labor in the 21st Century: Diverse Perspectives on the Psychology of Emotion Regulation at Work*. Routledge Academic.

Niven, K., Totterdell, P., Miles, E., Webb, T. L., & Sheeran, P. (in press). Achieving the same for less: Improving mood depletes blood glucose for people with poor (but not good) emotion control. *Cognition & Emotion,*

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behavior. In J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (Vol. 4, pp. 1-18). New York, US: Plenum

Oaten, M., Williams, K. D., Jones, A., & Zadro, L. (2008). The effects of ostracism on self-regulation in the socially anxious. *Journal of Social and Clinical Psychology, 27*(5), 471-504.

Oberman, L. M., Winkielman, P., & Ramachandran, V. S. (2007). Face to face: Blocking facial mimicry can selectively impair recognition of emotional expressions. *Social Neuroscience, 2*(3-4), 167-178.

Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. E. (2002). Rethinking feelings: An fMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience, 14*(8), 1215-1229.

Oravecz, Z., Tuerlinckx, F., & Vandekerckhove, J. (2009). A hierarchical Ornstein-Uhlenbeck model for continuous repeated measurement data. *Psychometrika*, *74*, 395-418

Oravecz, Z., Tuerlinckx, F., & Vandekerckhove, J. (2011). A hierarchical latent stochastic differential equation model for affective dynamics. *Psychological Methods*, *16*, 468-490.

Owens, D. S., Macdonald, I., Tucker, P., Sytnik, N., Totterdell, P., Minors, D., . . . Folkard, S. (2000). Diurnal variations in the mood and performance of highly practised young women living under strictly controlled conditions. *British Journal of Psychology, 91*(1), 41-60.

Panksepp, J. (2003). At the interface of the affective, behavioral, and cognitive neurosciences: Decoding the emotional feelings of the brain. *Brain and cognition, 52*(1), 4-14.

Parkinson, B. (1996). Emotions are social. *British Journal of Psychology, 87*(4), 663-683.

Parkinson, B. (2005). Do facial movements express emotions or communicate motives. *Personality and Social Psychology Review, 9*(4), 278-311.

Parkinson, B., Fischer, A., & Manstead, A. S. R. (2005). *Emotion in social relations: Cultural, group, and interpersonal processes.* New York, US: Psychology Press.

Parkinson, B., & Totterdell, P. (1999). Classifying affect-regulation strategies. *Cognition & Emotion, 13*(3), 277-303.

Parkinson, B., Totterdell, P., Briner, R. B., & Reynolds, S. (1996). *Changing moods: The psychology of mood and mood regulation*. London, UK: Addison Wesley Longman.

Parrott, W. G. (1993). Beyond hedonism: Motives for inhibiting good moods and for maintaining bad moods. In D. M. Wegner & J. W. Pennebaker (Eds.), *Handbook of mental control* (pp. 278 –305). Engle-wood Cliffs, US: Prentice Hall.

Petersen, M. B. (2010). Distinct emotions, distinct domains: Anger, anxiety and perceptions of intentionality. *The Journal of Politics, 72*(02), 357-365.

Powers, W. T. (1973). Feedback: beyond behaviorism. *Science, 179*(4071), 351-356.

Powers, W. T. (1974). *Behavior: The control of perception*. London, UK: Wildwood House.

Powers, W. T. (2005). *Behavior: The control of perception* (Rev. ed.). Benchmark Publications.

Powers, W. T., Clark, R. K., & McFarland, R. I. (1960a) A general feedback theory of human behaviour: Part 1, *Perceptual and Motor Skills*, 11, 71-88.

Powers, W. T., Clark, R. K., & McFarland, R. I. (1960b) A general feedback theory of human behaviour: Part 2, *Perceptual and Motor Skills*, 11, 71-88

Pugliesi, K. (1999). The consequences of emotional labor: Effects on work stress, job satisfaction, and well-being. *Motivation and Emotion, 23*(2), 125-154.

Quirk, G. J., & Beer, J. S. (2006). Prefrontal involvement in the regulation of emotion: convergence of rat and human studies. *Current opinion in neurobiology, 16*(6), 723-727.

Ragan, R. (2010, July). *Omitted Paramater Bias in Agent Based Models*. Paper presented at the 27th Annual Society for Political Methodology Summer Conference, Iowa.

Remington, N. A., Fabrigar, L. R., & Visser, P. S. (2000). Reexamining the circumplex model of affect. *Journal of Personality and Social Psychology; Journal of Personality and Social Psychology, 79*(2), 286-300.

Richards, J. M., & Gross, J. J. (1999). Composure at any cost? The cognitive consequences of emotion suppression. *Personality and Social Psychology Bulletin, 25*(8), 1033-1044.

Richards, J. M., & Gross, J. J. (2000). Emotion regulation and memory: the cognitive costs of keeping one's cool. *Journal of Personality and Social Psychology, 79*(3), 410-424

Riediger, M., Schmiedek, F., Wagner, G. G. and Lindenberger, U. (2009). Seeking Pleasure and Seeking Pain: Differences in Prohedonic and Contra-Hedonic Motivation From Adolescence to Old Age. *Psychological Science*, 20, 1529-1535.

Rimé, B. (2007). The social sharing of emotion as an interface between individual and collective processes in the construction of emotional climates. *Journal of Social Issues, 63*(2), 307-322.

Rimé, B. (2009). Emotion elicits the social sharing of emotion: Theory and empirical review. *Emotion Review, 1*(1), 60-85.

Rime, B., Mesquita, B., Boca, S., & Philippot, P. (1991). Beyond the emotional event: Six studies on the social sharing of emotion. *Cognition & Emotion, 5*(5-6), 435-465.

Roberts, S., & Pashler, H. (2000). How persuasive is a good fit? A comment on theory testing. *Psychological review, 107*(2), 358-367.

