Stress, Perseverative Cognition and Health Behaviours

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The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Chapter 2 contains material from the journal publication, 'Perseverative Cognition and Health Behaviours: A Systematic Review and Meta-Analysis' by Clancy, F., Prestwich, A., Caperon, L., & O'Connor, D.B., in *Frontiers in Human Neuroscience* (2016). Note that aspects of the introduction from this publication appear in Chapter 1 and aspects of the discussion in Chapter 6. This systematic review and meta-analysis was jointly devised by Andrew Prestwich, Daryl O'Connor and Faye Clancy. Data analysis was performed by Andrew Prestwich and Faye Clancy, and both Faye Clancy, Andrew Prestwich and Daryl O'Connor contributed to the written publication. Lizzie Caperon was the second reviewer and provided feedback on the final manuscript. Chapter 3 contains material from the journal publication that is currently under review, 'The Association between Perseverative Cognition and Sleep in Non-Clinical Populations: A Systematic Review and Meta-Analysis' by Clancy, F., Prestwich, A., Caperon, L., Tsipa, A., & O'Connor, D. B., in *Health Psychology Review,* (under review). Note that aspects of the introduction from this publication appear in Chapter 1, aspects of the method appear in Chapter 2 and aspects of the discussion in Chapter 6. This systematic review and meta-analysis was jointly devised by Andrew Prestwich, Daryl O'Connor and Faye Clancy. Faye Clancy performed the data analysis and wrote the manuscript, both of which Andrew Prestwich and Daryl O'Connor provided ongoing feedback on. Lizzie Caperon and Anastasia Tsipa were second reviewers and provided feedback on the final manuscript. Chapter 4 contains material from the journal publication that is currently under review, 'Cross-Sectional and Prospective Associations between Stress, Perseverative Cognition and Health Behaviours' by Clancy, F., Prestwich, A., & O'Connor, D. B., in *Psychology and Health,* (under review). Chapter 5 contains material from the journal publication that is currently under review, 'State and Trait Perseverative Cognition and Health Behaviors: A Daily Diary Investigation' by Clancy, F., O'Connor, D. B., & Prestwich, A., in *International Journal of Behavioral Medicine* (under review). The latter two papers were submitted for review after submission of the thesis and written and analytical material in these chapters is solely the work of Faye Clancy but were jointly devised by all co-authors.

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Abstract

Perseverative cognition (PC) is the repeated activation of stress-related cognitions (including worry and rumination). The Perseverative Cognition Hypothesis (PCH) posits that, in the same way as stress, PC damages health via its ensuing physiological activation. The central proposal of this thesis is that, like stress, PC may influence health via an indirect, behavioural pathway, termed the Extended PCH (EPCH). The principal aim was therefore to investigate the association between PC and health behaviours (HBs) and to investigate how PC interacts with stress in predicting HBs.

Meta-analyses of 19 studies suggested an association between PC and increased health-risk behaviours (Chapter 2), and between PC and poorer sleep across 55 studies (Chapter 3). Associations between stress, PC and HBs were assessed via survey (Chapter 4). Associations emerged between worry and rumination (brooding and reflection) and some health-risk behaviours, cross-sectionally and prospectively. Brooding predicted more snacking at low-medium stress levels, but there was no relationship during high stress. A diary study (Chapter 5) revealed that components of PC predict both health-risk and health-promoting behaviours and interact with daily hassles to contribute to HBs, including unhealthy snacking, sleep and physical activity.

Partial support was found for the EPCH. PC predicts some detrimental HBs but there were some contradictory findings and associations differed across types of PC (worry, brooding, reflection, state vs trait) and HBs and across measurement time-frames for stress and HBs. Therefore, the model may be more complex than originally conceptualised. There are remaining questions pertaining to the EPCH. Primarily, future research should (1) test causation, (2) assess bi-directional associations between PC and HBs, (3) improve measurement specificity of PC and, (4) test PC interventions on HBs. This thesis provides a testable theoretical framework in which to assess associations between stress, PC and HBs and contributes to our understanding of these associations.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Abbreviation	Explanation
PC	Perseverative Cognition
PCH	Perseverative Cognition Hypothesis
EPCH	The Extended Perseverative Cognition Hypothesis
RT	Repetitive Thinking
RNT	Repetitive Negative Thinking
HBs	Health Behaviours
SOL	Sleep Onset Latency
TST	Total Sleep Time
EMA	Ecological Momentary Assessment
M	The Mean
SD	Standard Deviation
SE	Standard Error
MANOVA	Multivariate Analysis of Variance

Chapter 1
Introduction: Background, Rationale, and Aims of the Thesis

1.1 Chapter Summary

This chapter will outline the theory that perseverative cognition (repetitive negative thinking about the past or future) may be a significant contributor to the relationship between stress and disease via the indirect pathway between stress and health behaviours. To do this, the theory will be placed within the overall context of research reporting an association between stress and health, as well as within the context of evidence highlighting an association between perseverative cognition and ill-health. To end the chapter, the aims of the thesis will be summarised, and the content of subsequent chapters will be described.

1.2 Stress and Physical Health

There is a substantial body of evidence demonstrating an association between stress and reduced health status. For instance, in a recent review, stress was identified as a risk-factor in the development of atherosclerosis and as an acute trigger of cardiac events (Steptoe & Kivimäki, 2012), which are thought to be mediated by aspects of the physiological stress response including raised blood pressure and reduced insulin sensitivity. An association has also been found between stress and the accumulation of visceral fat (Marniemi et al., 2002), which is risk-factor for a multitude of diseases (Bjorntorp, 1987). Work stress has been found to predict increased risk of type II diabetes even when accounting for other known risk factors including health behaviours and obesity (Heraclides, Chandola, Witte, & Brunner, 2009) and there is also evidence to suggest that stress is associated with increased cellular aging and with an increased risk of chronic disease and shorter life-span (Epel, 2009).

Additionally, research suggests an association between stress and impaired immunity. It has been found that rates of upper-respiratory infection increase in a dose-response manner with psychological stress when participants are exposed to the common cold virus (Cohen, Tyrrell, & Smith, 1991). Likewise, the stress associated with caregiving has been found to delay wound-healing as a result of decreased production of interleukin 1β (Kiecolt-Glaser, Marucha, Mercado, Malarkey, & Glaser, 1995). An early meta-analysis of the association between stress and immunity found reliable associations between increased stress and overall reduced immunity (Herbert & Cohen, 1993). Stress has also been associated with an increased proinflammatory response (Black, 2002; Cohen et al., 2012) which could increase susceptibility to diseases of chronic inflammation, with research supporting relationships between inflammatory diseases ranging from diabetes (Sepa, Wahlberg, Vaarala, Frodi, & Ludvigsson, 2005) to cancer (Chida, Hamer, Wardle, & Steptoe, 2008). Another meta-analysis of stress and immunity found that chronic stressors negatively impacted both natural and specific immunity (Segerstrom & Miller, 2004).

Overall, there are decades of evidence supporting an association between stress and disease. Furthermore, strong theoretical arguments have been made for how and why this process occurs. Formative work by Walter Cannon described the acute physiological changes in the autonomic and sympathetic nervous systems that occur when an animal is exposed to an external threat, which he described as the ‘fight or flight response’ (Cannon, 1939). When stress is perceived, in the short-term, the sympathetic-adrenomedullary axis is activated and, if stress persists, the hypothalamic-pituitary-adrenocortical (HPA) axis is activated. These systems have cascading effects on stress hormones such as cortisol which trigger the fight or flight stress response, incorporating increased heart rate and breathing, release of glucose for energy and decreased digestive activity. In another seminal paper, Selye (1950) evidenced that when rats are exposed to noxious physical agents, the body responds in predictable ways over a 48-hour period which he termed the General Adaptation Syndrome. He described the noxious environmental stimuli as ‘stress’, thus coining the term as it is known today. Early findings by these researchers provided insight into how the body responds to acute stress and stress over a longer period (chronic stress).

Allostasis, as outlined by Sterling and Eyer (1988), describes the process whereby, through physiological and behavioural changes, the body maintains physiological stability. Ramsay and Woods (2014) explain that allostasis, as opposed to homeostasis (in which a rigid physiological set-point is defended), allows the body to defend an adaptive set-point. For example, under conditions of chronic stress, a higher level of resting blood pressure may be maintained to respond to chronic external threats. In addition, allostasis incorporates learning and anticipation. However, despite its adaptive potential, McEwen (1998) describes allostasis as having a ‘price’, termed allostatic load (McEwen & Stellar, 1993). This refers to pathological physiology resulting from overworked allostatic systems, an allostatic response that occurs after a threat has ceded or when the allostatic systems are impaired, leading other systems to compensate for them and overreact. McEwen (1998) describes allostatic load as physiological wear and tear on the body which occurs when the stress systems are chronically activated.

In researching stress it is to be acknowledged that the definition of stress is somewhat elusive, as it represents a stimulus (stress), a physiological and psychological response (stress) and an emotional response to the stress response (distress) (Segerstrom & O'Connor, 2012). Over time, the definition of stress has mostly migrated from an objectively threatening external stimulus which an individual is exposed to, to an individual's perception of a stimulus as threatening. In their Theory of Cognitive Appraisal, Lazarus and Folkman (1984) suggested that stress is only experienced if the individual first appraises the event to be a threatening and, second, feels unequipped to cope with that threat. Research has focused upon diverse situations which have been found to trigger a stress response. These vary widely from physical stressors similar to those investigated in early research, including extreme temperatures, noise or pain (Babisch, 2002; Rainville, Feine, Bushnell, & Duncan, 1992; Smith, Egbert, Markowitz, Mosteller, & Beecher, 1966) to psychosocial threats, including loss of resources (Hobfoll, 1989), occupational stress (Johnson & Hall, 1988; Karasek, 1979; Siegrist, 1996) and negative social evaluation (Kirschbaum, Pirke, & Hellhammer, 1993). Stressors span major life events such as the death of a child (Li, Hansen, Mortensen, & Olsen, 2002) and bereavement (Parkes, Benjamin, & Fitzgerald, 1969) to an accumulation of minor daily hassles such as missing a bus or having an argument with a partner (DeLongis, Coyne, Dakof, Folkman, & Lazarus, 1982). Factors such as lower socioeconomic status are thought to contribute to an overall increased exposure to stressors, in addition to reducing the ability to cope with these stressors via stress-induced changes in brain anatomy (McEwen & Gianaros, 2010). A distinction is made between events such as taking an exam or performing a cognitive task in the laboratory (Slavish, Graham-Engeland, Smyth, & Engeland, 2015), which are thought to trigger an acute stress response, and ongoing stressful life circumstances such as caregiving (Kiecolt-Glaser et al., 1987; Lee, Colditz, Berkman, & Kawachi, 2003) which are associated with chronic levels of stress. However, this distinction is not completely clear as, as will be later discussed, even acute events can be subject to varying amounts of anticipatory stress or subsequent distress. Although research on stress is varied, it is thought that all of these environmental threats trigger the same physiological response and have the ability to cause damage to health over time.

To summarise, there is evidence of an association between stress and a multitude of detrimental health outcomes as a result of the body's physiological stress response. This stress response has been theorised to serve an adaptive purpose but over-time, creates wear and tear within the body, known as allostatic load. Allostatic load may explain the direct association between stress and disease. However, there is also evidence for an indirect association between stress and ill-health via health behaviours. This pathway will be considered in the next section.

1.3 Stress and Health Behaviours

Several behaviours have been shown to influence health. In a review of the literature, associations between short sleep duration and poorer general, cardiovascular, metabolic, mental and immunologic health, as well as greater experience of pain and greater overall rates of mortality have been reported (Watson et al., 2015). It is well documented that obesity increases the risk of a number of diseases, including coronary heart disease and diabetes (Lenz, Richter, & Mühlhauser, 2009), and the consumption of high calorie, low nutrient foods combined with time spent sedentary contribute to a positive energy balance and obesity (Malik, Willett, & Hu, 2013). Additionally, fast foods, typically high in fat and sugar, have been associated with increased body weight and poorer metabolic outcomes (Duffey, Gordon-Larsen, Steffen, Jacobs Jr, & Popkin, 2009; Pereira et al., 2005). On the other hand, consumption of fruits and vegetables may have a protective effect on stroke and coronary heart disease (Ness & Powles, 1997) and some types of cancer (van't Veer, Jansen, Klerk, & Kok, 2000). Likewise, physical activity has been found to be widely beneficial to health and health-related quality of life (Penedo & Dahn, 2005). As well, alcohol consumption has been shown to increase the risk of cancer and cancer-related death (Praud et al., 2016). McEwen (1998) suggests that behaviours which promote or damage health, such as smoking, drinking, eating behaviour and physical activity, can be considered within the conceptualisation of allostasis as they can be attempts to cope with stress and are known to contribute to allostatic load. In addition to the direct pathway between stress and disease outlined in the previous section, stress may influence health indirectly, via an association with poorer health behaviours and there is a growing body of evidence which supports an association between stress and poor health behaviour.

A recent meta-analysis has found that an association between stress and unhealthy eating patterns are witnessed in children and adolescents (8-18) and that, in older children (13-18), stress was also found to be associated with a decrease in healthy eating patterns (Hill, Moss, Sykes-Muskett, Conner, & O'Connor, 2018). In adults, in after a stress induction paradigm, high stress-reactivity was associated with greater between-meal snacking (Newman, O'Connor, & Conner, 2007). Likewise, in a 28-day diary study, O'Connor, Jones, Conner, McMillan, and Ferguson (2008) showed that daily stressors were associated with increased consumption of high fat and high sugar between-meal snack foods and with a reduction in main meal and vegetable consumption. In another naturalistic longitudinal study, Roberts, Campbell, and Troop (2014) found that higher cortisol measured throughout the day predicted increased calorie intake from carbohydrates and saturated fat, which they argue links to a 'comfort food hypothesis' of stress-induced hyperphagia (overeating).

This theory is supported by a review by Sominsky and Spencer (2014) in which the authors provide evidence that, after an initial appetite suppressing effect in response to acute stress, chronic elevation of glucocorticoids serves to increase appetite via several appetite-regulating hormones and neurotransmitters. Glucocorticoids may also facilitate the intake of highly palatable foods via a reduction in reward-sensitivity, meaning that food needs to be more rewarding (i.e. calorie-dense and high in fat and sugar) to trigger the same reward response. The importance of the brain's reward system in the stress-eating relationship is echoed in the theory of stress and eating-reward by Adam and Epel (2007).

Other studies have provided evidence of a relationship between stress and increased alcohol consumption, which has been identified as a significant risk factor for chronic disease (Rehm et al., 2009). For example, in a daily diary study, Grzywacz and Almeida (2008) reported that participants were more likely to binge drink on days when they experienced more severe stressors. Similarly, in an experimental study, a blunted cortisol response to a laboratory stressor was associated with greater post-stressor alcohol consumption (Pratt & Davidson, 2009). Corbin, Farmer, and Nolen-Hoekesma (2013) suggest that alcohol may be used to deal with negative emotion when alternative coping strategies are not available. In the sample of college students surveyed, stress levels were positively associated with drinking to cope and drinking problems. Moreover, those who reported drinking to cope drank more heavily. Like the association between stress and eating behaviour, there is evidence to suggest that, via its impact on neural reward pathways, stress increases motivation to drink and via reduced reward-sensitivity, requires higher quantities of alcohol to provide the same reward response, which can lead to alcohol use disorders and dependence (Blaine & Sinha, 2017).

Equally, in a study of nearly 50,000 employees, work stress was associated with greater likelihood of being a smoker and higher smoking intensity (Kouvonen, Kivimäki, Virtanen, Pentti, & Vahtera, 2005). As well, Guillaumier et al. (2017) found that current smokers were more likely to be experiencing financial stress than former or never smokers. Using a bogus pipeline procedure (which can limit self-report bias), Cohen and Lichtenstein (1990) assessed participant's smoking status across a 6-month period and found that higher stress predicted failure to quit smoking and low stress predicted greater abstinence. Again, it is suggested that the mechanism for this association may be the sensitisation of reward pathways in response to stress which contributes to an increased frequency of smoking or makes quitting at times of stress more difficult (McKee et al., 2011). Although, it is to be noted that all of these studies were correlational, so causal relationships cannot be inferred.

Some evidence suggests that stress may reduce engagement in physical activity. For instance, in a review of post-secondary school students, meeting vigorous physical activity guidelines was associated with lower odds of reporting perceived stress (Dogra et al., 2018). In another review, of 168 papers assessing the influence of stress on physical activity, Stults-Kolehmainen and Sinha (2014) found that the majority of studies reported that stress led to less physical activity and more sedentary behaviour, although 29 studies (of which 10 were prospective) showed an association between stress and more physical activity. The authors suggest that positive effects of stress on physical activity may be explained by the fact that some individuals utilise physical activity as a way of coping with stress (Cairney, Kwan, Veldhuizen, & Faulkner, 2014), and exercise has been shown to improve resilience to stress (Salmon, 2001). It is suggested that this protective effect may occur in relation to the amount of energy expended, with the amount of perceived stress reducing in accordance with the level of activity (Aldana, Sutton, Jacobson, & Quirk, 1996). Therefore, the association between stress and physical activity appears somewhat more complex than other behaviours.