Rodgers, J. L., & Rowe, D. C. (2002). Theory development should begin (but not end) with good empirical fits: A comment on Roberts and Pashler (2000), *109*(3), 599-603

Rosenberg, E. L., & Ekman, P. (1994). Coherence between expressive and experiential systems in emotion. *Cognition & Emotion, 8*(3), 201-229.

Rottenberg, J. (2005). Mood and emotion in major depression. *Current Directions in Psychological Science, 14*(3), 167-170.

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*(6), 1161-1178

Russell, J. A. (1989). Measures of emotion. In R. Plutchik, & H Kellerman (Eds.), *The measurement of emotions. Emotion: theory, research, and experience*, (Vol 4. pp. 83-111). San Diego, US: Academic Press.

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological review, 110*(1), 145-172.

Russell, J. A. (2009). Emotion, core affect, and psychological construction. *Cognition and Emotion, 23*(7), 1259-1283.

Russell, J. A., & Carroll, J. M. (1999). On the bipolarity of positive and negative affect. *Psychological Bulletin, 125*(1), 3-30.

Sander, D., Grandjean, D., & Scherer, K. R. (2005). A systems approach to appraisal mechanisms in emotion. *Neural networks, 18*(4), 317-352.

Schachter, S., & Singer, J. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review; Psychological Review, 69*(5), 379-399.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding: An inquiry into human knowledge structures* (Vol. 2): Lawrence Erlbaum Associates Hillsdale, NJ.

Scherer, K. R. (1984). On the nature and function of emotion: A component process approach. In K. R. Scherer & P. Ekman (Eds.) Approaches to emotion, (pp.293-318). Hillsdale, US: Erlbaum

Scherer, K. R. (2000a). Emotions as episodes of subsystem synchronization driven by nonlinear appraisal processes. In M. D. Lewis & I. Granic (Eds.), *Emotion, development, and self-organization: Dynamic systems approaches to emotional development* (pp. 70 –99). New York, US: Cambridge University Press.

Scherer, K. R. (2000b). Emotion. In M. Hewstone & W. Stroebe (Eds.) *Introduction to social psychology: A European perspective* (3rd ed., pp 151–191). Oxford, UK: Blackwell.

Scherer, K. R. (2009). The dynamic architecture of emotion: Evidence for the component process model. *Cognition and Emotion, 23*(7), 1307-1351.

Schmeichel, B. J., Demaree, H. A., Robinson, J. L., & Pu, J. (2006). Ego depletion by response exaggeration. *Journal of Experimental Social Psychology, 42*(1), 95-102.

Schmeichel, B. J., & Vohs, K. (2009). Self-affirmation and self-control: Affirming core values counteracts ego depletion. *Journal of Personality and Social Psychology, 96*(4), 770-782

Schmidt, R.A. (1988) *Motor control and learning: A behaviour emphasis* (2nd ed.) Champain, USA: Human Kinetics Publishers.

Schmidt, K. H., Neubach, B., & Heuer, H. (2007). Self-control demands, cognitive control deficits, and burnout. *Work & Stress, 21*(2), 142-154.

Schnall, S., Zadra, J. R., & Proffitt, D. R. (2010). Direct evidence for the economy of action: Glucose and the perception of geographical slant. *Perception, 39*(4), 464-482.

Schubert, T. W. (2004). The power in your hand: Gender differences in bodily feedback from making a fist. *Personality and Social Psychology Bulletin, 30*(6), 757-769.

Scott, J. P. R., McNaughton, L. R., & Polman, R. C. J. (2006). Effects of sleep deprivation and exercise on cognitive, motor performance and mood. *Physiology & Behavior, 87*(2), 396-408.

Segerstrom, S. C., & Nes, L. S. (2007). Heart rate variability reflects self-regulatory strength, effort, and fatigue. *Psychological Science, 18*(3), 275-281.

Sheppes, G., Catran, E., & Meiran, N. (2009). Reappraisal (but not distraction) is going to make you sweat: Physiological evidence for self-control effort. *International Journal of Psychophysiology, 71*(2), 91-96.

Sheppes, G., & Gross, J. J. (2011). Is timing everything? Temporal considerations in emotion regulation. *Personality and Social Psychology Review, 15*(4), 319-331.

Sloman, A. (2001). Beyond shallow models of emotion. *Cognitive Processing*, *2*(1), 177–198.

Smith, C. A., & Lazarus, R. S. (1990). Emotion and adaptation. In L. A. Pervin, (Ed), *Handbook of personality: Theory and research* (pp. 609-637). New York, US: Guilford Press.

Smith, E. R., & Conrey, F. R. (2007). Agent-based modeling: A new approach for theory building in social psychology. *Personality and Social Psychology Review, 11*(1), 87-104.

Smyth, J. M., & Arigo, D. (2009). Recent evidence supports emotion-regulation interventions for improving health in at-risk and clinical populations. *Current opinion in psychiatry, 22*(2), 205-210.

Snyder, M., & Gangestad, S. (1982). Choosing social situations: Two investigations of self-monitoring processes. *Journal of Personality and Social Psychology; Journal of Personality and Social Psychology, 43*(1), 123-135.

Solomon, R. L., & Corbit, J. D. (1974). An opponent-process theory of motivation: I. Temporal dynamics of affect. *Psychological review, 81*(2), 119-145

Sonnemans, J., & Frijda, N. H. (1994). The structure of subjective emotional intensity. *Cognition & Emotion, 8*(4), 329-350.

Soussignan, R. (2004). Regulatory function of facial actions in emotion processes. In S. P. Shohov (Ed), *Advances in psychology research* (Vol. 31 pp. 173-198). Hauppauge, US: Nova Science.

Stafford, T. (2009). What use are computational models of cognitive processes? In J. Mayor, N. Ruh & K. Plunkett (Eds.) *Connectionist Models of Behavior and Cognition II: Proceedings of the 11th Neural Computation and Psychology Workshop* (pp. 265-274). World Scientific.

Stepper, S., & Strack, F. (1993). Proprioceptive determinants of emotional and nonemotional feelings. *Journal of Personality and Social Psychology, 64*(2), 211-220.

Stone, A. A., Hedges, S. M., Neale, J. M., & Satin, M. S. (1985). Prospective and cross-sectional mood reports offer no evidence of a" blue Monday" phenomenon. *Journal of Personality and Social Psychology, 49*(1), 129-134.

Stone, A. A., & Neale, J. M. (1984). Effects of severe daily events on mood. *Journal of Personality and Social Psychology, 46*(1), 137-144.

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: a nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology, 54*(5), 768-777.

Sullins, E. S. (1991). Emotional contagion revisited: Effects of social comparison and expressive style on mood convergence. *Personality and Social Psychology Bulletin, 17*(2), 166-174.

Sun, R., Coward, L. A., & Zenzen, M. J. (2005). On levels of cognitive modeling. *Philosophical Psychology, 18*(5), 613-637.

Sy, T., Côté, S., & Saavedra, R. (2005). The contagious leader: impact of the leader's mood on the mood of group members, group affective tone, and group processes. *Journal of Applied Psychology, 90*(2), 295-305.

Tamir, M. (2005). Don't worry, be happy? Neuroticism, trait-consistent affect regulation, and performance. *Journal of Personality and Social Psychology, 89*(3), 449-461.

Tamir, M. (2009a). What Do People Want to Feel and Why? *Current Directions in Psychological Science, 18*(2), 101-105.

Tamir, M. (2009b). Differential Preferences for Happiness: Extraversion and Trait-Consistent Emotion Regulation. *Journal of Personality, 77*(2), 447-470.

Tamir, M., & Ford, B. Q. (2009). Choosing to be afraid: Preferences for fear as a function of goal pursuit. *Emotion; Emotion, 9*(4), 488-497.

Tamir, M., Mitchell, C., & Gross, J. J. (2008). Hedonic and instrumental motives in anger regulation. *Psychological Science, 19*(4), 324-328.

Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality*, *72*(2), 271-324.

Tempesta, D., Couyoumdjian, A., Curcio, G., Moroni, F., Marzano, C., De Gennaro, L., & Ferrara, M. (2010). Lack of sleep affects the evaluation of emotional stimuli. *Brain Research Bulletin*, *29*, 104–108.

Thagard, P., & Nerb, J. (2002). Emotional gestalts: Appraisal, change, and the dynamics of affect. *Personality and Social Psychology Review, 6*(4), 274-282.

Thayer, R. E., Newman, J. R., & McClain, T. M. (1994). Self-regulation of mood: Strategies for changing a bad mood, raising energy, and reducing tension. *Journal of Personality and Social Psychology, 67*(5), 910-925

Thompson, L., & Fine, G. A. (1999). Socially shared cognition, affect, and behavior: A review and integration. *Personality and Social Psychology Review, 3*(4), 278-302.

Thompson, N. S., & Derr, P. (2009). Contra Epstein, good explanations predict. *Journal of Artificial Societies and Social Simulation, 12*(1), 9. <http://jasss.soc.surrey.ac.uk/12/1/9.html>

Thompson, R. A. (1994). Emotion regulation: A theme in search of definition. *Monographs of the society for research in child development*, *59*(2) 25-52.

Tice, D. M. (1992). Self-concept change and self-presentation: The looking glass self is also a magnifying glass. *Journal of Personality and Social Psychology, 63*(3), 435-451.

Tice, D. M., Baumeister, R. F., Shmueli, D., & Muraven, M. (2007). Restoring the self: Positive affect helps improve self-regulation following ego depletion. *Journal of Experimental Social Psychology, 43*(3), 379-384.

Tice, D. M., & Bratslavsky, E. (2000). Giving in to feel good: The place of emotion regulation in the context of general self-control. *Psychological inquiry, 11*(3), 149-159.

Totterdell, P. (1995). Effects of depressed affect on diurnal and ultradian variations in mood in a healthy sample. *Chronobiology international, 12*(4), 278-289.

Totterdell, P. (2000). Catching moods and hitting runs: Mood linkage and subjective performance in professional sport teams. *Journal of Applied Psychology, 85*(6), 848-859.

Totterdell, P., Hershcovis, M. S., Niven, K., Reich, T. C., & Stride, C. (2012). Can employees be emotionally drained by witnessing unpleasant interactions between coworkers? A diary study of induced emotion regulation. *Work & Stress, 26*(2), 112-129.

Totterdell, P., & Holman, D. (2003). Emotion regulation in customer service roles: Testing a model of emotional labor. *Journal of Occupational Health Psychology; Journal of Occupational Health Psychology, 8*(1), 55-73.

Totterdell, P., & Kellett, S. (2008). Restructuring mood in cyclothymia using cognitive behavior therapy: an intensive time-sampling study. *Journal of Clinical Psychology, 64*(4), 501-518.

Totterdell, P., & Parkinson, B. (1999). Use and effectiveness of self-regulation strategies for improving mood in a group of trainee teachers. *Journal of Occupational Health Psychology, 4*(3), 219-232.

Totterdell, P., Wall, T., Holman, D., Diamond, H., & Epitropaki, O. (2004). Affect networks: a structural analysis of the relationship between work ties and job-related affect. *Journal of Applied Psychology, 89*(5), 854-867.

Trull, T. J., Solhan, M. B., Tragesser, S. L., Jahng, S., Wood, P. K., Piasecki, T. M., & Watson, D. (2008). Affective instability: Measuring a core feature of borderline personality disorder with ecological momentary assessment. *Journal of Abnormal Psychology, 117*(3), 647-661.