In a review of the physiological associations between stress and sleep, Van Reeth et al. (2000) presented evidence which identified an association between stress and circadian systems. The early phase of sleep is the only time of day when HPA-axis activity is persistently inhibited (Born & Fehm, 1998). As such, sleep onset is closely associated with decreasing cortisol levels (Weibel, Follenius, Spiegel, Ehrhart, & Brandenberger, 1995). On the other hand, in later stages of sleep, predominated by REM (rapid eye movement) and dreaming, secretory HPA activity increases, reaching a maximum upon awakening (Van Cauter, Van Coevorden, & Blackman, 1990). Therefore, it might be expected that stress would impair sleep and evidence supports this view. Kim and Dimsdale (2007) reviewed 63 studies assessing the impact of psychosocial stressors on sleep using the gold-standard of sleep measurement, polysomnography (PSG). Acute experimental stressors were associated with increased sleep onset latency (SOL), more awakenings and decreased sleep efficiency. Furthermore, sleep deprivation may itself be a stressor. This is evidenced by the fact that in studies of sleep deprivation, the following day, evening cortisol is elevated (Leproult, Copinschi, Buxton, & Van Cauter, 1997; Spiegel, Leproult, & Van Cauter, 1999). As such stress can be viewed both as a precursor to poor sleep and as a consequence of it, thus perpetuating a vicious, health-damaging cycle.

The evidence presented characterises a clear association between psychological stress and a multitude of behaviours which have been shown to impact on physical health. Therefore, taken together with the previous section, there is evidence for both a direct pathway between stress and health and an indirect pathway via health behaviours. In the next sections, recent developments in stress research, which have highlighted the important role of stress-related thought processes in these pathways, will be reviewed.

1.4 The Perseverative Cognition Hypothesis

As identified by Lazarus and Folkman (1984) stress represents the unique interplay between environmental events and the individual's perception of these events as threatening. Brosschot, Gerin, and Thayer (2006) emphasised the importance of the cognitive representation of stressors in their Perseverative Cognition Hypothesis (PCH). Perseverative cognition (PC) is the cognitive representation of past stressful events or feared future events. The hypothesis states that, in such instances where the physical stressor is absent, the cognitive representation alone induces the physiological stress response.

The PCH proposes that, when stress is perseverated upon, the damaging physiological activation associated with stress is also protracted, thus increasing susceptibility to stress-related ill-health. In this sense, the direct relationship between stress and disease is intensified when a stressor is subject to thought as the duration of time that the body is exposed to the damaging physiological stress response is also intensified. They go so far as to describe PC as the 'missing link' between stress and disease, with prolonged activation being key to disease processes (see Figure 1.1). PC was proposed as a mediator of the stress-disease relationship as, the authors argue, it can be considered as the final pathway by which stress impacts on health. The PCH can be considered as typifying what McEwen (1998) describes as a failure to shut-down the stress response (or type 2 allostatic load).

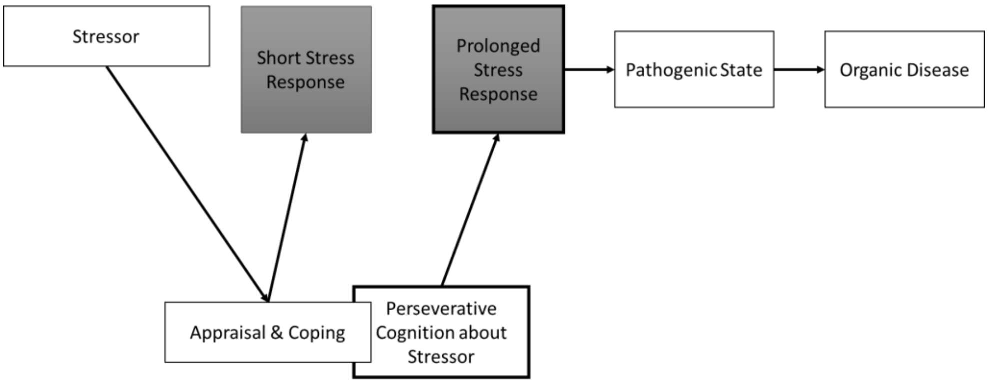

Figure 1.1 The Perseverative Cognition Hypothesis (Brosschot et al., 2006).

1.5 Conceptualising and Measuring Perseverative Cognition

Within the Brosschot et al. (2006) conceptualisation presented in the PCH, PC is an umbrella term which encompasses any type of negative, repetitive thought process. Key to the negative health implications of these thoughts is their perseveration, and the overall duration of exposure to them. The most commonly researched of such thought processes are rumination and worry. These two thought processes are temporally distinct as worry describes negative repetitive thoughts about anticipated future events whereas rumination describes negative repetitive thinking about events in the past (Watkins, Moulds, & Mackintosh, 2005).

Rumination can broadly be defined as repetitive thinking about negative affect and its causes, symptoms and consequences (Smith & Alloy, 2009). This conceptualisation of rumination aligns with the Response Styles Theory developed by Nolen-Hoeksema (1991), from which the widely used Ruminative Responses Scale was developed. Alternatively, the Stress-Reactive model of rumination (Alloy et al., 2000) conceptualises rumination as negative thoughts occurring after a stressful event, which most closely aligns with the PCH, but it has been argued that this model may not capture rumination unrelated to particular environmental events (e.g. self-deprecating thoughts) (Smith & Alloy, 2009).

In their comprehensive review of the construct of rumination, Smith and Alloy (2009) describe other theories of rumination but argue that these are less empirically tested and often overlap with other concepts. The authors highlight evidence that stress and negative affect are important triggers of ruminative thinking and emphasise that self-focus is also a defining trait of rumination. Smith and Alloy (2009) conclude that rumination may serve the role of an emotion regulation strategy, aid in problem solving and goal attainment, or help individuals process stressful or traumatic events. Nonetheless, the authors consider rumination to be largely ineffective as a coping strategy.

Factor analyses have identified a number of sub-factors within rumination. For instance, depressive rumination has been found to be a distinct subset of rumination (Treynor, Gonzalez, & Nolen-Hoeksema, 2003) in which a person focuses upon the symptoms and causes of their depression. Additionally, rumination can be conceptualised as having both a harmful and an adaptive component: brooding and reflection respectively. Brooding is described as a passive and judgemental form of rumination, whereas reflection is more contemplative with a focus on problem-solving. Treynor et al. (2003) provided evidence that brooding is the more maladaptive component of rumination as brooding predicted symptoms of depression one year later, whereas, although reflection predicted current depression, it predicted lower levels of depression over time. However, these variables do correlate highly with one another, supporting their consideration under the shared construct of rumination (Segerstrom, Stanton, Alden, & Shortridge, 2003).

Borkovec, Robinson, Pruzinsky, and DePree (1983) were the first research group to aim to define and categorise the process of worrying and to distinguish it from related processes such as anxiety, fear and mental problem-solving. Borkovec et al. (1983) defined worry as uncontrollable, negatively affect-laden thoughts in which an attempt is made at problem-solving regarding an issue with an uncertain, but potentially negative outcome. They emphasised the relationship between worry and fear and anxiety processes. Brosschot et al. (2006) note that this definition highlights both the cognitive and affective elements of worry. They also highlight the role of worry as a problem-solving strategy that can vary in its efficacy, with such attempts having the capacity to be counter-productive.

The Penn State Worry Questionnaire (PSWQ) (Meyer, Miller, Metzger, & Borkovec, 1990) is a reliable and valid measure of worry (van Rijsoort, Emmelkamp, & Vervaeke, 1999), which is used extensively to capture levels of trait worry (Verkuil, Brosschot, Gebhardt, & Thayer, 2010). During psychometric development, the PSWQ was found to predict generalised anxiety disorder. The Worry Domains Questionnaire (WDQ) (Tallis, Davey, & Bond, 1994) is another popular measurement tool used to capture trait worry. Whereas the PSWQ is most concerned with pathological worry and the process of worrying, the WDQ focuses upon the content of worries (Verkuil, Brosschot, & Thayer, 2007). The PSWQ has been found to be more predictive of daily worry duration than the WDQ (Verkuil et al., 2007) suggesting that this questionnaire is more useful in measuring the underlying construct of worry.

Whereas rumination has been shown to be associated with depression (Nolen-Hoeksema, 2000), worry is a central aspect of anxiety disorders and particularly generalized anxiety disorder (Borkovec & Inz, 1990), although this dichotomy is not absolute (Smith & Alloy, 2009). Apart from the distinctions noted, Smith and Alloy (2009) note that worry and rumination often correlate highly and share common properties so perhaps should be considered facets of some larger construct, which supports the conceptualisation of PC as the overall construct incorporating overlapping yet distinct types of negative, repetitive thought processes.

There have been some attempts to measure repetitive thought more holistically by capturing the distinct yet overlapping processes of rumination, reflection and worry. Segerstrom et al. (2003) identifies repetitive thought (RT) as a prolonged cognitive focus which can be directed on the domains of self, emotions or past or future life events, and notes that these thoughts, while sometimes considered to be adaptive (e.g. problem-solving and positive reinterpretation), have the potential to be physiologically damaging. In this sense, RT is used in a similar way to PC, although it also encapsulates adaptive thoughts. They consider the adaptive role of reflection in the processes of positive reinterpretation and acceptance, as well as the benefit of planning and rehearsal in coping with stressful events. Within their conceptualisation of RT, Segerstrom et al. (2003) consider worry, rumination and depressive rumination as maladaptive categories of RT. Using multidimensional scaling, the authors suggested that RT varies along at least two dimensions: content valence (the degree to which the thought is positive or negative) and the purpose of the thought (searching for perspective or understanding versus preparation and problem-solving), which broadly relate to rumination versus worry. They propose that these are likely to be important determinants of wellbeing.

There is also research which specifically focuses upon repetitive negative thinking (RNT) which more closely resembles the definition of PC proposed by Brosschot et al. (2006) than broader RT which incorporates more positive thoughts. Some, such as Ehring et al. (2011) argue that common measures of worry and rumination are too specific and that a broader construct is required and suggested that a wider definition of RNT is required and that this should focus upon the characteristics of the repetitiveness of such thoughts and the difficulty in disengaging from them, and argued that this definition should be independent of the content of the thoughts or their temporal focus (past, present or future). On this basis, they developed the Perseverative Thinking Questionnaire (PTQ). Factor analysis identified three higher-order factors: repetitiveness, intrusiveness and difficulty to disengage. This measure correlated highly with the PSWQ and the brooding subscale of the RSQ. Therefore, there is evidence of an attempt to measure and categorise common elements of RT/RNT and PC which span the independent constructs of rumination and worry, and which identify factors common to worry, brooding and reflection.

Verkuil et al. (2010) suggested that PC is the default stress response in high trait worriers as such individuals do not recognise safety signals which indicate that the threat posed by a stressor has subsided. They suggest that there are three processes which contribute to a failure to inhibit the stress response and engage in PC. First, as noted in earlier theories of worry and rumination, perseveration may occur when there is a threat to goal attainment and an individual is particularly committed to that goal. Second, the motivation to use PC as a coping strategy. Third, they suggest a biological vulnerability to PC in some individuals. However, despite evidence that the tendency to perseverate is a trait variable, PC can still fluctuate at a state level. In their review of the association between PC and health, Ottaviani et al. (2016) assessed whether outcomes differed depending upon whether PC was measured at a state or trait level (i.e. the difference between engaging in PC at a point in time versus the overall tendency to engage in PC). They found that this covariate moderated the association between PC and heart rate and heart rate variability. A significant association between PC and heart rate and heart rate variability was only found in studies assessing state, as opposed to trait PC. Similarly, Verkuil et al. (2007) found that both the PSWQ and the WDQ predicted the duration and frequency of worry in daily life, as captured by a daily worry log validated in an earlier study (Brosschot & van der Doef, 2006). However, these measures captured only 24% of the variance in daily worry measured across a 6-day period. The findings suggest that majority of the experience of daily worry is not predicted by trait measures.

Researchers have developed measures for assessing PC at a state level. In terms of worry, there is the aforementioned measure of daily worry created by Verkuil et al. (2007). Cropley, Michalianou, Pravettoni, and Millward (2012) developed a trait measure of rumination specifically related to post-work ruminative thinking which has been successfully adapted for use at a state level (Cropley, Rydstedt, Devereux, & Middleton, 2015) and incorporates measures of affective rumination, detachment and problem-solving pondering. Likewise, Takano and Tanno (2011) created a measure of state rumination consisting of self-focus, unpleasantness and uncontrollability which has been shown to correlate with levels of trait rumination. Therefore, there are some tools available for measuring both state and trait PC, although there is less research overall of state PC and therefore these measures have not been subject to nearly as much empirical testing as oft-used trait measures.

To conclude, PC is a term which broadly describes negative repetitive thinking about past or future events. There are arguments for and against measuring this construct holistically compared to measuring facets of PC (e.g. brooding, reflection and worry) separately. Overall, PC is a complex construct and there are numerous measures and definitions within the literature. The PCH argues that PC mediates the association between stress and health and theories have been put forward for why individuals engage in PC. There is some evidence to suggest that state and trait PC are distinct and should be measured separately. In the next section, evidence supporting the PCH will be presented.

1.6 Perseverative Cognition and Physical Health

Since the PCH was proposed, a substantial amount of evidence has been identified which supports the main tenets of the theory. In a systematic review of the literature Verkuil et al. (2010) presented convincing research evidence of an association between the prolonged physiological activation associated with PC and somatic health outcomes. For instance, state worry duration was found to prospectively predict somatic health complaints, and both were reduced by a worry intervention (Brosschot & van der Doef, 2006). As well as reporting that trait worry predicted somatic health complaints cross-sectionally, (see Jellesma, Verkuil, and Brosschot (2009), state worry duration was found to prospectively predict somatic health complaints, and both were reduced by a worry intervention. However, Versluis, Verkuil, and Brosschot (2016) failed to replicate the effect of the same worry intervention, although this was the first to use online, rather than pen-and-paper methods. A relationship was also reported between trait rumination and health complaints across a 1-year period, but only in younger participants (Thomsen, Mehlsen, Olesen, et al., 2004). Therefore, there appears to be an association between PC and individual’s subjective experience of their health.

Chronic elevation of heart rate (Palatini & Julius, 1997), and reduced heart rate variability (Tsuji et al., 1994) are both risk-factors for all-cause mortality. Studies have evidenced an association between state (experimentally-induced) and trait worry and both of these factors (Lyonfields, Borkovec, & Thayer, 1995; Thayer, Friedman, & Borkovec, 1996), and trait rumination has been associated with slower heart rate recovery after stress (Roger & Jamieson, 1988). It has also been found that individuals high in angry rumination showed higher levels of resting systolic blood pressure (Chambers & Davidson, 2000). In terms of objective health outcomes, Brosschot et al. (2006) found only one study which reported that trait worry predicted a second myocardial infarction (Kubzansky et al., 1997). Brosschot et al. (2006) also note that psychological conditions that worry is a central characteristic of, such as anxiety disorders and depression (which rumination is also central to), are known risk factors for cardiovascular disease (Kawachi et al., 1994; Wulsin, Vaillant, & Wells, 1999).

The evidence also suggests an association between PC and increased endocrine and immune system activity. One study found an association between higher trait rumination and higher morning cortisol levels (Schlotz, Hellhammer, Schulz, & Stone, 2004), and was also associated with higher leukocyte count, independently of negative affect (Thomsen, Mehlsen, Hokland, et al., 2004). Similarly, higher levels of salivary immunoglobin were found in anticipation of an exam, compared to a less emotionally challenging/threatening laboratory stressor (a memory test), despite the fact that physiological reactivity during these stressors was not significantly different (Spangler, 1997), highlighting the role of anticipation. These findings are reflective of increased immunity in response to acute stress noted in section 1.2.

Verkuil et al. (2010) concluded that most studies in the area were correlational and more experimental studies were required to investigate causal effects. Furthermore, the research mainly focused on physiological rather than disease outcomes, which is necessary to support the suggested pathogenic link between stress and disease outlined in the PCH. The authors also suggest that research needed to assess whether the amount of cognitive effort expended during PC was not the explanation for its impact on somatic health, rather than, as hypothesised, the unique aspects of PC. For instance, in an experimental study Verkuil, Brosschot, Borkovec, and Thayer (2009) showed that the effect of PC on heart rate and heart rate variability was due to the emotional rather than cognitive component by comparing it to an equally effortful cognitive task.

Ten years after the publication of the PCH, Ottaviani et al. (2016) synthesised the existing evidence by conducting a systematic review and meta-analysis of 60 studies to investigate the physiological concomitants of PC in healthy participants. Associations were found between PC and higher systolic blood pressure, diastolic blood pressure, heart rate and cortisol and lower heart rate variability across both experimental and correlational studies. The authors concluded that there was clear evidence that PC affects cardiovascular, autonomic and endocrine nervous system pathways consistent with a pathogenic route to long-term disease outcomes. However, the review emphasised a need for more prospective research in order to fully test directionality and there were too few studies to meta-analyse the association with immunity. Likewise, only 9 studies from clinical samples met inclusion criteria and outcomes were too heterogeneous to perform a meta-analysis. Therefore, data from clinical samples has not as yet been synthesised and more research is needed to do so.

From this, it is clear that there remain some relatively unexplored areas within the literature such as whether PC mediates the association between stress and illness or whether it acts as a moderator, like other coping styles (Brosschot et al., 2006). However, the research presented provides compelling evidence of a direct association between PC and the physiological determinants of health status. Therefore, it is also possible that, like stress, PC also acts on health via an indirect behavioural pathway. This theory will be considered in the next section.

1.7 Perseverative Cognition and Health Behaviours (The Extended PCH)

In the broader stress literature presented, there is evidence for the proposal that stress can affect health indirectly, through the modification of health behaviours (see section 1.3). It is proposed here that, in the same way as stress, there may be an additional indirect pathway between PC and health outcomes via health behaviours. Little consideration has been given to the relationship between measures of PC and health behaviours. Given that research has demonstrated an association between PC and physiological parameters associated with the stress response, it is also possible that, as the experience of the stressor is prolonged by worry or ruminative processes, so too may be its detrimental impact on health behaviours.