Tsai, J. L., Miao, F. F., Seppala, E., Fung, H. H., & Yeung, D. Y. (2007). Influence and adjustment goals: sources of cultural differences in ideal affect. *Journal of Personality and Social Psychology, 92*(6), 1102-1117.

Tyler, J. M., & Burns, K. C. (2008). After depletion: The replenishment of the self's regulatory resources. *Self and Identity, 7*(3), 305-321.

Tyler, J. M., & Burns, K. C. (2009). Triggering conservation of the self's regulatory resources. *Basic and Applied Social Psychology, 31*(3), 255-266.

Urry, H. L. (2009). Using reappraisal to regulate unpleasant emotional episodes: Goals and timing matter. *Emotion, 9*(6), 782-797.

Van Kleef, G. A. (2009). How Emotions Regulate Social Life The Emotions as Social Information (EASI) Model. *Current Directions in Psychological Science, 18*(3), 184-188.

Van Kleef, G. A., De Dreu, C. K. W., & Manstead, A. S. R. (2004). The interpersonal effects of emotions in negotiations: a motivated information processing approach. *Journal of Personality and Social Psychology, 87*(4), 510-528.

Vancouver, J. B., & Kendall, L. N. (2006). When self-efficacy negatively relates to motivation and performance in a learning context. *Journal of Applied Psychology, 91*(5), 1146-1153.

vanDellen, M. R., & Hoyle, R. H. (2010). Regulatory accessibility and social influences on state self-control. *Personality and Social Psychology Bulletin, 36*(2), 251-263.

Velasquez, J.D. 1997. Modeling Emotions and Other Motivations in Synthetic Agents. In *Proceedings of the Fourteenth National Conference on Artificial Intelligence*, 10-15. Menlo Park, Calif.: AAAI Press.

Verduyn, P., Van Mechelen, I., Tuerlinckx, F., Meers, K., & Van Coillie, H. (2009). Intensity profiles of emotional experience over time. *Cognition and Emotion, 23*(7), 1427-1443.

Vohs, K. D., Glass, B. D., Maddox, W. T., & Markman, A. B. (2011). Ego depletion is not just fatigue. *Social Psychological and Personality Science, 2*(2), 166-173.

Vroom, V. H. (1964). *Work and motivation*. Oxford, UK: Wiley.

Walker, M. P., & Van Der Helm, E. (2009). Overnight therapy? The role of sleep in emotional brain processing. *Psychological Bulletin; Psychological Bulletin, 135*(5), 731-748

Wallbott, H. G. (1998). Bodily expression of emotion. *European journal of social psychology, 28*(6), 879-896.

Watson, D. & Clark, L A. (1994) Emotions, moods, traits, and temperaments: Conceptual distinctions and empirical findings. In P. Ekman, & R. J. Davidson (Eds.), *The nature of emotion: Fundamental questions* (89-93). New York: Oxford University Press.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of personality and social psychology*, *54*(6), 1063.

Watson, D., Wiese, D., Vaidya, J., & Tellegen, A. (1999). The two general activation systems of affect: Structural findings, evolutionary considerations, and psychobiological evidence. *Journal of Personality and Social Psychology, 76*(5), 820-838

Wegge, J., Dick, R., Fisher, G. K., West, M. A., & Dawson, J. F. (2006). A Test of Basic Assumptions of Affective Events Theory (AET) in Call Centre Work1. *British Journal of Management, 17*(3), 237-254.

Wiener. N. (1948). *Cybernetics: Or control and communication in the animal and the machine.* Cambridge US: MIT Press.

Weiss, H. M., & Cropanzano, R. (1996). Affective events theory: A theoretical discussion of the structure, causes and consequences of affective experiences at work. B. M. Staw, & L. L. Cummings (Eds.), *Research in organizational behavior: An annual series of analytical essays and critical reviews* (Vol. 18 pp. 1-74). New York, US: Elsevier Science.

Whitton, J. L. (1978). Periodicities in self-reports of health, sleep and mood variables. *Journal of Psychosomatic Research, 22*(2), 111-115.

Wild, B., Erb, M., & Bartels, M. (2001). Are emotions contagious? Evoked emotions while viewing emotionally expressive faces: quality, quantity, time course and gender differences. *Psychiatry research, 102*(2), 109-124.

Williams, K. J., Donovan, J. J., & Dodge, T. L. (2000). Self-regulation of performance: Goal establishment and goal revision processes in athletes. *Human Performance, 13*(2), 159-180.

Williams, L. E., Bargh, J. A., Nocera, C. C., & Gray, J. R. (2009). The unconscious regulation of emotion: nonconscious reappraisal goals modulate emotional reactivity. *Emotion, 9*(6), 847-854.

Wood, J. V., Heimpel, S. A., Manwell, L. A., & Whittington, E. J. (2009). This mood is familiar and I don't deserve to feel better anyway: Mechanisms underlying self-esteem differences in motivation to repair sad moods. *Journal of Personality and Social Psychology, 96*(2), 363-380.

Wrosch, C., Scheier, M. F., Carver, S. C., & Schulz, R. (2003). The importance of goal disengagement in adaptive self-regulation: When giving up is beneficial. *Self and Identity, 2*(1), 1-20.

Zapf, D. (2002). Emotion work and psychological well-being: A review of the literature and some conceptual considerations. *Human Resource Management Review, 12*(2), 237-268.

Zohar, D., Tzischinsky, O., Epstein, R., & Lavie, P. (2005). The effects of sleep loss on medical residents' emotional reactions to work events: a cognitive-energy model. *Sleep: Journal of Sleep and Sleep Disorders Research, 28*(1), 47-54.