Furthermore, over time, PC-induced increases in health-risk behaviours and decreases in health-promoting behaviours are likely to influence pathogenic pathways to long-term disease outcomes. Figure 1.2 demonstrates the extended PCH and includes an additional route within the PCH to the pathogenic disease state via poorer health behaviours (e.g. poorer sleep, higher levels of alcohol, tobacco and unhealthy food consumption and lower physical activity levels and lower consumption of healthy foods). In this conceptualisation, it is theorised that rumination about past stressful events or worry about feared future events will moderate the effects of stressors on health behaviours (particularly those previously shown to be influenced by stress), which will have knock-on effects for health outcomes and disease processes. Predictions regarding reflection are less clear, considering its potentially adaptive component.

There is some research evidence supporting an association between PC and health behaviours. In regard to eating behaviours, PC might also amplify, prolong and reactivate the same physiological and psychological processes that account for the negative effects of stress on eating behaviour. Research is emerging showing an association between rumination and the consumption of unhealthy foods such as cakes, crisps and confectionary (Cropley et al., 2012). Likewise, the same mechanisms identified as contributing to greater smoking and alcohol consumption when stressed may be amplified by PC. One study has shown that measures of rumination are associated with more alcohol consumption on workdays (Frone, 2015) and a daily diary study found an association between emotional rumination and greater alcohol consumption (Aldridge-Gerry et al., 2011). Also, Rutten, Blake, Hesse, Augustson, and Evans (2011) found that high worriers were more likely to be current smokers than never smokers. Regarding exercise, one study found an association between worry and lower engagement in physical activity (Ferrer, Portnoy, & Klein, 2013). Research has also identified an association between negative over-thinking and sleep difficulties. Studies have reported an association between thought processes such as worry and rumination and difficulty falling asleep (McGowan, Behar, & Luhmann, 2016; Zoccola, Dickerson, & Lam, 2009), poorer quality sleep (Barclay & Gregory, 2010; Cropley et al., 2015) and shorter total sleep duration (Cropley, Dijk, & Stanley, 2006; Nota & Coles, 2015). As physiological arousal has been found to predict sleep disturbance (Bonnet & Arand, 2003; Hall et al., 2007), PC and its accompanying physiological activation may play a role in explaining an inability to fall asleep, stay asleep or an overall disruption in the quality of sleep.

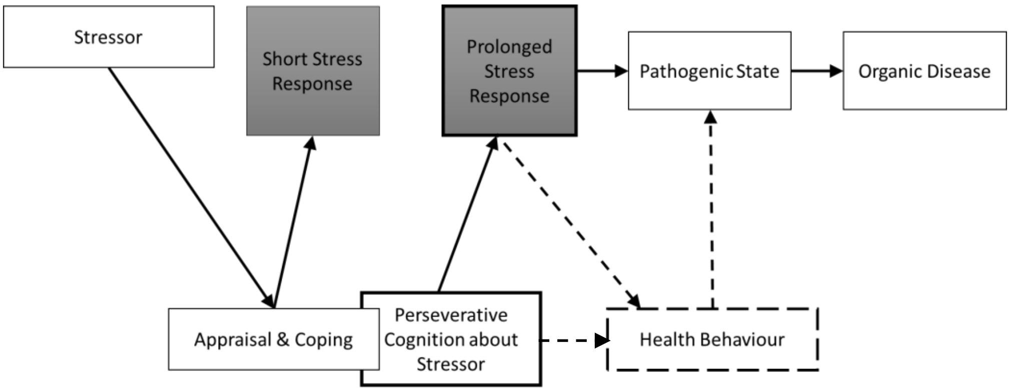

Figure 1.2. The Extended Perseverative Cognition Hypothesis

Hence, there are theoretical reasons for suspecting that PC may contribute to negative health behaviours and this appears to be supported by some existing research evidence. The theoretical model described will form the central proposal of this thesis.

1.8 Thesis Aims

This chapter has demonstrated the importance of better understanding the association between stress and morbidity. Evidence suggests that PC may be key to understanding this relationship. The evidence presented indicates that PC prolongs the stress response and consequently, prolongs the damaging physiological activation associated with it, leading to an increase in stress-related markers of ill-health. As stress has also been shown to be associated with behaviours which impact on health, the question remains as to whether PC can also exacerbate the association between stress and health behaviours, which is important from a health behaviour intervention perspective. Therefore, the aims of the thesis were:

I. To systematically review and meta-analyse the existing literature regarding PC and health behaviours in order to assess whether the theorised association between PC and health behaviour is supported by existing research, and to identify gaps in the existing literature (Chapters 2 & 3).
II. To empirically assess the cross-sectional and prospective associations between stress, PC and health behaviours to evaluate the extended PCH (Chapters 4 & 5).
III. To assess the association between facets of PC (worry, brooding and reflection) and health behaviours (Chapters 2, 3, 4 & 5)

IV. To assess the associations between both trait (Chapters 3, 4 & 5) and state PC (Chapters 3 & 5) and health behaviours.

1.9 Thesis Outline

1.9.1 Chapter 2

In this chapter, findings from a systematic review and meta-analysis of the association between PC and health behaviours in non-clinical populations are presented. Outcomes are categorised as health-risk and health-promoting. Additionally, outcomes are analysed by health behaviour (eating behaviour, physical activity, alcohol consumption, smoking behaviour and cancer screening uptake) and type of PC (worry, health worry, brooding and reflection).

1.9.2 Chapter 3

This chapter contains a systematic review and meta-analysis of the association between PC and sleep in non-clinical populations. Sleep outcomes were reviewed separately to other health behaviours as (1) the number of studies far exceeded other health behaviours, (2) there were moderators which were only relevant to sleep outcomes such as the type of sleep measurement (actigraphy or self-report) and sleep subtypes (sleep quality, sleep onset latency and total sleep time). As in Chapter 2, outcomes were analysed by type of PC, but categories of reflection and health worry did not emerge within the literature so only worry, brooding and general PC were considered.

1.9.3 Chapter 4

The systematic review and meta-analysis of PC and health behaviours identified a scarcity of studies investigating an association between PC and health behaviours and very few studies measured multiple behaviours. There were few studies which had used validated measures of worry or rumination and, in both reviews, there were few studies which had assessed prospective associations. Additionally, the role of stress within the extended PCH could not be assessed within the meta-analyses. In this survey study these limitations were addressed and associations between stress, PC and health behaviours were assessed both cross-sectionally and prospectively.

1.9.4 Chapter 5

The systematic review and meta-analysis of both health behaviours and sleep identified a need for daily diary studies to assess the daily relationships between PC and health behaviours including sleep. As such, a daily diary study was conducted in which daily (state) PC was assessed as a direct predictor of daily health behaviours and trait PC was investigated as a moderator of the association between daily hassles (stress) and daily health behaviours.

1.9.5 Chapter 6

This chapter discusses the findings from the reviews and empirical studies from this thesis within the context of the extended PCH and the existing literature. The strengths and limitations of the thesis are considered and areas for future research are identified.

Chapter 2
Perseverative Cognition and Health Behaviours: A Systematic Review and Meta-Analysis

2.1 Introduction

Evidence suggests a consistent association between stress and disease via the physiological stress response (Cohen et al., 2012; Epel, 2009; Heraclides et al., 2009; Steptoe & Kivimäki, 2012). Research also identifies a clear association between psychological stress and several behaviours which have been shown to impact on physical health, such as poorer eating behaviour (Hill et al., 2018; Newman et al., 2007; O'Connor et al., 2008), greater alcohol consumption (Grzywacz & Almeida, 2008; Pratt & Davidson, 2009) and more smoking (Cohen & Lichtenstein, 1990; Kouvonen et al., 2005) and there is also some evidence of decreased physical activity in response to stress (Stults-Kolehmainen & Sinha, 2014). McEwen (1998) argues that behaviours which promote or damage health, including smoking, drinking, eating behaviour and physical activity, can be considered within the conceptualisation of allostasis as they are known to contribute to allostatic load. Consequently, there is evidence for both a direct pathway between stress and health and an indirect pathway via health behaviours.

The PCH proposes that, when stress is perseverated upon, the damaging physiological activation associated with stress is also protracted, thus increasing susceptibility to stress-related ill-health (Brosschot et al., 2006). Since the PCH was proposed, systematic reviews and meta-analyses have revealed compelling evidence of a direct association between PC and the physiological determinants of health status (Brosschot et al., 2006; Ottaviani et al., 2016; Verkuil et al., 2010). For instance, in their systematic review and meta-analysis, Ottaviani et al. (2016) reported an association between PC and higher systolic blood pressure, diastolic blood pressure, heart rate and cortisol and lower heart rate variability across both experimental and correlational studies. The authors concluded that there was clear evidence that PC affects cardiovascular, autonomic and endocrine nervous system pathways consistent with a pathogenic route to long-term disease outcomes. Given that research has demonstrated an association between PC and physiological parameters associated with the stress response, it is also possible that, as the experience of the stressor is prolonged via PC, so too may be its detrimental impact on health behaviours. It is proposed here that, in the same way as stress, there may be an additional indirect pathway between PC and health outcomes via health behaviours. There is some research evidence supporting an association between PC and health behaviours. Studies have evidenced associations between rumination and unhealthy eating (Cropley et al., 2012), increased smoking (Rutten et al., 2011), higher alcohol intake (Aldridge-Gerry et al., 2011; Frone, 2015) and less physical activity (Ferrer, Portnoy, et al., 2013). However, to date, this research has not been subject to systematic review or meta-analysis.

PC is an umbrella term for negative repetitive thinking, which incorporates thought processes such as worry and rumination (Brosschot et al., 2006). Research suggests that worry is more predictive of anxiety disorders (Brosschot et al., 2006) whereas rumination (and particularly brooding) is more predictive of depression (Nolen-Hoeksema, 2000). Therefore, there is reason to expect that they may predict health behaviour outcomes differentially. It has also been found that women display a greater tendency towards rumination than men (Johnson & Whisman, 2013) and it has been suggested that this may explain the greater prevalence of depression in women (Nolen-Hoeksema, Larson, & Grayson, 1999). Women have also been found to worry more than men (Robichaud, Dugas, & Conway, 2003; Zlomke & Hahn, 2010). Hence, it may be anticipated that gender will moderate the hypothesised association between PC and health behaviour.

Another factor which may influence the association between PC and health behaviour is whether this variable is measured at a state or trait level. Ottaviani et al. (2016) found that this covariate moderated the association between PC and heart rate and heart rate variability such that a significant association between PC and heart rate and heart rate variability was only found in studies assessing state, as opposed to trait PC. Similarly, Verkuil et al. (2007) reported evidence that the majority of the experience of daily worry is not predicted by trait measures. This research indicates that state and trait PC may have differential associations with health and therefore may moderate the association between PC and health behaviours.

If an association between PC and poorer health behaviours is found, interventions which focus upon reducing PC may prove effective in improving a number of health behaviours. However, firstly, this evidence must be considered systematically to address questions such as whether associations between PC and health behaviours are found across all or only some categories of PC (e.g. worry, brooding and reflection) and health behaviours (e.g. health risk vs health-promoting, eating, physical activity, drinking and smoking), whether state or trait PC is more predictive of health behaviour outcomes and whether differences are found across gender. This review evidence will allow researchers to identify gaps in the existing literature and can be used to inform the development of intervention studies. Additionally, this review will allow for partial assessment of the extended PCH.

2.1.1 Aims

The primary aim was to systematically review empirical studies which have investigated the relationship between any type of PC and a health behaviour outcome. A secondary aim was to establish whether different types of PC had a differential impact on health behaviours. As the PCH aimed to model how stress-related thinking may impact on health outcomes in otherwise healthy populations, the aim here was also to review studies involving physically and mentally healthy participants. It was hypothesised that higher levels of PC would be associated with more health-risk behaviours (defined as those behaviours which, if performed, would hinder health) and less health-promoting behaviours (defined as those behaviours which, if performed, would benefit health). Another aim was to explore whether different types of PC (brooding, reflection and worry) have differential associations with health behaviours. The final aim was to explore the role of moderating variables on the association between overall PC and health-risk and health-promoting behaviours (i.e. study design, study quality, state vs trait PC and the percentage of female participants). The final aim was exploratory, and no directional predictions were made.

2.2 Method

2.2.1 Eligibility Criteria

To be eligible, studies had to (1) include a measure of PC, (2) include a measure of health behaviour and (3) report the relationship between the measures of PC and the health behaviour within a statistical analysis that could be used to estimate an effect size (even if the relationship between PC and health behaviours was not the primary outcome of the study). Studies were excluded if they were (1) not peer-reviewed, (2) not an empirical investigation, (3) were reviews, editorials or ‘think pieces’, dissertations, book chapters, protocols or unpublished, (4) if all study participants had been diagnosed with physical or mental health problems (but included if a sample of healthy participants were analysed separately).

Regarding eligibility criterion (1), some researchers have argued that concepts such as angry rumination and co-rumination are separate forms of rumination. Angry rumination is a type of rumination in which the focus of the rumination is on an anger-inducing event and has been found to predict aggressive behaviour (Denson, 2013) and was included in our conceptualisation here. However, co-rumination is described as a group form of rumination in which interpersonal discussion focuses upon emotions and problems (Rose, 2002) but was not included here as it is not a purely cognitive form of

PC and a similar approach was adopted by Ottaviani et al. (2016). Also, despite research which suggests that reflection may serve as an adaptive component of rumination, studies measuring reflection were retained to assess whether this type of rumination is, in fact, adaptive in terms of health behaviours.

Illegal substance use was not included in these analyses as the focus of this thesis was on legal health behaviours. This excluded Shoal, Castaneda, and Giancola (2005) as the outcome variable included marijuana use. Additionally, smoking cessation outcomes were excluded as the focus of this thesis is on ongoing health behaviours rather than quitting behaviour in the context of addictive substance use (i.e. frequency of use). This excluded Yong et al. (2014) from analyses. In these ways, this meta-analysis differs from the published record (Clancy, Prestwich, Caperon, & O'Connor, 2016).

2.2.2 Search Strategy

PsycINFO (1806 to Present) and Medline (1946 to Present) were searched using OVID. The search was last run on the 11th of February 2016 using search terms relating to PC and health behaviour. The search has not been re-run since the review has been published (Clancy et al., 2016) to ensure consistency with the published record.

PC terms were adapted from Querstret and Cropley (2013) and Ottaviani et al. (2016): (1) perseverati∗ AND cogniti∗ (2) reflection (3) brooding (4) ruminat∗ (5) reflect∗ AND thought∗ OR thinking (6) brood∗ AND thought∗ OR thinking (7) perseverative AND thought∗ OR thinking (8) repetitive AND thought∗ OR thinking (9) intrusive AND thought∗ OR thinking (10) negative AND thought∗ OR thinking (11) self-referential AND thought∗ OR thinking (12) stress AND thought∗ OR thinking (13) obsessive AND thought∗ OR thinking (14) worry (15) unconscious stress∗ (16) implicit stress∗ (17) anticipat∗ stress∗ (17) cognitive intrusion∗.

Alcohol terms were adapted from Kaner et al. (2018), exercise terms from Foster, Hillsdon, Thorogood, Kaur, and Wedatilake (2005), eating terms from Nield et al. (2007), smoking terms from Secker-Walker, Gnich, Platt, and Lancaster (2002) and sleep terms from Hu et al. (2015): (1) exp alcohols/ (2) Alcohol$.tw. (3) exercise.sh. (3) physical activity.sh (4) sports.sh (5) dance.sh (6) [physical$ adj5 (fit$ or train$ or activ$ or endur$)].tw. (7) [exercis$ adj5 (train$ or physical$ or activ$)].tw. (8) sport$.tw. (9) walk$.tw. (10) bicycle$.tw. (11) (exercise$ adj aerobic$).tw. (12) [(lifestyle or life-style) adj5 (activ$)].tw. (13) [(lifestyle or life-style) adj5 physical$].tw. (14) Diets.sh (15) Eating behavio?r.sh (16) weight control.sh (17) (diet$ adj5 carbohydrat$).tw (18) (diet$ adj5 fat$).tw (19) (diet$ adj5 weigh$).tw (20) (diet$ adj5 sugar$).tw (21) (diet$ adj5 fiber$).tw (24) (diet$ adj5 fiber$).tw (22) (diet$ adj5 salt$).tw (23) (diet$ adj5 calorie$).tw (24) healthy eating.tw (25) smok$.mp. (26) nicotine.mp. (27) tobacco.mp. (28) cigarette$.mp.

The items below were developed by the research team as they were not captured by the terms adapted from the previous reviews cited: (32) hypophagi∗ (33) hyperphagi∗ (34) caffein∗ (35) snack∗ (36) meal∗ (37) junk food∗ (38) fast food∗ (39) vegetable∗ (40) fruit∗ (41) unhealthy food∗ (42) unhealthy diet (43) healthy food∗ (44) alcohol∗ intake (45) alcohol∗ unit (46) alcohol∗ consum∗ (47) caffein∗.

The search was limited by (1) English language, (2) human studies and (3) studies published from 1990. The Penn State Worry Questionnaire (Meyer et al., 1990) was developed as a multi-item measure of worry. Prior to its publication, it was common to measure worry with only a single item. Therefore, this date represents a starting point from which studies with a potentially psychometrically sound measure of worry can be evaluated. The titles were screened by the first author. All abstracts and full-texts that were not excluded at the title screening stage (n = 206) were independently double-screened. There was 100% agreement between the two reviewers regarding the studies to be included.