Appendix 1: Resource Model Formulae

Resource (R_c) at time (t) is determined by the following formulae:

Awake function:

$S(t) = (Sa - L)\ e^{-0.0353t} + L$

Where S is the current level of alertness, Sa is alertness at time of waking and L is the lower asymptote for alertness in this function. L is specified as being 2.4. As time passes in the simulation alertness levels deplete from the level at Sa to that of L due to the wake function.

Sleep function:

$\mathrm{S}(t) = M - (M - Ss)\ e^{-0.0381t}$

Unless $S(t) < 12.5$ then $S(t) = S_{(t\text{-}1)} + (M - (M - Ss)\ \mathrm{e}^{-0.0381t}) - 12.5$

Where R is the current level of alertness, Ss is alertness at time of sleeping and M is the max asymptote for alertness in this function. M is specified as being 14.3. As time passes in the simulation alertness levels restore from the level at S*s* to that of M due to the sleep function.

The use of either the *sleep* or *awake* function to determine S(t) is governed by an external signal determining the model's sleeping or waking status.

Circadian function:

$C(\mathrm{t}) = \cos (\pi / 12 / \tau * t - p_c)$

Where τ represents the temporal resolution of the simulation (specified at 1000) and p_c represents the point of achrophase for the circadian cycle (adjusted for each individual, default value 4.3966)

An Ultradian function is set with a peak of 0.5 the circadian function, a period of 12 hours and an acrophase 3 hours ahead of the circadian acrophase. $p_u = p_c - 3$

$U(\mathrm{t}) = 0.5 \cos (\pi / 6 / \tau * t - p_u * \pi / 6)$

Resource (R_c) in the resource block is determined by the collective output of the functions:

$R_c(t) = S(t) + 0.1748 * (C(t) - U(t))$

Appendix 2: Glossary of Terms Used in Chapter 5

Coherence	Current Perceived Felt-Affect state acting as a home-base for Perceived Affect-Expression
Discrep.	Detected discrepancy between perceived affect or affect goal state and reference state
Eval.	Evaluation of stimulus intensity.
FFh	Expressive feedback from Perceived Affect-Expression to Perceived Felt-Affect
PAE	Perceived Affect-Expression – the model's current affect-expression state
PEG	Perceived Affect-Expression Goal – the model's current affect-expression goal state
PFA	Perceived Felt-Affect – the model's current felt-affect state
PFG	Perceived Felt-Affect Goal – the model's current felt-affect goal state
Reg.	Intensity of regulation output
Reg On.	Instruction determining if regulation is in use – signals the model to stop regulation when the model is in a 'sleep' state
Res.	Perceived self-regulatory resource capacity
Stim.	Stimulus's affective intensity

Appendix 3: Parameter Ranges used in Sleep Deprivation Simulation

Fixed Values

```
k = 0.02
k3 = 0.08
feedback = 0.2
int_goal = 0.6
exp_goal = 0.6

id_noise_fuzz = 0.02 % SD of Gaussian noise shaping affect trajectory
id_noise_seed_range = round(1000*rand(100,1)) % Random seed for noise
```

Parameter values drawn randomly from these ranges:

```
home_base = 0
k2_base = 0.02
int_cost_base = 3
exp_cost_base = 6


home_base_range: Min = home_base -0.15,  Max = home_base +0.15
k2_range:        Min = k2_base -0.005,   Max = k2_base + 0.015
int_cost_range:  Min int_cost_base -0.5, Max = int_cost_base + 0.5
exp_cost_range:  Min exp_cost_base -0.5, Max = exp_cost_base + 0.5
```

Appendix 4: Example of Research Materials for Study 1

Preliminary Screening:

Do you experience any irregular sleep patterns (e.g. due to shift work):

Do you experience, or have previously been diagnosed with a mood disorder:

Sample Diary Questions

Please take time to familiarise yourself with the questions below. These will make up the majority of the diary study. If you have any queries about these or if you have any issues you wish to raise about these questions please inform the researcher.

Current Feelings

*Please rate the extent to which you **currently** feel each of the following by ringing the appropriate ratings.*

A mark of 5 indicates that you currently feel that emotion a great deal, 3 indicates feeling that to a moderate degree and 0 indicates not feeling either state.

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

*The body consumes energy for activities such as physical exertion or extended concentration: this can be viewed as draining of a resource stored in a tank that has to be replenished from time to time. Please rate the extent to which you **currently** feel the following by ringing the appropriate ratings.*

	Not At All					Neutral					A Great Extent	
	0	1	2	3	4	5	6	7	8	9	10	Emotionally Drained

Target Feelings

*Please rate the extent to which you **currently would want to feel** each of the following by ringing a **continuous range** of appropriate ratings.*

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

Events That Have Happened To You In The Past 3 Hours

This includes any events that were of any significance to you.

Time – time event happened (approximate if necessary)

Duration – how long event lasted (in minutes).

Emotional strength – rate each event for its emotional strength on each scale, again from -5 to 5. E.g. a mark of 5 in the gloomy – happy box indicates that you felt happy to a great extent in response to the event. A mark of -3 on the sluggish – energetic scale indicates feeling sluggish to a moderate degree and 0 indicates not feeling either state in response to the event. This is to measure how you **as an individual feel in response to each event**.

Time	Duration	Gloomy- Happy	Sluggish- Energetic

Your Emotional Expressions In The Past 3 Hours

This includes any significant verbal or nonverbal expressions of feelings to others.

Time – time it happened (approximate if necessary).

Duration – how long it lasted (in minutes).

Emotional strength – rate each of your expressions for its emotional strength on each scale, again from -5 to 5 E.g. a mark of 5 in the gloomy – happy box indicates that you expressed happiness to a great extent. A mark of -3 on the sluggish – energetic scale indicates a sluggish expression to a moderate degree and 0 indicates not expressing either state. This is a measure of how you **as an individual express emotion**

Time	Duration	Gloomy- Happy	Sluggish- Energetic

Target Expressions

Sometimes we are required to express certain emotions, even if we do not actually feel those emotions, e.g.as a requirement of a job. Please rate the extent to which you ***are expected to express*** *each of the following by ringing a* ***continuous range*** *of appropriate ratings.*

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

Example Consent Form:

Introduction

What is this diary about?

This is designed to track changes of mood across a week. In addition to this we will also ask you to record desired mood states, sleeping patterns, emotional events and emotional expression. The aim of this study is to better understand how these factors are related across time.

The diary is part of a wider project looking at how we regulate, or attempt to change, our own and others emotional states. The data collected here is designed to test a computer model's predictions of mood change across time. Your data will be used to help validate the model.

What will happen with my data?

The information that you provide in this diary will be kept completely confidential.

To protect anonymity you do not need to put your name on the diary, each book has a unique identification number so only the research team know whose answers are whose. No personal information of yours will be stored with the data, events or personal interactions described will be numerically coded in the final data.

We remind you that participation in this study is voluntary and you may stop at any time

How do I fill out the diary?

The diary has two sections for completion on waking and three sections for most other entries later in the day. For the 'waking' entries, the first questions are about the duration of sleep, followed by questions on your current mood state and your energy levels. You are requested to ring the values that most closely match your current state.

For the other entries later in the day the first set of questions concern your current mood state, your energy levels and your desired moods states. You are requested to ring the values that most closely match your current state. The second set of questions concern emotive events that have occurred since the last diary entry and how these made you feel. You are requested to write the time, duration, and the degree to which you felt each emotion in response to the events. The final set of questions concern your emotional expression since the last diary entry. You are requested to write the time, duration, and the degree to which you expressed each emotion.

There are examples of both a completed waking and regular diary entry at the end of this introduction.

How often do I complete the diary?

For most days you will complete the diary on waking and then at three hourly intervals until the end of the day – e.g. 9am, 12noon, 3pm, 6pm, 9pm, and 12midnight. However, for two of the days (one weekday and one day from the weekend) you will fill out the diary on waking and then on the hour until the end of the day.

You will be asked to start completing the diary on Thursday.

What happens if I miss a time?

If you miss a time, be that through waking up after the time for a diary entry has passed, going to sleep before the next diary entry is due, or simply forgetting; please **do not** fill in the missing time. Instead, **please continue on with the diary as normal**.

Contact Information

If you are unsure about how to complete this booklet, or have any other questions, please contact the researcher by email:

d.s.cameron@shef.ac.uk

or by phone:

+44 (0) 114 222 3257

If you experience any distress over the course of this study please end participation in the study and contact your GP or another trusted health professional.

I have read and understood the above introduction

Signed................................Date.............

Example Morning Diary Entry:

Affect Diary, Day ….

TO BE COMPLETED ON WAKING UP

Sleep

What time did you go to sleep last night:

What time did you wake up this morning:

Minutes of sleep lost between those times (if any):

Current Feelings

Please rate the extent to which you ***currently*** *feel each of the following by ringing the appropriate ratings.*

A mark of 5 indicates that you currently feel that emotion a great deal, 3 indicates feeling that to a moderate degree and 0 indicates not feeling either state.

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

The body consumes energy for activities such as physical exertion or extended concentration: this can be viewed as draining of a resource stored in a tank that has to be replenished from time to time. Please rate the extent to which you ***currently*** *feel the following by ringing the appropriate ratings.*

	Not At All					Neutral					A Great Extent	
	0	1	2	3	4	5	6	7	8	9	10	Emotionally Drained

Example Regular Diary Entry:

TO BE COMPLETED AT ….. AM (continued)

Current Feelings

*Please rate the extent to which you **currently feel** each of the following by ringing the appropriate ratings.*

A mark of 5 indicates that you currently feel that emotion a great deal, 3 indicates feeling that to a moderate degree and 0 indicates not feeling either state.

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

*The body consumes energy for activities such as physical exertion or extended concentration: this can be viewed as draining of a resource stored in a tank that has to be replenished from time to time. Please rate the extent to which you **currently feel** each of the following by ringing the appropriate ratings.*

	Not At All					Neutral					A Great Extent	
	0	1	2	3	4	5	6	7	8	9	10	Emotionally Drained

Target Feelings

*Please rate the extent to which you **currently would want to feel** each of the following by ringing a **continuous range** of appropriate ratings.*

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

TO BE COMPLETED AT ..… AM (continued)

Events That Have Happened To You In The Past 3 Hours

This includes any events that were of any significance to you.

Time – time event happened (approximate if necessary)

Duration – how long event lasted (in minutes).

Emotional strength – rate each event for its emotional strength on each scale, again from -5 to 5. E.g. a mark of 5 in the gloomy – happy box indicates that you felt happy to a great extent in response to the event. A mark of -3 on the sluggish – energetic scale indicates feeling sluggish to a moderate degree and 0 indicates not feeling either state in response to the event. This is to measure how you **as an individual feel in response to each event**.

Time	Duration	Gloomy- Happy	Sluggish- Energetic

TO BE COMPLETED AT ….. AM (continued)

Your Emotional Expressions In The Past 3 Hours

This includes any significant verbal or nonverbal expressions of feelings to others.

Time – time it happened (approximate if necessary).

Duration – how long it lasted (in minutes).