2.2.3 Data Extraction

The following data were extracted (see Table 2.1) by the lead author for each study: (1) the type of PC, categorized as worry (reported as worry in the paper or as any type of future-oriented negatively affect-laden repetitive thought), health worry (reported as worry focused on health in the paper), brooding (reported as brooding in the paper, or as rumination which excluded reflective or positive thoughts, or as any type of past-oriented negatively affect-laden repetitive thought), and reflection (reported as reflection in the paper or as any past-orientated reflective thoughts (e.g. problem-solving pondering), (2) the health behaviour outcome, (3) the study design (multiple outcomes were possible in this case e.g. a study could report both cross-sectional and longitudinal outcomes (4) the number of participants included in the analyses, (5) the percentage of female participants (averaged if this differed across study outcomes), (6) the age of participants (preferably the mean and SD if reported), (averaged if this differed across study outcomes) and then categorised as children (0-12), adolescents (12-18), adults (18+) or a combination of these categories (7) whether PC was measured at a state or trait level. PC measures were coded as trait when reference was made to the habitual tendency to engage in PC, within no specific time-period, whereas PC measures were coded as state when there was a particular time-focus (e.g. to what extent participants engaged in PC that day, month, year), (8) whether PC measures were multi- or single-item, (9) whether self-reported health behaviour measures were multi- or single-item, (10) whether PC measures were reported as validated, (11) whether self-reported health behaviour measures were reported as validated, (12) whether PC measures were reported as reliable in that sample (Cronbach's $\alpha \geq .70$), (13) whether self-reported health behaviour measures were reported as reliable in that sample (Cronbach's $\alpha \geq .70$) (14) effect size data for relationships between PC and health behaviour, (15) whether any covariates were included (authors were contacted for direct associations but not all had this information or responded to requests).

If any of this information was not available, first authors were contacted for this information or for clarifications. In the event of no response, second authors were contacted. If simple statistical associations could not be obtained, sensitivity analyses were performed for studies which included covariates. To maximize reliability of the data extraction process, each aspect of the data extraction was checked by a second reviewer. Note that, in the published review (Clancy et al., 2016), brooding was described as rumination as this term is more widely used. Here, the decision was made to change this to brooding as, first, this term more accurately describes how the data was coded. That is, reflection was coded separately to the negative component of rumination (brooding). Second, the use of the term brooding here is consistent with how the terms brooding and rumination are used across the rest of the thesis.

2.2.4 Study Quality

All study quality items (whether all PC and health behaviours were measured within that study were multi-item measures and whether all PC and health behaviours were reported as reliable and valid) were coded as 0 for no and 1 for yes. One outcome was produced per study, and therefore, the item was only coded as yes if this was true for all measures within that study. These items were analysed as individual moderators rather than combined as (1) summing scores would include an element of double-counting e.g. a single item measure would be penalized for being a single item and for not being reliable, (2) combining scores is problematic as it is difficult to ascertain the importance of each individual criterion and (3) the Cochrane Handbook (Higgins & Green, 2008) advises against such an approach. Note that these items were selected to assess study quality as they are applicable to all included study designs (and no such validated quality assessment tool was available).

2.2.5 Method of Analysis

Comprehensive Meta-Analysis software (Borenstein, Rothstein, & Cohen, 2005) was used to calculate effect sizes reflecting the relationship between measures of PC and measures of health behaviours. Effect sizes were calculated based on correlation coefficients and, when not available, were based on other statistical information (e.g., beta or p-values). Effect sizes were meta-analysed within studies when necessary (e.g., when the same variables were assessed at multiple time-points; when different measures of the same behaviour were taken in the same study etc.). Effect sizes were combined across studies, where appropriate, using random effect models (where each study estimates different underlying effect sizes) rather than fixed effects models (where all studies are assumed to be estimates of the same one true effect size) because (1) it was assumed that the true effect should vary across studies because they differ in critical ways (e.g., type of behaviour; type of PC) and (2) the sample of studies, selected systematically, should reflect a random sample of the relevant distribution of effects.

To account for the issue of dependence resulting from multiple outcomes per study, mean effect sizes reflecting the strength of the association between a specific type of PC and health behaviour were used in analysis. For instance, several studies measured more than one type of PC, some studies used more than one measure of PC and health behaviour and several studies included more than one time-point. All such effect sizes were included as there was no theoretical justification to exclude outcomes (e.g., first versus second versus last follow-up; one type of sleep quality measure over another) on any of these bases. This method has the limitation of increasing the type II error rate (Scammacca, Roberts, & Stuebing, 2014) and therefore this should be taken into consideration when interpreting the findings of these analyses. This was deemed preferable to increasing the type I error rate when assuming independence between non-independent outcomes.

After considering the overall association between PC (worry + brooding) and health behaviours, additional analyses were conducted to identify the association between different types of health behaviour (health-promoting and health-risk) and different types of PC (brooding and worry; plus, the related adaptive construct of reflection). Note that reflection was not included in the overall association as this type of PC has been theorised to have an adaptive component (Smith & Alloy, 2009; Treynor et al., 2003) and therefore it was possible that its inclusion would alter the magnitude or direction of the association between overall PC and health behaviours. In most instances, formal moderation analyses were not conducted because there were studies in which the same participants completed multiple measures (e.g., participants in the study by Cropley et al. (2012) or completed measures of health-promoting and health-risk behaviours; the participants in the study by Ciesla, Dickson, Anderson, and Neal

(2011) completed measures of brooding and worry). Additionally, the association between PC (worry + brooding) and different categories of health behaviour were assessed (alcohol consumption behaviour, smoking behaviour, eating behaviour and physical activity).

In all analyses, a positive correlation reflects an association between increased levels of PC and increased unhealthy behaviour (i.e., either more health-risk behaviour or less health-promoting behaviour). A negative correlation reflects an association between increased levels of PC and increased healthy behaviour (i.e., either less health-risk behaviour or more health-promoting behaviour). An effect size of the magnitude r = .1 - .3 was considered small, .3 - .5 was considered medium and .5 and above was considered large. Q and I^2 values were used in assessing heterogeneity and I^2 values of .25, .50 and .75 relate to low, moderate and high between-study heterogeneity (as per Ottaviani et al. 2016). Egger's regression test (Egger, Smith, Schneider, & Minder, 1997) was used to assess publication bias and Duval and Tweedie's Trim and Fill analysis (Duval & Tweedie, 2000) was used to adjust for any existing publication bias.

2.2.6 Meta-Regression

In accordance with the Cochrane Handbook (Higgins & Green, 2008), meta-regressions were only conducted where there were at least 10 studies. Similarly, where moderators were categorical, consistent with Ottaviani et al. (2016), a minimum of 5 studies per subgroup was selected as the criterion for moderator analyses. The continuous and categorical moderators were analysed via meta-regression using a maximum likelihood method. Moderators analysed were: (1) the percentage of female participants; (2) study quality items with a yes/no response code and, (3) study design (cross-sectional coded as 0, longitudinal coded as 1).

2.2.7 Sensitivity Analyses

Sensitivity analyses were conducted to examine if the results changed when underage substance users were removed from the analysis as these behaviours may be limited by external factors (e.g. parental restriction) more so than the other included behaviours (sensitivity analysis 1). Excluded on this basis were Adrian, McCarty, King, McCauley, and Stoep (2014), Aldridge-Gerry et al. (2011), Dijkstra and Brosschot (2003), Willem, Bijttebier, Claes, and Raes (2011) and Willem, Bijttebier, Claes, Vanhalst, and Raes (2013). Additionally, this sensitivity analysis bore the dual purpose of restricting studies to only those with adult participants which are more pertinent to the aims of this thesis. Sensitivity analysis 2 excluded the study by Harwell, Cellucci, and Iwata (2010), given they only considered drinking in negative situations rather than drinking across all situations and the measure of PC (anxious rumination) also controlled for anxiety sensitivity. Ciesla et al. (2011) was also excluded within this analysis as the effect size controlled for sex. Sensitivity analysis 3 combined sensitivity analysis 1 and 2. In sensitivity analysis 4, the one study that measured general worry (Ciesla et al., 2011), as opposed to health worry, was removed from analyses. It is possible that health worry, more so than non-specific worry may trigger fear-appeals, and therefore have the capacity to promote some health behaviours (Tannenbaum et al., 2015). This sensitivity analysis was only conducted when the association between worry and health behaviour outcomes were being assessed, as opposed to when the association between all PC and health behaviour outcomes were being assessed, as the aim here was to assess how the association between worry and health behaviour outcomes differ when only health worry is included in analyses, not how the association between overall PC and health behaviour outcomes differ when general worry is removed. Also, Ciesla et al. (2011) only measured a health-risk outcome so this sensitivity analysis was not relevant for analyses of the association between all worry and health-promoting behaviours.

2.3 Results

2.3.1 Overview of Included Studies

The search returned 7504 papers which were screened for inclusion. Screening identified 17 relevant studies (see Figure 2.1). Of the 17 included studies, 9 measured brooding, 8 studies measured health-related worry and 1 study measured general worry. In addition, 4 studies measured reflection. Note that Ciesla et al. (2011) also measured co-rumination but this was removed as the conceptualisation of rumination/brooding in this thesis did not include this and the Cropley et al. (2012) measure of problem-solving pondering was classified as reflection in these analyses. Studies were excluded based on (1) not including a measure of PC within the conceptualisation (n = 11), (2) not including a health behaviour, or included a health behaviour that did not meet inclusion criteria (n = 4) and, (3) participants were not healthy and a healthy subset of the sample was not analysed (n = 5). Health behaviours investigated were alcohol consumption, smoking behaviour, eating behaviour, cancer screening uptake and levels of physical activity. See Table 2.1 for a more detailed overview of the included studies. Table 2.2 presents the results of the meta-analyses.

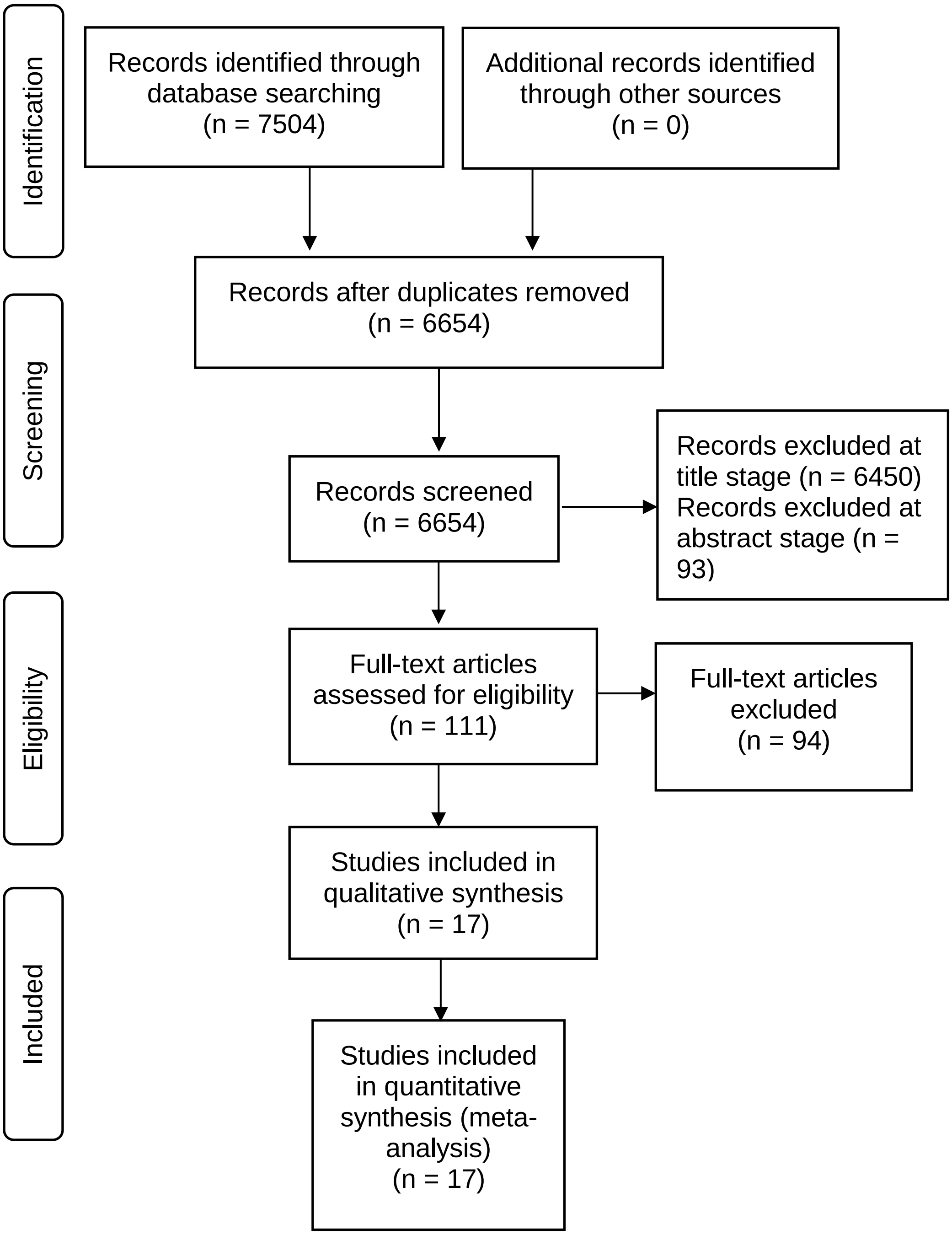

Figure 2.1 PRISMA Diagram adapted from Moher, Liberati, Tetzlaff and Altman (2009)

Table 2.1 Overview of Included Studies

Study	Design	Health Behaviour	Type of PC	PC State or Trait	Sample Size	% Female	Age
Adrian et al. (2014)	Longitudinal	Alcohol	Brooding and Reflection	Trait	428	48%	Children and Adolescents (11-13, *M* = 12.0)
Aldridge-Gerry et al. (2011)	Diary	Alcohol	Brooding	State	365	69%	Adolescents and Adults (17-25, *M* = 20.1, *SD* = 2.1)
Bernat, Anderson, Parrish-Sprowl, and Sparks (2015)	Cross-Sectional	Physical Activity	Health Worry	Trait	451	100%	Adults (*M* = 20, *SD* = 3.42)
Ciesla et al. (2011)	Cross-Sectional	Alcohol	Brooding and Worry	Trait	447	65%	Adults (18-25+)
Cropley et al. (2012)	Cross-Sectional	Eating Behaviour	Brooding and Reflection	Trait	268	59%	Adults (19-63, *M* = 36.7, *SD* = 12.9)
Dijkstra and Brosschot (2003)	Longitudinal	Smoking	Health Worry	Trait	704	69%	Adolescents and Adults

							(15-80, *M* = 44.55)
Dvorak, Simons, and Wray (2010)	Cross-Sectional	Smoking	Brooding	Trait	53	79%	Adults (*M* = 20.17, *SD* = 2.29)
Ferrer, Bergman, and Klein (2013)	Cross-Sectional	Eating Behaviour	Health Worry	State	3397	52%	Adults (18-55+)
Ferrer, Portnoy, et al. (2013)	Cross-Sectional	Physical Activity	Health Worry	Trait	10,230	52%	Adults (*M* = 45.46, *SD* = 0.06)
Frone (2015)	Cross-Sectional	Alcohol	Brooding	Trait	2831	47%	Adults (18-65, *M* = 41.0)
Harwell et al. (2010)	Cross-Sectional	Alcohol	Brooding	Trait	113	82%	Adults (*M* = 25.8)
Li, Cardinal, and Vuchinich (2009)	Longitudinal	Physical Activity	Health Worry	State	7527	62%	Adults (70+, *M* = 76.83, *SD* = 5.59)
Malmi et al. (2010)	Case-Control	Prostate Cancer Screening Uptake	Health Worry	Trait	423	0%	Adults (55-67, *M* = 60.35, *SD* = 4.35)

Rutten et al. (2011)	Cross-Sectional	Smoking	Health Worry	Trait	1765	54%	Adults (18-65+)
Swayampakala et al. (2013)	Longitudinal	Smoking	Health Worry	Unclear	1206	32%	Adults (18-55+)
Willem et al. (2011)	Cross-Sectional	Alcohol	Brooding and Reflection	Trait	189	50%	Adolescents and Adults (14-19, *M* = 16.67, *SD* = 1.26)
Willem et al. (2013)	Cross-Sectional and Longitudinal	Alcohol	Brooding and Reflection	Trait	216	38%	Adolescents and Adults (13-20, *M* = 16.82, *SD* = 1.32)

2.3.2 Main Results

Averaging across all types of PC (brooding + worry but excluding reflection), behaviours and time-points, PC was associated with poorer health behaviours, k = 17, r = .07, p = .02, although this association was very small and with very heterogeneous effect sizes, Q = 181.28, p < .001, I^2 = 91.17. This association remained significant in sensitivity analysis 1, k = 11, r = .10, 95% CI = .02 to .18, Z = 2.61, p = .01, but was reduced to non-significance in sensitivity analysis 2, k = 16, r = .05, p = .08, and 3, k = 10, r = .07, p = .07. All moderators were non-significant (p > .05), see Table 2.3. See appendix A for forest plots of these associations.

2.3.3 PC Type

Higher brooding was associated with unhealthier behaviours (combination measure of more health-risk behaviours/fewer health-promoting behaviours), k = 9, r = .10, p = .01, Q = 28.42, I^2 = 71.85, p = .01, and this remained significant across sensitivity analyses (SA 1: k = 5, r = .16, p = .01; SA 2: k = 8, r = .07, p < .001; SA 3: k = 3, r = .08, p < .001).