Emotional strength – rate each of your expressions for its emotional strength on each scale, again from -5 to 5 E.g. a mark of 5 in the gloomy – happy box indicates that you expressed happiness to a great extent. A mark of -3 on the sluggish – energetic scale indicates a sluggish expression to a moderate degree and 0 indicates not expressing either state. This is a measure of how you **as an individual express emotion**

Time	Duration	Gloomy- Happy	Sluggish- Energetic

Target Expressions

*Sometimes we are required to express certain emotions, even if we do not actually feel those emotions, e.g.as a requirement of a job. Please rate the extent to which you **are expected to express** each of the following by ringing a **continuous range** of appropriate ratings.*

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

Appendix 5: Example of Research Materials for Study 2

Preliminary Screening:

Do you experience any irregular sleep patterns (e.g. due to shift work):

Do you experience, or have previously been diagnosed with a mood disorder:

Sample Diary Questions:

Expressed Emotions

*Please rate the extent to which you have over the past two hours **generally expressed** your feelings. This can include expression through facial expressions, posture, gestures, tone of voice, as well as saying how you feel, both in person or through written means such as emails or texts.*

*E.g. A mark of 5 on the scale indicates a great extent of positive expressions (such as enthusiasm, happiness or calmness), a mark of -3 indicates a moderate degree of negative expressions (such as annoyance, sadness or anxiety). If you cannot think of a time you have expressed your feelings please circle the **X** on the left of the scale and then rate what you would have expected to express to others, had you needed to.*

N/A		A Great Extent					Neutral					A Great Extent	
X	Negative Expressions	-5	-4	-3	-2	-1	0	1	2	3	4	5	Positive Expressions

Current Feelings

*Please rate the extent to which you **currently feel** each of the following by ringing the appropriate ratings.*

E.g. a mark of 5 on the gloomy – happy scale indicates that you are currently feeling happy to a great extent. A mark of -3 on the sluggish – energetic scale indicates feeling sluggish to a moderate degree and 0 indicates not feeling either state.

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

*The body consumes energy for activities such as physical exertion or extended concentration: this can be viewed as draining of a resource stored in a tank that has to be replenished from time to time. Please rate the extent to which you **currently feel** the following by ringing the appropriate rating.*

	Not At All					Somewhat					A Great Extent	
	0	1	2	3	4	5	6	7	8	9	10	Emotionally Drained

Target Emotions

Taking in mind any external or situational factors you may be experiencing, please rate the extent to which you ***currently would want to express*** *the following by ringing the appropriate rating. For example, at times it may be necessary to express emotions other than what you currently feel, such as appearing calm while feeling anxious or appearing positive when feeling sad or annoyed.*

	A Great Extent					Neutral					A Great Extent	
Negative Expressions	-5	-4	-3	-2	-1	0	1	2	3	4	5	Positive Expressions

Please rate the extent to which you ***currently would want to feel*** *each of the following by ringing the appropriate ratings.*

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

Events That Have Happened To You In The Past 2 Hours

This includes any events that were of any significance to you. Please record the approximate ***time*** *and* ***duration*** *of the events*

Please also rate ***how you felt in response to each event*** *on each scale, again from -5 to 5. E.g. a mark of +5 in the Gloomy – Happy box indicates that you felt happy to a great extent in response to the event. A mark of -3 in the sluggish – energetic box indicates feeling sluggish to a moderate degree and 0 indicates not feeling either state in response to the event.*

Time	Duration	(-5) Gloomy – Happy (+5)	(-5) Sluggish – Energetic (+5)

Example Consent Form:

Introduction

What is this diary about?

This is designed to track changes of emotional expressions and mood across a week. In addition to this we will also ask you to record what you want to express and feel, sleeping patterns, and any significant emotional events. The aim of this study is to better understand how these factors are related across time.

Emotional expressions can often vary with how we are feeling, for example feeling happy would often be associated with more positive expressions. However, there are also circumstances in which we do not express what they feel. For example, you may feel anxious about a situation but need to appear calm, or you may feel annoyed with another person but are required to appear positive and pleasant towards them. In this study, we are interested in both your expressions towards others and also your general expressions. Your general expressions includes *facial expressions, posture, gestures, tone of voice*, as well as *saying how you feel*, both *in person* or through written means such as *emails* or *texts* and can occur in private as well as being directed towards others.

The diary is part of a wider project looking at how we regulate, or attempt to change, our own and others' emotional states. The data collected here is designed to test a computer model's predictions of mood change across time. Your data will be used to help validate the model.

Who will see my answers?

The information that you provide in this diary will be kept completely confidential. None of your responses will be released to anyone outside the research team. To protect anonymity you do not need to put your name on the diary, each book has a unique identification number so only the research team know whose answers are whose.

We remind you that participation in this study is voluntary and you may stop at any time

How do I fill out the diary?

The diary is divided into two main parts: entries made on waking and entries made throughout the day.

For the 'waking' entries, the first questions are about the duration of sleep, followed by questions on your current mood state and your energy levels. You are requested to ring the values that most closely match your current state.

For the other entries throughout the day, the first set of questions concern your expressions of emotions, your current feelings, and your energy levels. You are requested to ring the values that most closely match your expressions and feelings. The second set of questions concern what you *want* to express and *want* to feel. You are requested to ring the values that most closely match your target expressions and feelings.

Finally, the third set of questions (on the same page as the second set) concern emotive events that have occurred since the last diary entry and how these made you feel. You are requested to write the time, duration, source of emotion, and the degree to which you felt each emotion in response to the events. *There are examples of both a completed waking and regular diary entry at the end of this introduction.*

How often do I complete the diary?

For the six days of the study you are asked to complete the diary on waking and then at two hourly intervals until the end of the day – e.g. 8am, 10am, 12noon, 2pm, 4pm, 6pm, 8pm, 10pm, and 12midnight.

You will be asked to start completing the diary on Thursday.

What happens if I miss a time?

If you miss a time, be that through waking up after the time for a diary entry has passed, going to sleep before the next diary entry is due, or simply forgetting; please **do not** fill in the missing time. Instead, **please continue on with the diary as normal**.

Contact Information

If you are unsure about how to complete this booklet, or have any other questions, please contact the researcher by email:

d.s.cameron@shef.ac.uk

or by phone:

+44 (0) 114 222 3225

I have read and understood the above introduction

Signed……..........……………………………..........Date........……......................

Example Morning Diary Entry:

Affect Diary, Day ….

TO BE COMPLETED ON WAKING UP

Sleep

What time did you go to sleep last night:

What time did you wake up this morning:

Minutes of sleep lost between those times (if any):

Current Feelings

*Please rate the extent to which you **currently** feel each of the following by ringing the appropriate ratings.*

A mark of 5 indicates that you currently feel that emotion a great deal, 3 indicates feeling that to a moderate degree and 0 indicates not feeling either state.

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

*The body consumes energy for activities such as physical exertion or extended concentration: this can be viewed as draining of a resource stored in a tank that has to be replenished from time to time. Please rate the extent to which you **currently** feel the following by ringing the appropriate ratings.*

	Not At All					Neutral					A Great Extent	
	0	1	2	3	4	5	6	7	8	9	10	Emotionally Drained

Example Regular Diary Entry:

TO COMPLETED AT ..... AM

Expressed Emotions

Please rate the extent to which you have over the past two hours ***generally expressed*** *your feelings. This can include expression through facial expressions, posture, gestures, tone of voice, as well as saying how you feel, both in person or through written means such as emails or texts.*

E.g. A mark of 5 on the scale indicates a great extent of positive expressions (such as enthusiasm, happiness or calmness), a mark of -3 indicates a moderate degree of negative expressions (such as annoyance, sadness or anxiety). If you cannot think of a time you have expressed your feelings please circle the ***X*** *on the left of the scale and then rate what you would have expected to express to others, had you needed to.*

N/A		A Great Extent					Neutral					A Great Extent	
X	Negative Expressions	-5	-4	-3	-2	-1	0	1	2	3	4	5	Positive Expressions

Current Feelings

Please rate the extent to which you ***currently feel*** *each of the following by ringing the appropriate ratings.*

E.g. a mark of 5 on the gloomy – happy scale indicates that you are currently feeling happy to a great extent. A mark of -3 on the sluggish – energetic scale indicates feeling sluggish to a moderate degree and 0 indicates not feeling either state.

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

The body consumes energy for activities such as physical exertion or extended concentration: this can be viewed as draining of a resource stored in a tank that has to be replenished from time to time. Please rate the extent to which you ***currently feel*** *the following by ringing the appropriate rating.*

	Not At All					Somewhat					A Great Extent	
	0	1	2	3	4	5	6	7	8	9	10	Emotionally Drained

TO BE COMPLETED AT ….. AM (continued)

Target Emotions

*Taking in mind any external or situational factors you may be experiencing, please rate the extent to which you **currently would want to express** the following by ringing the appropriate rating. For example, at times it may be necessary to express emotions other than what you currently feel, such as appearing calm while feeling anxious or appearing positive when feeling sad or annoyed.*

	A Great Extent					Neutral					A Great Extent	
Negative Expressions	-5	-4	-3	-2	-1	0	1	2	3	4	5	Positive Expressions

*Please rate the extent to which you **currently would want to feel** each of the following by ringing the appropriate ratings.*

	A Great Extent					Neutral					A Great Extent	
Gloomy	-5	-4	-3	-2	-1	0	1	2	3	4	5	Happy
Sluggish	-5	-4	-3	-2	-1	0	1	2	3	4	5	Energetic

Events That Have Happened To You In The Past 2 Hours

*This includes any events that were of any significance to you. Please record the approximate **time** and **duration** of the events*

*Please also rate **how you felt in response to each event** on each scale, again from -5 to 5. E.g. a mark of +5 in the Gloomy – Happy box indicates that you felt happy to a great extent in response to the event. A mark of -3 in the sluggish – energetic box indicates feeling sluggish to a moderate degree and 0 indicates not feeling either state in response to the event.*

Time	Duration	(-5) Gloomy – Happy (+5)	(-5) Sluggish – Energetic (+5)

Appendix 6: Parameter Ranges used in Dyad Simulation

Fixed values:

```
k = 0.02
k3 = 0.08
feedback = 0.2
exp_cost = 6

id_noise_fuzz = 0.02 % SD of Gaussian noise shaping affect trajectory
id_noise_seed_range = round(1000*rand(100,1)) % Random seed for noise
```

Variable parameters in simulations:

	Scenario 1	Scenario 2	Scenario 3a	Scenario 3b
home_base_1	0.2	0.2	-0.2	-0.2
home_base_2	0.2	-0.6	0.2	-0.4
int_goal_home_1	1.0	1.0	0.4	0.4
int_goal_home_2	1.0	1.0	1.0	-0.2
exp_goal_home_1	1.0	1.0	1.0	1.0
exp_goal_home_2	1.0	1.0	1.0	-0.2

```
k2_base = 0.02
k4_base = 0.02
int_cost_base = 5
```

Parameter values drawn randomly from these ranges:

```
home_base_1_range: Min = home_base_1 -0.15, Max = home_base_1 +0.15
home_base_2_range: Min = home_base_2 -0.15, Max = home_base_2 +0.15

k2_1_range: Min = k2_base -0.005, Max = k2_base + 0.015
k2_3_range: Min = k2_base -0.005, Max = k2_base + 0.015

k4_1_range: Min = k4_base -0.0025, Max = k4_base + 0.0125
k4_2_range: Min = k4_base -0.0025, Max = k4_base + 0.0125

int_cost_1_range: Min int_cost_base -0.5, Max = int_cost_base + 0.5
int_cost_2_range: Min int_cost_base -0.5, Max = int_cost_base + 0.5
```