Reflection, k = 4, r = -.02, p = .64, Q = 3.18, I^2 = 5.74, p = .36, and worry, k = 9, r = .04, p = .45, Q = 157.06, I^2 = 94.91, p <.001 (SA 1: k = 8, r = .04, p = .47; SA 4: k = 8, r = .05, p =.34), were unrelated with health behaviours.

2.3.4 Health-Risk vs Health-Promoting

PC was unrelated to health-promoting behaviours, k = 6, r = -.03, p = .61, Q = 140.24, I^2 = 96.44, p < .001, but was significantly related with health-risk behaviours, k = 13, r = .12, p = .001, Q = 101.24, I^2 = 88.15, p < .001. Regarding the latter, higher PC was associated with increased performance of health-risk behaviours. These relationships were consistent across sensitivity analyses (SA 1: k = 8, r = .18, p < .001; SA 2: k = 12, r = .09, p = .004; SA 3: k = 7, r = .14, p = .004). All moderators were non-significant (p > .05), see Table 2.3.

2.3.5 PC Type and Health-Risk vs Health-Promoting

Higher brooding was associated with increased performance of health-risk behaviour, k = 9, r = .12, p = .003, Q = 36.48, I^2 = 78.07, p < .001 (SA 1: k = 5, r = .20, p = .004; SA 2: k = 8, r = .08, p = .003; SA 3: k = 4, r = .12, p = .01) but not health-promoting behaviour, *k* = 1, *r* = -.12, *p* = .99, (though only one study (Cropley et al., 2012), has considered the latter association).

Worry was unrelated to health-promoting, *k* = 5, *r* = -.04, *p* = .59, *Q* = 139.12, I^2 = 97.13, *p* < .001, and health-risk behaviours, *k* = 5, *r* = .10, *p* = .19, *Q* = 63.89, I^2 = 93.74, *p* < .001 (SA 1: *k* = 4, *r* = .11, *p* = .21; SA 4: *k* = 4, *r* = .13, *p* = .11). Reflection was not associated with health-risk behaviour, *k* = 4, *r* = .01, *p* = .89, *Q* = 6.98, I^2 = 57.03, *p* = .07. Sensitivity analysis 1 revealed a significant association between reflection and more health-risk behaviour but this only left one study (Cropley et al., 2012), *k* = 1, *r* = .12, *p* = .05. Reflection was not associated with health-promoting behaviour but only one study measured this (Cropley et al., 2012), *k* = 1, *r* = -.08, *p* = .19.

2.3.6 Health Behaviour Category

Breaking down by health behaviour category, there was a small significant association between higher levels of PC and more unhealthy drinking behaviour, *k* = 7, *r* = .09, *p* = .04, *Q* = 29.42, I^2 = 79.61, *p* < 001, which differed across sensitivity analyses (SA 1: *k* = 3, *r* = .18, *p* = .08; SA 2 : *k* = 6, *r* = .06, *p* < .001; SA 3: *k* = 2, *r* = .05, *p* = .19). There was no significant association between PC and smoking, *k* = 4, *r* = .17, *p* = .15, *Q* = 46.62, I^2 = 93.57, *p* < .001 (SA 1: *k* = 3, *r* = .21, *p* = .19), eating behaviour, *k* = 2, *r* = .05, *p* = .46, *Q* = 4.80, I^2 = 79.16, *p* = .03, or physical activity, *k* = 3, *r* = -.03, *p* = .82, *Q* = 50.76, I^2 = 96.06, *p* < .001. There was only one study which assessed cancer screening uptake (Malmi et al., 2010) and this was non-significant, *k* = 1, *r* = -.06, 95% *p* = .30.

Table 2.2. Summary of Meta-Analyses

Type of PC	Health Behaviour	Study Design	*k*	*r*	95% CI		*Z*	Sensitivity Analyses			
					Lower	Upper		1	2	3	4
All (excluding reflection)	All	All	17	.07	.01	.13	2.38*	2.37*	1.80	1.69	n/a
Brooding	All	All	9	.10	.03	.16	2.83*	2.71**	4.86***	4.96***	n/a
Reflection	All	All	4	-.02	-.08	.05	-0.47	-	n/a	n/a	n/a
Worry (all)	All	All	9	.04	-.06	.13	0.75	0.72	0.96	0.94	0.96
All (excluding reflection)	Health promotion	All	6	-.03	-.15	.09	-0.51	n/a	n/a	n/a	n/a
Worry (all)	Health promotion	All	5	-.04	-.17	.10	-0.54	n/a	n/a	n/a	n/a
All (excluding reflection)	Health risk	All	13	.12	.05	.18	3.38**	3.52***	2.86**	2.87**	n/a

Brooding	Health risk	All	9	.12	.04	.19	3.00**	2.88**	2.75**	2.16*	n/a
Reflection	Health risk	All	4	.01	-.09	.11	0.14	-	n/a	-	n/a
Worry (all)	Health risk	All	5	.10	-.05	.23	1.31	1.25	1.60	1.54	1.60
All (excluding reflection)	Alcohol	All	7	.09	.004	.17	2.05*	1.75	4.40***	-	n/a
All	Smoking	All	4	.17	-.06	.38	1.43	1.31	n/a	n/a	n/a
All (excluding reflection)	Eating	All	2	.05	-.08	.18	0.74	n/a	n/a	n/a	n/a
All	Physical Activity	All	3	-.03	-.24	.19	-0.23	n/a	n/a	n/a	n/a

Note. *** significant at the <.001 level, **significant at the <.01 level, *significant at the .05 level

Table 2.3. Summary of Moderator Analyses

Moderator	Type of PC	Type of Health Behaviour	*k*	*Coefficient*	*SE*	95% CI		*Z*
						Lower	Upper	
Cross-Sectional vs Longitudinal	All	All	15	-.05	.09	-.24	.13	-0.59
%Female	All	All	17	.002	.002	-.002	.01	0.81
PC Reliable	All	All	17	-.01	.08	-.17	.14	-0.18
PC Valid	All	All	17	.08	.08	-.23	.07	-1.05
PC Multi-Item	All	All	17	-.001	.08	-.16	.16	-0.01
HB Multi-Item	All	All	13	.02	.10	-.18	.21	0.17
%Female	All	Health Risk	13	.004	.003	-.002	.01	1.34
PC Reliable	All	Health Risk	13	-.07	.09	-.25	.11	-0.78
PC Valid	All	Health Risk	13	-.11	.09	-.29	.07	-1.23
HB Multi-Item	All	Health Risk	10	.03	.12	-.20	.26	0.27

2.3.7 Publication Bias

Egger's regression coefficient (Egger et al., 1997) was non-significant for the relationship between PC and health behaviours with reflection removed (a combination of health-risk and health-promoting behaviours; p = .57) suggesting an absence of publication bias. Nonetheless, to consider the potential impact of missing studies, Duval and Tweedie's Trim and Fill analyses were conducted (Duval & Tweedie, 2000). These results suggested that no studies were missing from the left-side of the mean effect, but four studies were missing from the right-side of the mean effect. After imputing these, the imputed point estimate, r = .12, 95% *CI* = .06 to .18, suggested, if anything, that the relationship between PC and unhealthy behaviours is slightly stronger than estimated in the main analyses.

2.4 Discussion

The main findings of this systematic review and meta-analysis was that there was a small-sized association between higher levels of PC and higher reported performance of health-risk behaviours that are driven primarily through brooding. In contrast, measures of worry and reflection were not significantly associated with health behaviours. Additionally, although when outcomes were categorised by the type of health behaviour, the numbers of included studies were very small, there was a significant small-sized association between overall PC and greater alcohol consumption. Significant findings were not demonstrated for smoking, eating or physical activity but this is not surprising given there were less than five studies in each category. These results are important for a number of reasons. First, they provide partial support for the hypothesis that in Brosschot and colleagues (Brosschot et al., 2006) original PCH, there may be scope for an additional route to pathogenic disease via poorer health behaviours (i.e. the extended PCH). In this conceptualisation, it is theorised that brooding about past stressful events will moderate the effects of stressors on health behaviours (particularly those previously shown to be influenced by stress), which will have knock-on effects for health outcomes and disease processes.

Nevertheless, it is recognised that the current results ought to be considered preliminary at this stage precluding any firm conclusions. The analyses did not find evidence that worry about feared future events was associated with health behaviours. This is surprising given that worry has been identified as important in recent narrative reviews and meta-analyses in the context of the PCH (Ottaviani et al., 2016; Verkuil et al., 2010). A likely explanation for the absence of a significant effect here might be related to the heterogeneity of effect sizes across the studies and/or to do with the variability in types of worry measures utilised (e.g., health-related worry, cancer worry, trait worry etc. as well as single-item versus multi-item measures). Alternatively, this null finding may reflect that there are relatively few studies that have directly investigated the relationship between worry (and brooding) and health-risk and health-promoting behaviours. In many of the studies reviewed, exploring the relationship between worry (and brooding) has been of secondary interest. It might also be that worry, triggered by fear-appeals, has the capacity to promote some health behaviours, thereby, contributing to the observed mixed findings (Tannenbaum et al., 2015). This may be especially relevant here as all but one study measured worry-related to health which may be qualitatively different to general worry. Also, it may be more likely to trigger health-related fear, thus motivating, in some individuals at least, positive health behaviours and producing mixed findings. Likewise, no relationship with reflection was found but there were only four studies which measured this construct and so no definitive conclusions can be drawn.

None of the proposed moderators significantly moderated the associations between PC and health-risk or health-promoting behaviours. This on the one hand could suggest that the findings evidenced are relatively robust as they were not influenced by study quality, for example. On the other hand, studies were mostly cross-sectional which may have limited comparisons of cross-sectional versus longitudinal designs, especially as there were only seventeen studies in total. As well, the percentage of female participants was only a proxy measurement of gender and cannot be considered as meaningful as direct comparison of male and female participants, which unfortunately, was not possible here. Therefore again, the small amount of studies available for review makes extrapolation difficult.

Ottaviani et al. (2016) found that whether PC was measured at a trait or state level moderated the association between PC and physiological outcomes, and Verkuil et al. (2007) found evidence to suggest that daily worry is only partially predicted by trait measures. This research indicates that the association between PC and health behaviours may differ depending upon whether this variable is measured at a state or trait level. However, as only three studies measured PC at a state level, it was not possible to make this comparison here.

Overall, this review has identified a scarcity of studies which have assessed the association between PC and health-promoting or health-risk behaviours (aside from sleep). Furthermore, these studies have rarely used validated measures of PC, with a heavily reliance on single-item measures of this construct. As well, studies have mostly been cross-sectional and so few inferences can be made about whether PC is predictive of health behaviour prospectively. Only two studies employed diary designs and there were no experimental studies so causation cannot be inferred. Nor were there any intervention studies to draw conclusions from. The majority of studies measured drinking behaviour (and, to a lesser extent, smoking) so little is known about other stress-sensitive health behaviours such as eating behaviour and physical activity. However, the full model also remains to be tested as it is unknown whether, as predicted, PC moderates the relationship between stress and health behaviours specified in Chapter 1. It is suggested that future research address these issues so that a clearer picture of the relationship between stress, PC and health behaviour can emerge.

It is acknowledged that, as the review was limited to English language papers, some relevant studies may have been missed. Likewise, only published studies were reviewed which could have led to an over-estimation of the effect sizes due to publication bias. The decision to exclude unpublished studies was based on two arguments. First, we were concerned that, in the absence of peer review, the quality of the reporting of key moderators may be insufficient for us to reliably code them. Second, we were concerned that there could be differences between the unpublished data/studies that authors were willing to share and those studies for which authors were not willing to share and this would result in a different type of systematic bias. Promisingly, analyses suggested only a very small degree of publication bias.

In conclusion, this systematic review and meta-analysis showed that there is a positive, small-sized association between PC and health-risk behaviours that are driven primarily through brooding. These findings provide partial support for the hypothesis that in the original PCH (Brosschot et al., 2006), there may be scope for an additional route to pathogenic disease via poorer health behaviours (the extended PCH). Therefore, based upon the current findings, future research into the effects of PC ought to incorporate measures of health behaviours, whilst addressing the limitations within the current literature.

Chapter 3
Perseverative Cognition and Sleep: A Systematic Review and Meta-Analysis

3.1 Introduction

The American Academy of Sleep Medicine advises that adults should sleep for 7 or more hours per night to reduce the risk of negative health outcomes (Watson et al., 2015). In a review of the literature, the panel reported evidence for associations between short sleep duration and poorer general, cardiovascular, metabolic, mental and immunologic health, as well as greater experience of pain and greater overall rates of mortality. Similarly, sleep disturbance has been associated with markers of inflammation in a recent meta-analysis (Irwin, Olmstead, & Carroll, 2016).

In 2017, the UK Sleep Council surveyed 5002 British adults and found that 74% slept for less than 7 hours per night and this percentage had risen from 2013. Most survey respondents (61%) slept between 5 and 7 hours each night and 12% reported sleeping for less than 5 hours (a 5% rise since 2013). As well, nearly a third reported regular poor-quality sleep. Similarly, in a sample of 25,580 adults from 7 European countries, 10.8% reported experiencing non-restorative sleep and this rose to 16.1% when the UK was analysed separately (Ohayon, 2005). Likewise, in the US, a trend analysis of sleep duration from 1985-2012 found that the number of adults reporting 6 or fewer hours of sleep per night had risen by 31% (Ford, Cunningham, & Croft, 2015). This divergence from sleep recommendations, and the associated health consequences, suggest that identifying the predictors of disturbed sleep is of vital importance from a public health perspective.

Research has identified an association between negative over-thinking and sleep difficulties. Harvey, Tang, and Browning (2005) reviewed studies exploring the prevailing cognitive explanations for insomnia. They provided evidence for the role of repetitive thought processes including cognitive arousal, intrusive and worrisome thoughts and unhelpful beliefs about sleep in the incidence of insomnia. Studies in non-clinical samples have also reported an association between thought processes such as worry and rumination/brooding and difficulty falling asleep (McGowan et al., 2016; Zoccola et al., 2009), poorer quality sleep (Barclay & Gregory, 2010; Cropley et al., 2015) and shorter total sleep duration (Cropley et al., 2006; Nota & Coles, 2015).

Ottaviani et al. (2016) demonstrated an association between PC and physiological parameters associated with the stress response (higher systolic blood pressure, diastolic blood pressure, heart rate and cortisol and lower heart rate variability) across both experimental and correlational studies. It is also possible that, as the experience of the stressor is prolonged by PC, so too may be its detrimental impact on health behaviours. It is proposed here that, in the same way as stress, there may be an additional indirect pathway between PC and health outcomes via health behaviours. Furthermore, given that both PC and sleep have been found to negatively impact on cardiovascular and endocrine processes (Ottaviani et al., 2016; Watson et al., 2015), it is possible that another route by which PC predicts ill-health is via sleep disturbance. It was reported in Chapter 2 (see section 2.3.3) that brooding, but not worry or reflection, was associated with poorer health behaviours, although the small number of studies, the scarcity of non-health worry studies and the heterogeneity of measures may have contributed to non-significant findings. Nonetheless, these findings suggest that components of PC may also differ in their association with sleep.

Review evidence suggests that although women evidence more self-reported sleep complaints, such as inadequate sleep time and insomnia, their overall sleep quality (measured via actigraphy) is better (Krishnan & Collop, 2006) which may reflect a greater sensitivity to poor sleep in women or a greater likelihood of reporting symptoms. As such, the evidence regarding gender and sleep is somewhat contradictory. Evidence regarding PC and gender tends to show that females are more likely to engage in perseverative thinking. For instance, in a recent meta-analysis, it was found that women displayed a greater tendency towards rumination than men (Johnson & Whisman, 2013) and it has been suggested that this may explain the greater prevalence of depression in women (Nolen-Hoeksema et al., 1999). A similar greater tendency to engage in worry has also been found in women (Robichaud et al., 2003; Zlomke & Hahn, 2010). On the other hand, review evidence suggests that although women evidence more self-reported sleep complaints, such as inadequate sleep time and insomnia, their overall sleep quality (measured via actigraphy) is better (Krishnan & Collop, 2006). This may reflect a greater sensitivity to poor sleep in women suggesting that, compared to men, they more reliably report poor sleep. Alternatively, the lack of correspondence between self-reported and objectively verified sleep in women may reflect less reliable reporting of sleep in women compared to men. A potential difference in the reliability of reporting sleep in women versus men could lead to possible differences in the associations between

PC and sleep, given reliability of construct measurement influences the size of the correlation between two variables (Goodwin & Leech, 2006). Thus, sex may moderate the association between PC and sleep outcomes. Given it is unclear whether sleep (and PC) are more reliably reported by women or men, and no such studies have directly tested whether such associations vary across the sexes, no directional predictions are made.

Another factor which may moderate the PC-sleep association, is measurement of both of these variables. In their review, Ottaviani et al. (2016) assessed whether outcomes differed depending upon whether PC was measured at a state or trait level. They found that this covariate moderated the association between PC and heart rate and heart rate variability. A significant association between PC and heart rate and heart rate variability was only found in studies assessing state, as opposed to trait PC. It is therefore possible that state and trait PC may have different associations with other health/behavioural outcomes, including sleep. Likewise, in Chapter 2, section 2.3, it was found that brooding, but not worry, predicted health-risk behaviours, and it is therefore possible that types of PC may differentially predict sleep outcomes.

Similarly, another measurement type which may moderate the PC-sleep association is whether sleep is measured by self-report or actigraphy. Lauderdale, Knutson, Yan, Liu, and Rathouz (2008) found that, compared to objectively measured sleep duration (actigraphy), self-reported sleep was systematically over-reported. It can be concluded from this that objectively measured sleep and participant’s perception of their sleep are arguably two different outcomes and that it is therefore important to assess whether PC is associated with both. This is especially important as it has been found that worry may sensitize individuals to health complaints (Verkuil, Brosschot, & Thayer, 2007), making high worriers more likely to recall health complaints, and it is therefore possible that this may also apply to sleep complaints. Consequently, an association between PC and actigraphy-measured sleep would be more definitive as sleep measured in this way would not be prone to any distorted perception of sleep which might be evident in high worriers.

Overall, several studies have reported an association between PC and shorter sleep duration (Cropley et al., 2006; Nota & Coles, 2015), longer SOL (McGowan et al., 2016; Zoccola et al., 2009) and poorer overall sleep quality (Barclay & Gregory, 2010; Cropley et al., 2015) in non-clinical populations. To date, these studies have not been reviewed or subject to meta-analysis. In the insomnia literature, some attention has been given to the contribution of cognitive processes and negative thinking to sleep (Harvey, Gregory, & Bird, 2002; Hiller, Johnston, Dohnt, Lovato, &

Gradisar, 2015), but similar research in non-clinical populations has not been synthesized, despite widespread sleep problems at a population level. Furthermore, even if assumptions were made about PC and sleep in healthy populations based on the insomnia literature, the association between cognitive processes and clinical sleep disorders has not been reviewed systematically nor have the effect sizes been subject to meta-analysis.

If a relationship between PC and poorer sleep is established, interventions which focus upon managing PC may prove effective in improving sleep quality and associated health outcomes. This evidence must be reviewed systematically to address whether associations between PC and sleep are found across all or only some categories of PC (e.g. worry and brooding) and sleep outcomes (SOL, sleep quality and total sleep time, TST), whether state or trait PC is more predictive of sleep outcomes, whether differences are found across sleep measurement (self-report vs actigraphy) and whether differences are found across gender. Such evidence will enable researchers to identify gaps in the existing literature and can be used to inform the development of intervention studies. As well, findings from this review and meta-analysis will allow for assessment of the extended PCH (the pathway between PC and health behaviours) and for further studies in this thesis to address limitations of the existing literature in understanding this theory.

3.1.1 Aims

The primary aim of the current review was to establish whether there is an association between PC and sleep in non-clinical populations. Specifically, the first objective was to examine the association between PC and SOL, TST and sleep quality. The secondary objective was to test whether this relationship was moderated by other variables (i.e. gender, study quality, study design, state versus trait perseverative cognition measurement, self-reported versus actigraphy-measured sleep, the time between measures of perseverative cognition and the number of perseverative cognition measurements).

3.2 Method

3.2.1 Eligibility Criteria

Eligible studies had to (1) include a measure of PC, (2) include a measure of sleep (3) report the relationship between the measures of PC and sleep within a statistical analysis that could be used to estimate an effect size. Studies were excluded if they (1) were not peer-reviewed (including dissertations and unpublished papers), (2) were not an empirical investigation, (3) were reviews, editorials, 'think pieces', book chapters or protocols, (4) recruited only participants diagnosed with physical or mental health problems (including insomnia and other clinical sleep disorders), but if a sample of healthy participants were analysed separately, they were included, (5) were published in a paper that could not be retrieved after trying to contact authors. Studies with non-clinical samples were chosen as mental health conditions such as depression and anxiety have shown an association with sleep disturbance (Alvaro, Roberts, & Harris, 2013), as have various physical conditions such as cancer (Davidson, MacLean, Brundage, & Schulze, 2002) and diabetes (Resnick et al., 2003) and individuals who suffer from insomnia have been found to show distorted perception of sleep (Harvey & Tang, 2012). Therefore, to reduce the risk of confounding factors, only studies of non-clinical participants were included in this review.

3.2.2 Search Strategy

PsycINFO (1806 to Present) and Medline (1946 to Present) were searched using OVID. The search was first conducted on the 11th February 2016 and was last performed on the 10th of January 2018 using search terms relating to PC and sleep. The search was limited by (1) English language, (2) human studies and (3) studies published from 1990. The search was restricted to 1990 onwards for the same reasons noted in Chapter 2, section 2.2.2, namely, due to publication of a key measure of worry around this time and to increase the specificity of the search. The titles were screened by me and all abstracts and full-texts of papers from 1990-2016 that were not excluded at the title screening stage were independently double-screened, and any discrepancies were resolved via discussion. There was 100% agreement between the two reviewers regarding the studies to be included from this period and therefore it was deemed justifiable for only myself to screen papers returned from the second search.

3.2.3 Search Terms

Perseverative cognition terms are reported in Chapter 2, section 2.2.2. Sleep terms, adapted from Hu et al. (2015), were combined with OR, (1) exp Sleep/, (2) (sleep adj3 (promot* or help* or support* or initiat*)).mp., (3) sleep.ti,ab.

3.2.4 Data Extraction

The following data was extracted for each study: (1) the type of PC reported, categorised as worry (reported as worry in the paper or as any type of future-oriented negatively affect-laden repetitive thought), brooding (reported as rumination/brooding in the paper or as any type of past-oriented negatively affect-laden repetitive thought e.g. nocturnal regret), non-specific PC (reported as PC in the paper or categorised as any type of negatively affect-laden repetitive thought in which a past/future orientation was not specified e.g. pre-sleep cognitive arousal). It should be noted that, within the non-specific PC category, there were measures of PC which combined both worry and rumination/brooding (i.e. both a past and future orientation) as well as papers which did not specify a temporal focus. Where PC and sleep were conflated, for example, the Sleep Disturbance Ascribed to Worry Scale (Kelly, 2002) outcomes were excluded; (2) PC assessment (state, trait or both). PC measures were coded as trait when reference was made to the habitual tendency to engage in PC, within no specific time-period, whereas PC measures were coded as state when there was a particular time-focus (e.g. to what extent participants engaged in PC that day, month, year); (3) the type of sleep outcome (TST, SOL or sleep quality). Other parameters such as sleep efficiency and the number of night-time awakenings are also found across the sleep literature but, to maintain an adequate sample size in these meta-analyses, such parameters were considered under the classification of sleep quality, as is done in the widely used Pittsburgh Sleep Quality Index (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989); (4) sleep assessment (actigraphy, self-report or both); (5) the study design (multiple outcomes were possible in this case e.g. a study could report both cross-sectional and longitudinal outcomes); (6) the age range of participants (the mean or median were extracted if this was not available), then categorised as children (0-12), adolescents (12-18), adults (18-65), older adults (65+) or a combination of these categories; (7) the percentage of female participants (averaged if this differed across study outcomes); (8) whether PC measures were multi- or single-item; (9) whether (self-reported) sleep measures were multi- or single-item; (10) whether PC measures were reported as validated; (11) whether sleep measures (self-report and actigraphy) were reported as validated; (12) whether PC measures were reported as reliable in that sample (Cronbach's α ≥ .70); (13) whether (self-reported) sleep measures were reported as reliable in that sample (Cronbach's α ≥ .70); (14) effect size data for relationships between PC and sleep; (15) whether any covariates were included. If any of this information was not available, first authors were contacted for this information or for clarifications. In the event of no response, second authors were contacted. If simple statistical associations could not be obtained, sensitivity analyses were performed for studies which included covariates. Note that, in the unpublished manuscript of this systematic review and meta-analysis (Clancy, Prestwich, Caperon, Tsipa, & O'Connor, under review), brooding was described as rumination as this term is more widely used. As in Chapter 2 (see section 2.2.3), the decision was made to change this to brooding to remain consistent with how the terms brooding and rumination are used across the rest of the thesis.

Study quality was assessed using scores from items 8-13 from the data extraction process. All items (whether all PC and sleep were measured within that study were multi-item measures and whether all PC and sleep were reported as reliable and valid) were coded as 0 for no and 1 for yes. One score was produced per study and therefore, the item was only coded as yes if this was true for all measures within that study. These items were analysed as individual moderators rather than combined as (1) summing scores would include an element of double-counting e.g. a single item measure would be penalized for being a single item and for not being reliable, (2) combining scores is problematic as it is difficult to ascertain the importance of each individual criterion and (3) the Cochrane handbook (Higgins & Green, 2008) advises against such an approach. Note that these items were selected to assess study quality as they are applicable to all included study designs (and no such validated quality assessment tool was available).

To maximize reliability of the data extraction process, data extraction was completed by a second reviewer for 20% of included papers except in the case of effect size data in which effect sizes from all 1990-2016 papers were extracted by a second reviewer, which equates to approximately 70% of the total papers. As there was 100% agreement between reviewers for effect size data from 1990-2016, effect sizes from 2016-18 were only extracted by the first author. In all cases, discrepancies were resolved via discussion.

3.2.5 Method of Analysis

Comprehensive Meta-Analysis software (Borenstein et al., 2005) was used to calculate effect sizes and perform the meta-analyses. To account for the issue of dependence resulting from multiple outcomes per study, mean effect sizes reflecting the strength of the association between a specific type of PC and sleep outcome were used in analysis. For instance, several studies measured more than one type of PC, some studies used more than one measure of PC and sleep and several studies included more than one time-point. All such effect sizes were included as there was no theoretical justification to exclude outcomes (e.g., first versus second versus last follow-up; one type of sleep quality measure over another) on any of these bases. As noted in Chapter 2, section 2.2.5, this method has the limitation of increasing the type II error rate (Scammacca et al., 2014) and therefore this should be taken into consideration when interpreting the findings of these analyses. Again, this was deemed preferable to increasing the type I error rate when assuming independence between non-independent outcomes.

A random effects model was chosen for all analyses based on the assumption that effect sizes would be similar but not identical across studies (Borenstein, Hedges, Higgins, & Rothstein, 2011). The association between combined PC categories and each category of sleep outcome (sleep quality, TST and SOL) was analysed. Additionally, the association between each category of PC (worry, brooding and non-specific PC) and each sleep outcome was analysed.

In all analyses, the correlation between measures is reported and a negative correlation reflects an association between higher levels of PC and poorer sleep (i.e. worse quality sleep, longer SOL and shorter TST). In accordance with Chapter 2, an effect size of the magnitude r = .1 - .3 was considered small, .3 - .5 was considered medium and .5 and above was considered large. Q and I^2 values were used in assessing heterogeneity. Significant Q values indicate between-study heterogeneity and I^2 values of .25, .50 and .75 relate to low, moderate and high between-study heterogeneity (Ottaviani et al., 2016). Egger's regression test (Egger et al., 1997) was used to assess publication bias for each sleep outcome and Duval and Tweedie's Trim and Fill analysis (Duval & Tweedie, 2000) was used to adjust for any existing publication bias.

Three sets of sensitivity analyses were conducted. Studies which reported effect sizes that accounted for covariates were removed (sensitivity analysis 1). The following studies were excluded on this basis: Fichten et al. (2001), Kocoglu, Akin, Cingil, and Sari (2013), LaBrash et al. (2008), McGowan et al. (2016) and Rodríguez-Muñoz, Notelaers, and Moreno-Jiménez (2011).

Effect sizes for PC measures that only broadly met the specified conceptualization of PC were removed (sensitivity analysis 2). The Pre-Sleep Arousal Scale (Nicassio, Mendlowitz, Fussell, & Petras, 1985) was removed as, although this measure includes items which encapsulate PC (e.g. 'worry about falling asleep' and 'worry about problems other than sleep'), it also includes other items assessing more general overthinking which were not necessarily negatively valanced (e.g. 'review and ponder events of the day' and 'being mentally alert, active'). Studies using the measure were Doos Ali Vand, Gharraee, Farid, and Bandi (2014), Fichten et al. (2001), Wicklow and Espie (2000) and Yeh, Wung, and Lin (2015). The same issue was apparent for pre-sleep arousal measured by the Glasgow Content of Thoughts Inventory (Harvey & Espie, 2004). This measure was used in Loft and Cameron (2014). Similarly, both Åkerstedt et al. (2002) and Åkerstedt, Nordin, Alfredsson, Westerholm, and Kecklund (2012) used a measure of work preoccupation. In the former, it is not clear whether these are preoccupations with negative aspects of work and, in the latter, one item refers to work problems but the other two relate to over-thinking more generally. As such, both were excluded in these sensitivity analyses.

As there were too few studies including only children, adolescents and older adults to perform sub-group analyses, analyses were conducted only on studies with exclusively adult samples (sensitivity analysis 3). This was deemed necessary as research has found that sleep patterns differ in children and older adults (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). The following studies were excluded on this basis: Annunziata, Muzzatti, Flaiban, Giovannini, and Carlucci (2016), Bagley, Kelly, Buckhalt, and El-Sheikh (2015), Barclay and Gregory (2010), Fichten et al. (2001), Hartz, Ross, Noyes, and Williams (2013), Jean-Louis et al. (2009), Lin, Xie, Yan, and Yan (2017), Liu et al. (2017), Querstret and Cropley (2012), Schmidt, Renaud, and van der Linden (2011) and Yan et al. (2014). Age was not analysed as a continuous moderator as, upon initial inspection of the included papers, several papers did not report mean age, hence age categories were used instead.

Analysed as moderators were (1) gender (percentage female); (2) PC assessment (state or trait); (3) sleep assessment (at least one measure of actigraphy or self-report only); (4) study design (cross-sectional only (yes/no), longitudinal only (yes/no), diary study (yes/no), experimental outcomes were removed as there were too few studies to analyse experimental outcomes separately); (5) study quality items. Consistent with Ottaviani et al. (2016), a minimum of 5 studies per subgroup was selected as the criterion for moderator analyses. This meant that it was not possible to compare effect sizes from experimental and non-experimental studies, study design (cross-sectional vs longitudinal) could not be considered as a moderator of the relationship between PC and SOL, and some study quality meta-regressions could not be performed (see Table 3.3). Where meta-regressions revealed significant moderation by categorical variables, sub-group analyses were reported per category to decompose this effect.

Continuous and categorical moderators were analysed via meta-regression using a maximum likelihood method. Meta-regressions were only conducted on the relationship between combined PC categories and sleep quality, SOL and TST due to the limited number of studies in analyses investigating the relationship between PC subtypes and sleep outcomes.

3.3 Results

3.3.1 Overview of Included Studies

The search retrieved 2106 papers which were screened for inclusion. The screening process is depicted in Figure 3.1. After duplicates were removed, 1360 papers remained and 1230 were then excluded during title and abstract screening. A further 77 papers were excluded at full text screening. Full texts were excluded on the basis of (1) being a review paper (*n* = 2), (2) the paper did not include a measure of PC which met inclusion criteria (*n* = 27), (3) the paper did not include a measure of sleep which met inclusion criteria (*n* = 1), (4) PC and sleep were conflated (*n* = 4), (5) the population was a clinical sample and no non-clinical subset was analysed (*n* = 33), (6) the statistical association between PC and sleep was not reported (*n* = 5), (7) it was not possible to access the full-text (*n* = 4), and (8) data from the same sample was analysed in an earlier paper which already met inclusion criteria (*n* = 1). The 53 papers remaining met the inclusion criteria of the review and an additional 2 eligible papers were identified via hand-search. The final 55 papers comprised of data from 181,366 participants (see Table 3.1). Of these, 41 measured worry, 32 measured brooding and 29 measured non-specific PC. See Table 3.1 for additional information regarding included studies. See Table 3.2 for a summary of the meta-analyses.

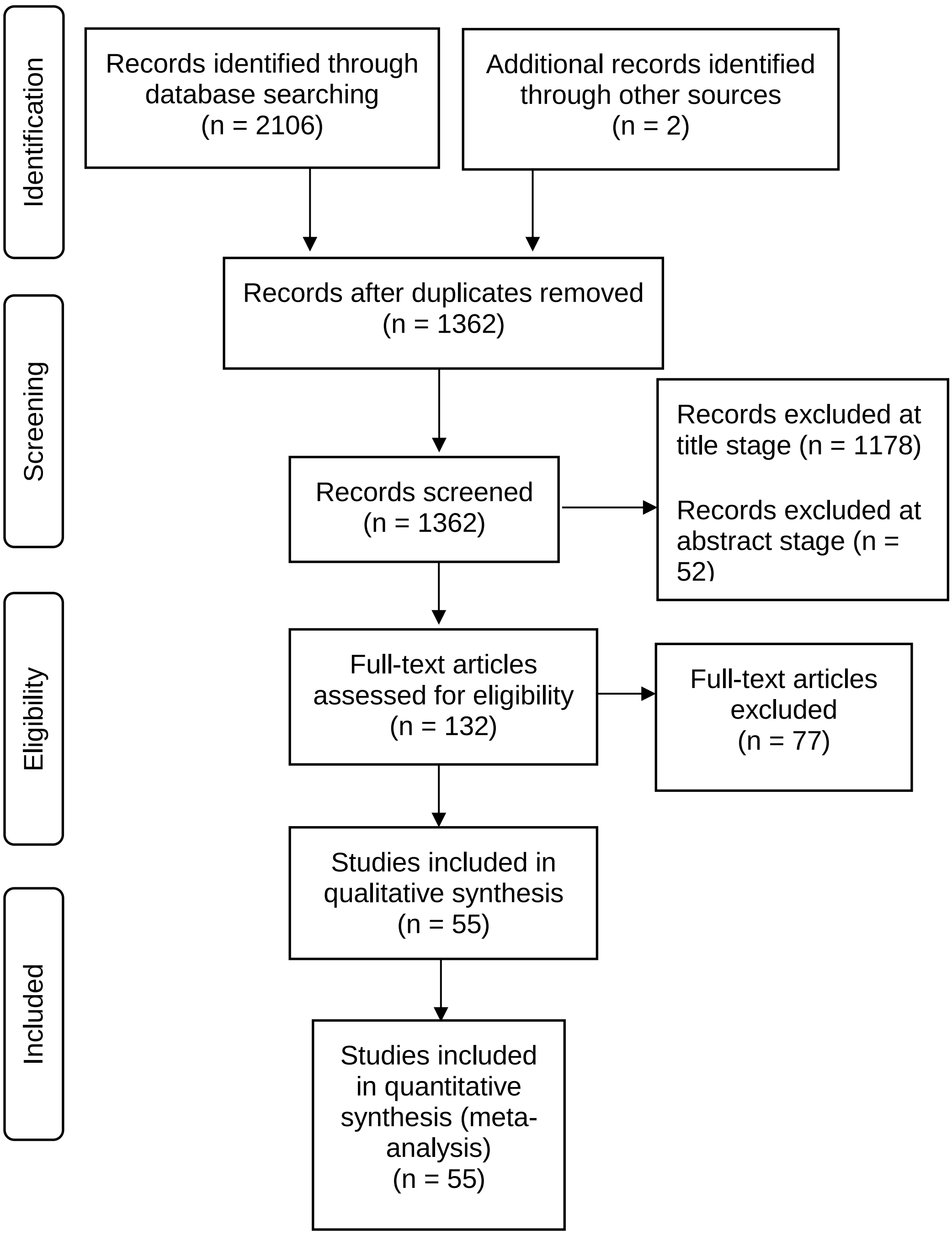

Figure 3.1 PRISMA diagram adapted from Moher, Liberati, Tetzlaff and Altman (2009)

3.3.2 Sleep Quality

Fifty papers measured sleep quality. Higher combined PC was associated with worse sleep quality, *k* = 50, *r* = -.28, *p* < .001, and there was a significant amount of heterogeneity amongst effect sizes, *Q* = 661.67, *p* < .001, I^2 = 92.59. In meta-analyses of the association between PC categories and sleep quality, worry was associated with poorer sleep quality, *k* = 23, *r* = -.23, *p* < .001, as was rumination, *k* = 23, *r* = -.33, *p* < .001, and non-specific PC, *k* = 12, *r* = -.29, *p* < .001. These findings were similar across sensitivity analyses (see Table 3.2Table 2.2). See Appendix B for a forest plot of these associations.

The association between combined PC and sleep quality was stronger in studies which: (1) employed multi-item, *k* = 43*, r* = -.30, *95% CI* = -.33 to -.26*, Z* = 14.72, *p* < .001, as opposed to single-item, *k* = 7, *r* = -.14, 95% *CI* = -.20 to -.08, *Z* = 4.30, *p* < .001, measures of PC; (2) where sleep resulted from self-report, *k* = 41, *r* = -.29, 95% *CI* = -.32 to -.25, *Z* = -15.66, *p* < .001, as opposed to actigraphy measurement, *k* = 9, *r* = -.18, 95 *CI* = -.27 to -.08, *Z* = -3.46, *p* = .001. All other moderators were non-significant (see Table 3.3).

Table 3.1 Overview of Included Studies

Study	Design	PC as Reported	PC Category	PC Measure (State or Trait)	Sleep Outcome(s)	Measure of Sleep	%Female	Age of Participants (range in years)[a]	Sample Size (n = 181,366)
Åkerstedt et al. (2002)	Cross-Sectional	Work Preoccupation	PC	Trait	Sleep Quality	Self-Report	43%	Adults (18-45+)	5231
Åkerstedt et al. (2012)	Longitudinal	Work Preoccupation	PC	Trait	Sleep Quality	Self-Report	17%	Adults (median = 42.0)	3637
Annunziata et al. (2016)	Cross-Sectional	Health Worry	Worry	Trait	Sleep Quality	Self-Report	58%	Adults and Older Adults (28-75)	112
Bagley et al. (2015)	Diary	Pre-Sleep Worry	Worry	State	Sleep Quality	Actigraphy and Self-Report	47%	Children (10-12)	271
Baker, Baldwin, and Garner (2015)	Cross-Sectional	Intrusive Thoughts	Worry	State	Sleep Quality, SOL and TST	Self-Report	82%	Adults (mean = 20.7)	109
Barclay and Gregory (2010)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	73%	Adults and Older Adults (20-76)	60
Carciofo, Song, Du, Wang, and Zhang (2017)	Cross-Sectional and Longitudinal	Uncontrollable Thoughts and Associated Danger	Worry	Trait	Sleep Quality, SOL and TST	Self-Report	68%	Adults (18-28)	370
Carney, Edinger,	Cross-Sectional	Self- and Symptom-	Brooding	Trait	Sleep Quality	Self-Report	87%	Adults	243

Meyer, Lindman, and Istre (2006)		Focused Rumination						(18-39)	
Cox, Ebesutani, and Olatunji (2016)	Cross-Sectional	Rumination and Worry	Brooding and Worry	Trait	Sleep Quality	Self-Report	82%	Adults[b] (18-66, mean = 33.56)	341
Cropley et al. (2006)	Diary	Work Rumination	Brooding	State	Sleep Quality and TST	Self-Report	87%	Adults (21-59)	98
Cropley et al. (2015)	Diary	Work Rumination	Brooding	State	Sleep Quality	Self-Report	83%	Adults (21-61)	108
Doos Ali Vand et al. (2014)	Cross-Sectional	Pre-Sleep Cognitive Arousal and Worry	PC and Worry	Trait	Sleep Quality	Self-Report	59%	Adults (20-46)	400
Fichten et al. (2001)	Cross-Sectional	Pre-Sleep Cognitive Arousal and Worry	PC and Worry	Trait	Sleep Quality and TST	Self-Report	69%	Adults and Older Adults (55-89)	220
Hairston and Shpitalni (2016)	Cross-Sectional	Rumination	Brooding	Trait	Sleep Quality	Self-Report	74%	Adults (18-37)	598
Hartz et al. (2013)	Cross-Sectional	Worry about Expressing Anger	Worry	Trait	Sleep Quality	Self-Report	100%	Adults and Older Adults (49-81)	148,938
Harvey et al. (2002)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	62%	Adults (mean ranges from 18-21)	120

Huhtala, Kinnunen, and Feldt (2017)	Longitudinal	Rumination and Dilemma Rumination	Brooding	Trait	Sleep Quality	Self-Report	95%	Adults (25-64)	133
Jean-Louis et al. (2009)	Cross-Sectional	Breast Cancer Worry	Worry	State	Sleep Quality	Self-Report	100%	Adults and Older Adults (50-70)	1038
Joormann and Stöber (1999)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	75%	Adults (mean = 25.7)	183
Kelly (2002)	Cross-Sectional	Worry	Worry	Trait	TST	Self-Report	69%	Adults (18-65)	222
Kocoglu et al. (2013)	Cross-Sectional	Worry about Insomnia	Worry	Trait	Sleep Quality	Self-Report	60%	Adults (18-65)	523
Kompier, Taris, and van Veldhoven (2012)	Cross-Sectional	Work Rumination	Brooding	Trait	Sleep Quality	Self-Report	48%	Adults (mean = 38.9)	5210
LaBrash et al. (2008)	Cross-Sectional	Financial Worry	Worry	State	TST	Self-Report	40%	Adults (16+)	195
Lin et al. (2017)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality, SOL and TST	Self-Report	52%	Adolescents (11-18)	2286
Liu et al. (2017)	Cross-Sectional	Rumination	Brooding	Trait	Sleep Quality	Self-Report	47%	Adolescents and Adults (14-20)	1196
Loft and Cameron (2014)	Cross-Sectional	Pre-Sleep Cognitive Arousal	PC	Trait	Sleep Quality	Self-Report	66%	Adults (21-65)	73

MacNeil et al. (2017)	Cross-Sectional and Longitudinal	Worry	Worry	Trait	Sleep Quality	Self-Report	78%	Adults (mean = 21.0)	102
McGowan et al. (2016)	Diary	Pre-Sleep Worry	Worry	State	Sleep Quality, SOL and TST	Self-Report	82%	Adults (mean = 19.72)	50
Mitchell, Mogg, and Bradley (2012)	Cross-Sectional	Rumination and Worry	Brooding and Worry	Trait	Sleep Quality	Self-Report	88%	Adults (mean = 19.9)	196
Nota and Coles (2015)	Cross-Sectional	Perseverative Thinking, Brooding and Worry	PC, Brooding and Worry	Trait	SOL and TST	Self-Report	58%	Adults[b] (17-33)	100
Nota, Schubert, and Coles (2016)	Cross-Sectional	Perseverative Thinking	PC	Trait	TST	Self-Report	69%	Adults (mean = 19.5)	67
Omvik, Pallesen, Bjorvatn, Thayer, and Nordhus (2007)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality, SOL and TST	Actigraphy and Self-Report	100%	Adults (mean = 21.2)	96
Querstret and Cropley (2012)	Cross-Sectional	Work Rumination	Brooding	Trait	Sleep Quality	Self-Report	49%	Adults and Older Adults (19-69)	719
Querstret, Cropley, Kruger, and Heron (2015)	Cross-Sectional, Longitudinal and Experimental	Work Rumination	Brooding	State	Sleep Quality	Self-Report	63%	Adults[b] (22-66)	227

Querstret, Cropley, and Fife-Schaw (2017)	Cross-Sectional and Experimental	Work Rumination	Brooding	State	Sleep Quality	Self-Report	81%	Adults (21-62)	118
Radstaak, Geurts, Beckers, Brosschot, and Kompier (2014)	Diary	Perseverative Cognition about Work	PC	State	Sleep Quality, SOL and TST	Actigraphy and Self-Report	4%	Adults (mean = 44.1)	23
Rodríguez-Muñoz et al. (2011)	Cross-Sectional	Work Worry	Worry	Trait	Sleep Quality	Self-Report	44%	Adults (19-64)	4068
Schmidt et al. (2011)	Cross-Sectional	Rumination and Worry	Brooding and Worry	Trait	Sleep Quality	Self-Report	70%	Adults and Older Adults (51-98)	81
Slavish and Graham-Engeland (2015)	Cross-Sectional	Rumination	Brooding	Trait	Sleep Quality	Self-Report	64%	Adults (mean = 20.38)	165
Stoia-Caraballo et al. (2008)	Cross-Sectional	Anger Rumination	Brooding	Trait	Sleep Quality and SOL	Self-Report	55%	Adults (18-23)	277
Syrek and Antoni (2014)	Diary	Rumination	Brooding	State	Sleep Quality	Self-Report	26%	Adults[b] (17-46)	89
Syrek, Weigelt, Peifer, and Antoni (2017)	Diary	Affective Rumination	Brooding	State	Sleep Quality	Self-Report	67%	Adults (21-59)	59
Takano, Iijima, and	Cross-Sectional	Rumination and Worry	Brooding and Worry	Trait	Sleep Quality	Self-Report	25%	Adults (mean = 19.0)	208

Tanno (2012)	and Longitudinal								
Takano, Sakamoto, and Tanno (2014)	Diary	Repetitive Thought	PC	State	Sleep Quality, SOL and TST	Actigraphy	78%	Adults (mean = 19.4)	43
Tang and Harvey (2004)	Experimental	Pre-Sleep Cognitive Activity	PC	State	SOL and TST	Actigraphy and Self-Report	53%	Adults (18-40)	36
Thomsen, Yung Mehlsen, Christensen, and Zachariae (2003)	Cross-Sectional	Rumination	Brooding	Trait	Sleep Quality	Self-Report	60%	Adults (19-40)	118
Vahle-Hinz, Bamberg, Dettmers, Friedrich, and Keller (2014)	Diary	Rumination	Brooding	State	Sleep Quality	Self-Report	4%	Adults (mean = 42.0)	50
Van Laethem et al. (2015)	Cross-Sectional and Longitudinal	Perseverative Cognition	PC	Trait	Sleep Quality	Actigraphy and Self-Report	36%	Adults[b] (23-66)	877
Van Laethem, Beckers, van Hooff, Dijksterhuis, and Geurts (2016)	Diary	Perseverative Cognition	PC	State	Sleep Quality, SOL and TST	Actigraphy and Self-Report	80%	Adults (mean = 35.0)	44

Weise, Ong, Tesler, Kim, and Roth (2013)	Diary	Pre-Sleep Worry and Worry	Worry	Both	Sleep Quality, SOL and TST	Actigraphy and Self-Report	85%	Adults (mean ranges from 36.1-37.1)	55
Wicklow and Espie (2000)	Diary	Pre-Sleep Cognitive Arousal	PC	State	Sleep Quality and SOL	Actigraphy and Self-Report	67%	Adults (mean = 36.0)	21
Yan et al. (2014)	Cross-Sectional	Worry	Worry	Trait	Sleep Quality	Self-Report	62%	Adolescents and Adults (12-22)	1072
Yeh et al. (2015)	Cross-Sectional	Pre-Sleep Cognitive Arousal, Active Cognitive Appraisal, Dwelling on the Negative and Worry Engagement	PC, Brooding and Worry	Trait	Sleep Quality, SOL and TST	Self-Report	64%	Adults (18-30)	202
Zawadzki, Graham, and Gerin (2013)	Cross-Sectional	Rumination	Brooding	Trait	Sleep Quality	Self-Report	57%	Adults (mean = 20.3)	218
Zoccola et al. (2009)	Experimental	Rumination and Stressor-Specific Rumination	Brooding	Both	SOL and TST	Actigraphy and Self-Report	63%	Adults (18-26)	70

Note. [a]The range is reported where this was available. If this was not available, the mean (or median) was reported and categories were based on this. [b]age range falls slightly outside of category grouping.

3.3.3 Sleep Onset Latency

Sixteen studies included a measure of SOL. Higher combined PC was associated with longer SOL, $k = 16$, $r = -.16$, $p < .001$, and there was a significant degree of heterogeneity in effect sizes, $Q = 37.75$, $p = .001$, $I^2 = 60.26$. Worry was associated with longer SOL, $k = 7$, $r = -.16$, $p < .001$, as was rumination, $k = 5$, $r = -.15$, $p = .001$, and non-specific PC, $k = 8$, $r = -.21$, $p = .01$. These findings were similar across sensitivity analyses (see Table 3.2). See Appendix B for a forest plot of these associations.

Stronger associations between a combined measure of PC and longer SOL were detected when studies: (1) included a lower percentage of female participants, $k = 16$, *Coefficient* = .004, $p = .002$; (2) incorporated reliable, $k = 10$, $r = -.18$, 95% $CI = -.25$ to -.11, $Z = -4.84$, $p < .001$, rather than non-reliable measures of PC, $k = 6$, $r = -.09$, 95% $CI = -.14$ to -.05, $Z = -3.96$, $p < .001$; (4) employed multi-item, $k = 5$, $r = -.20$, 95% $CI = -.23$ to -.16, $Z = -10.50$, $p <.001$, compared to single-item measures of sleep, $k = 10$, $r = -.13$, 95% $CI = -.22$ to -.04, $Z = -2.78$, $p = .01$; (5) employed trait, $k = 6$, $r = -.20$, 95% $CI = -.24$ to -.16, $Z = -9.16$, $p < .001$, as opposed to state measures of PC, $k = 8$, $r = -.13$, 95% $CI = -.23$ to -.02, $Z = -2.37$, $p = .02$; (6) were non-diary, $k = 9$, $r = -.19$, 95% $CI = -.23$ to -.15, $Z = -8.31$, $p < .001$, as opposed to diary studies, $k = 6$, $r = -.17$, 95% $CI = -.31$ to -.04, $Z = -2.46$, $p = .01$; (7) consisted of only cross-sectional outcomes, $k = 8$, $r = -.19$, 95% $CI = -.23$ to -.15, $Z = -9.45$, $p < .001$, as opposed to studies which included outcomes generated from non-cross-sectional study designs, $k = 7$, $r = -.15$, 95% $CI = -.26$ to -.03, $Z = -2.38$, $p = .02$. All other moderators were non-significant (see Table 3.3).

Table 3.2 Summary of Meta-Analyses

Type of PC	Type of Sleep	*K*	*R*	95% CI		*Z*	Sensitivity Analyses: *Z*		
				Lower	Upper		1	2	3
Combined	Sleep Quality	50	-0.28***	-0.31	-0.24	-15.76	-14.96	-13.27	-11.67
Combined	SOL	16	-0.16***	-0.22	-0.11	-5.60	-5.82	-4.95	-4.55
Combined	TST	19	-0.15***	-0.19	-0.11	-7.75	-12.00	-6.77	-7.05
Worry	Sleep Quality	23	-0.23***	-0.27	-0.20	-12.88	-11.60	-11.84	-6.92
Worry	SOL	7	-0.16***	-0.22	-0.10	-4.94	-10.36	-4.25	-3.48
Worry	TST	11	-0.14***	-0.19	-0.09	-5.52	-6.93	-4.86	-4.86
Brooding	Sleep Quality	23	-0.33***	-0.37	-0.29	-14.75	n/a	-14.87	-12.66
Brooding	SOL	5	-0.15**	-0.24	-0.06	-3.32	n/a	-2.04	-3.32
Brooding	TST	4	-0.17**	-0.27	-0.08	-3.46	n/a	-2.36	-3.46
Non-Specific PC	Sleep Quality	12	-0.29***	-0.37	-0.21	-6.51	-6.01	-3.27	-6.01
Non-Specific PC	SOL	8	-0.21*	-0.35	-0.05	-2.56	n/a	-1.81	n/a
Non-Specific PC	TST	9	-0.18***	-0.24	-0.12	-5.68	-4.92	-4.43	-4.92

*** significant at the <.001 level, **significant at the <.01 level, *significant at the .05 level

3.3.4 Total Sleep Time

Nineteen studies measured TST. Higher combined PC was associated with shorter TST, $k = 19$, $r = -.15$, $p < .001$, and there was little heterogeneity in effect sizes, $Q = 25.92$, $p = .10$, $I^2 = 30.57$. Worry was associated with shorter TST, $k = 11$, $r = -.14$, $p < .001$, as was rumination, $k = 4$, $r = -.17$, $p = .001$, and non-specific PC, $k = 9$, $r = -.18$, $p < .001$. These findings were similar across sensitivity analyses (see Table 3.2). See Appendix B for a forest plot of these associations.

Stronger associations between a combined measure of PC and shorter TST were detected when studies consisted of only cross-sectional outcomes, $k = 9$, $r = -.19$, 95% $CI = -.22$ to $-.16$, $Z = -11.36$, $p < .001$, as opposed to studies which included outcomes generated from non-cross-sectional study designs, $k = 9$, $r = -.11$, 95% $CI = -.15$ to $-.07$, $Z = -5.71$, $p < .001$. There were no other significant moderators of the association between combined PC and TST (see Table 3.3).

Table 3.3 Summary of Moderator Analyses

Moderator	Type of Sleep	*K*	Coefficient	Std Error	95% CI Lower	95% CI Upper	*Z*
%Female	Sleep Quality	50	.001	.001	-.001	.003	1.40
%Female	SOL	16	.004**	.001	.002	.01	3.16
%Female	TST	19	.002	.001	-.000	.004	1.71
PC Measure Multi-Item	Sleep Quality	50	-.15**	.05	-.25	-.05	-2.83
PC Measure Reliable	Sleep Quality	50	-.04	.04	-.12	.04	-1.02
PC Measure Reliable	SOL	16	-.09***	.03	-.15	-.04	-3.31
PC Measure Reliable	TST	19	-.06	.03	-.12	.01	-1.70
PC Measure Valid	Sleep Quality	50	-.08	.04	-.15	.002	-1.91
PC Measure Valid	SOL	16	.08	.05	-.02	.18	1.62
PC Measure Valid	TST	19	-.03	.04	-.11	.05	-0.76
PC Assessment Type[a]	Sleep Quality	48	.07	.04	-.02	.15	1.58

PC Assessment Type[a]	SOL	14	.10***	.03	.05	.16	3.65
PC Assessment Type[a]	TST	17	.05	.03	-.02	.11	1.32
Sleep Measure Multi-Item	Sleep Quality	49	-.05	.05	-.15	.05	-0.94
Sleep Measure Multi-Item	SOL	15	-.10***	.03	-.15	-.04	-3.46
Sleep Measure Multi-Item	TST	18	-.06	.03	-.12	.01	-1.80
Sleep Measure Reliable	Sleep Quality	50	-.02	.04	-.10	.06	-0.46
Sleep Measure Reliable	TST	19	-.02	.04	-.11	.06	-0.56
Sleep Measure Valid	Sleep Quality	50	-.04	.04	-.12	.05	-0.85
Sleep Measure Valid	SOL	16	-.04	.05	-.13	.05	-0.90
Sleep Measure Valid	TST	19	-.05	.03	-.12	.02	-1.39
Sleep Assessment Type[b]	Sleep Quality	50	.13*	.06	.01	.24	2.15
Sleep Assessment Type[b]	SOL	16	.07	.06	-.04	.18	1.23
Sleep Assessment Type[b]	TST	19	.01	.05	-.08	.10	0.28

Cross Sectional Only	Sleep Quality	50	-.08	.04	-.17	.00	-1.96
Cross Sectional Only	SOL	15	-.11***	.03	-.16	-.05	-3.66
Cross Sectional Only	TST	18	-.08**	.03	-.13	-.03	-3.28
Longitudinal Only	Sleep Quality	50	.10	.06	-.03	.22	1.55
Longitudinal Only	TST	15	-.03	.06	-.14	.09	-0.46
Diary Study	Sleep Quality	50	.03	.05	-.07	.13	0.62
Diary Study	SOL	15	.10***	.03	.04	.15	3.44
Diary Study	TST	15	.02	.05	-.07	.11	0.38

Note. Where outcomes are not included, there were insufficient number of studies in each category to perform meta-regression, *** significant at the <.001 level, **significant at the <.01 level, *significant at the <.05 level, for yes/no responses, No = 0, Yes = 1, [a]PC Assessment Type: Trait = 0, State = 1, [b]Sleep Assessment Type: Self-Report = 1, Actigraphy Only or Actigraphy and Self-Report = 2

3.3.5 Publication Bias

Egger's regression coefficient was significant for the association between combined PC and sleep quality, which indicated potential publication bias, $t = 3.56$, $df = 48$, $p < .001$. To consider the potential impact of these missing studies, Duval and Tweedie's Trim and Fill analyses were conducted. These results suggested that no studies were missing from the right-side of the mean effect, but 1 study was missing from the left-side of the mean effect. After imputing these, the imputed point estimate, $r = -0.28$, 95% *CI* = -0.31 to -0.24, suggested that the association between combined PC and sleep quality is almost identical when accounting for publication bias. Egger's regression coefficient was non-significant for the association between combined PC and SOL, $t = 0.57$, $df = 14$, $p = .58$, and combined PC and tTST, $t = 0.53$, $df = 17$, $p = .30$, indicating an absence of publication bias in these meta-analyses.

3.4 Discussion

In this systematic review and meta-analysis, the aim was to assess the direction and magnitude of the association between PC and sleep outcomes (sleep quality, SOL and TST). The primary findings from this review were that there is a small-sized association between PC and poorer quality sleep, shorter sleep duration and longer sleep onset latency. Regarding the association between different types of PC and sleep outcomes, brooding had a small association with shorter sleep duration and longer sleep onset latency and a medium-sized association with poorer sleep quality. Worry had a small association with shorter sleep duration, longer SOL and poorer sleep quality. This was also evident in the associations between non-specific PC and all sleep outcomes. All effect sizes were statistically significant, and, for all PC types, the strongest associations were with sleep quality.

These finding provide partial support for the PCH (Brosschot et al., 2006) as they provide an additional explanatory pathway between PC and adverse health outcomes, as poor sleep is associated with both PC and ill-health (Irwin et al., 2016; Watson et al., 2015). The findings of this meta-analysis are consistent with recent theorising that disturbed sleep may act as a pathway between PC and ill-health in addition to other physiological (Ottaviani et al., 2016) and behavioural pathways (see Chapter 2, section 2.4). Overall, all types of PC appear to be significant predictors of poorer sleep in non-clinical populations. This is in comparison to the findings reported in Chapter 2, section 2.3.3, in which no relationship between worry and health behaviours was found. Thus, PC appears to have a stronger and more consistent association with sleep compared to other health behaviours. The strongest association in the Chapter 2 review (see section 2.3.5) was between brooding and health-risk behaviours and was small ($r = .12$) whereas the strongest association in this review, between brooding and sleep quality, was medium-sized ($r = .33$). It could be argued that sleep and other health behaviours (such as physical activity and eating behaviour) differ in their relationship with intentions. Webb and Sheeran’s (2006) meta-analysis suggested that there is a small- to medium-sized association between intention and behaviour, and research has found intention to be a significant predictor of multiple health behaviours (Conner, McEachan, Lawton & Gardner, 2016). On the other hand, in a theoretical review, Espie, Broomfield, MacMahon, Macphee and Taylor (2006) suggest that good sleep is a largely automatic and passive process and conversely, that sleep problems can arise when an individual applies intentions to sleep or disrupts this automaticity via effortful control. It is therefore possible that PC may relate more to an automatic process such as sleep via its association with physiological arousal. However, the differences found across systematic reviews in this thesis are only suggestive as it is difficult to make comparisons across meta-analyses, and especially as there were fewer studies, and behaviour types were much more heterogenous in the Chapter 2 meta-anlysis.

There were some notable moderators of the association between PC and sleep. First, the type of sleep assessment was found to moderate the association between PC and sleep, with a stronger association being found in studies measuring sleep quality via self-report as opposed to actigraphy. This may suggest that as PC levels increase so does a bias for perceiving and reporting poorer quality sleep. However, there was still a small significant association between PC and poorer sleep quality measured via actigraphy, indicating a 'real' association with disturbed sleep. Omvik et al. (2007) explicitly compared the discrepancy between self-reported and actigraphy-measured sleep in high and low worriers and, across several sleep outcomes, only found a greater underestimation of sleep efficiency in the high worry group. Nevertheless, in this review, the effect size doubled for self-reported sleep, indicating a substantial negative reporting bias.

The type of PC assessment also significantly moderated the association between PC and longer SOL, and this association was stronger in studies measuring trait, as opposed to state PC. This suggests that it is the overall tendency to engage in PC rather than discrete instances of negative repetitive thinking that are more likely to influence longer SOL. However, state PC measurements were more varied and less likely to be validated than trait measurements which could partially explain the smaller effect size. This is reflected by the fact that, in instances where study quality outcomes moderated the association between PC and sleep, effect sizes were larger where studies were of a higher quality (e.g. employing multi-item measures which were reliable and valid) which allows for more confidence in the findings.

On the other hand, study design moderated the association between perseverative cognition and SOL and TST such that these associations were stronger in studies with only cross-sectional outcomes. In addition, as the number of PC measurements increased, there was a weaker association between PC and SOL, all suggesting that PC is less predictive of SOL and sleep duration over time. Furthermore, diary study status moderated the association between PC and longer SOL such that this association was stronger in non-diary studies. This perhaps also indicates that this association is weaker when these variables are measured at a state/daily level. It is suggested that future studies incorporate daily longitudinal measurements to investigate these associations in more detail.

There was a moderating effect of gender such that being female appears to act as a protective factor between PC and longer SOL, as there was an association between a lower percentage of female participants and less time taken to fall asleep. It is first to be acknowledged that it was not possible to analyse male and female samples separately and therefore the percentage of female participants in the sample was used as a proxy for gender. As such, any conclusions drawn on this basis are only tentative. This notwithstanding, the finding is slightly anomalous as women are known to engage in more PC (Johnson & Whisman, 2013; Robichaud et al., 2003; Zlomke & Hahn, 2010) and therefore might be expected to experience greater difficulty in falling asleep. However, it is unknown from the current review whether women in the included studies did engage in more PC and therefore, the findings may not, in fact be anomalous. Alternatively, the findings may reflect evidence that although women report more sleep-related complaints, their overall sleep quality has been found to be better, including shorter SOL (Krishnan & Collop, 2006). One possible explanation for this may be that women employ more effective coping strategies to ameliorate the impact of PC on their sleep. Therefore, studies which experimentally compare levels of PC and subsequent sleep outcomes in males and females would be a useful avenue for future research, particularly if women are shown to develop coping strategies which could inform sleep interventions. Nevertheless, it is worth noting that there were considerably more significant moderators of the association between PC and SOL which may indicate that this relationship is less robust than associations between PC and sleep quality and TST. However, it could also reflect the small number of studies reporting SOL outcomes, or more heterogeneity between studies.

It is acknowledged that, as the review was limited to English language papers, some relevant studies may have been missed. Likewise, only published studies were reviewed which could have led to an over-estimation of the effect sizes due to publication bias. The decision to exclude unpublished studies was based on two arguments. First, a concern was that, in the absence of peer review, the quality of the reporting of key moderators may be insufficient to reliably code them. Second, we were concerned that there could be differences between the unpublished data that authors were willing to share, and data which authors were not willing to share, and this would result in a different type of systematic bias. Promisingly, analyses suggested only a very small degree of publication bias and only for sleep quality outcomes.

Overall, few of the proposed moderators influenced the associations between PC and sleep and effect sizes remained stable across sensitivity analyses, suggesting that these associations are relatively robust. The strength and consistency of these findings makes PC a good candidate for interventions which aim to improve sleep. In summary, the current findings are important as they provide partial support for the PCH and provide robust evidence for an additional explanatory pathway between PC and adverse health outcomes via sleep disturbance, thus supporting the extended PCH. Specifically, PC was found to be associated with worse overall sleep i.e. shorter sleep duration, longer SOL and poorer quality sleep. As poor sleep is associated with numerous adverse health outcomes, interventions which improve sleep are important and this review provides evidence that targeting PC may prove effective in improving sleep.

Chapter 4
Stress and Health Behaviour: An Online Longitudinal Survey Exploring the Role of Perseverative Cognition

4.1 Introduction

The central tenet of this thesis is that, in the same way as stress, there may be an additional indirect pathway between PC and health outcomes via health behaviours. In this conceptualisation, it is theorised that rumination about past stressful events or worry about feared future events will moderate the effects of stressors on health behaviours (particularly those previously shown to be influenced by stress). It is suggested that PC might amplify, prolong and reactivate the same physiological and psychological processes that account for the negative effects of stress on health behaviours (see section 1.3 for evidence of the association between stress and health behaviours). See Figure 1.2 for a visual representation of the proposed model (the extended PCH).

To test this hypothesis, the existing literature regarding PC and health behaviours was subject to systematic review and meta-analyses. The systematic review and meta-analysis of the association between PC and health behaviours presented in Chapter 2, suggested an association between PC and more health-risk behaviours but not less health-promoting behaviours. When categorised by type of PC, this association was found for brooding, but not worry or reflection and, when categorised by the type of health behaviour, the only significant association was between overall PC and more alcohol consumption. However, there were only 17 studies overall and when categorised by types of PC and type of health behaviours, there were very few studies in some categories, making inferences inconclusive. As such, a need was identified for studies assessing the association between PC (worry, brooding and reflection) and stress-sensitive health behaviours (e.g. eating behaviour and physical activity). Furthermore, few studies used validated measures of PC and there was an over-reliance on cross-sectional measurements. It was suggested that future studies address these limitations via use of validated measures of PC and by assessing the association between PC and health behaviours prospectively.

The overall evidence seems to suggest that types of PC relate differently to health and health behaviour outcomes. Although worry was not found to be associated with health behaviours in the Chapter 2 meta-analysis, it was associated with all types of poorer sleep outcomes in the Chapter 3 review and meta-analysis. However, in the health behaviour review, only one study had investigated worry that was not specifically-related to health, which may influence behaviour differently to general worry and, as such, worry may potentially influence health behaviours to a greater extent than was suggested in the Chapter 2 review. This is supported by the fact that in their review and meta-analysis, Ottaviani et al. (2016) found a negative association between worry and health outcomes. As noted, in Chapter 2, it was found that brooding, but not worry or reflection, predicted health-risk behaviours and, furthermore, despite both general PC, worry and brooding predicting sleep outcomes, the strength of these associations differed slightly. Overall, components of PC appear to be differentially related to health behaviour outcomes. Therefore, it would be useful to know whether components of PC predict different health behaviour outcomes when considered separately, and whether, when considered together, which components emerge as the strongest predictors of particular behaviours. This will allow researchers designing intervention studies to target the most appropriate component of PC for that behaviour.

In particular, there is reason to expect that reflection may relate differently to health behaviours than worry or brooding. As mentioned in Chapter 1, both brooding and reflection form rumination but whereas brooding is described as a passive and judgemental form of rumination, reflection is more contemplative with a focus on problem-solving (Smith & Alloy, 2009). Treynor et al. (2003) provided evidence that although reflection predicted current depression, it predicted lower levels of depression over time. In the systematic review and meta-analysis reported in Chapter 2, although reflection was not associated with health-risk behaviours, there were only 4 studies in total and these studies provide contradictory evidence regarding the association between this type of PC and health behaviours. Adrian et al. (2014) found a negative association between reflection and problem drinking. However, Willem et al. (2011) failed to show an association between alcohol and problem drinking and Willem et al. (2013) found only one prospective association between reflection and problem drinking across a number of analyses. Similarly, Cropley et al. (2012) found that the related construct of problem-solving pondering was not associated with healthy or unhealthy food choice. In the studies retrieved for the review of PC and sleep (Chapter 3), only one study had investigated reflection and a sleep outcome and therefore this could not be meta-analysed. Querstret et al. (2017) found that after a mindfulness intervention, levels of affective rumination and problem-solving pondering reduced and sleep quality increased. However, it is difficult to ascertain whether the increase in sleep quality was attributable to a decrease in problem-solving pondering or affective rumination. Therefore, research regarding reflection and health behaviour outcomes is limited and mixed. There is theoretical justification to explore these associations within the context of the extended PCH, but it is difficult to make directional predictions given the conflicting findings.

In assessing which health behaviours to target in analyses, it is worth noting to what extent specific health behaviours have the potential to influence health status and the risk of disease. For instance, review evidence has been reported for associations between short sleep duration and poorer general, cardiovascular, metabolic, mental and immunologic health, as well as greater experience of pain and greater overall rates of mortality (Watson et al., 2015). Sleep disturbance has also been associated with markers of inflammation in a recent meta-analysis (Irwin et al., 2016). Obesity has been shown to increase the risk of a number of diseases, including coronary heart disease and diabetes (Lenz et al., 2009), and the consumption of high calorie, low nutrient foods combined with time spent sedentary contribute to obesity (Malik et al., 2013). Furthermore, fast foods, high in fat and sugar, have been associated with increased body weight and poorer metabolic outcomes (Duffey et al., 2009; Pereira et al., 2005). Alternatively, consumption of fruits and vegetables may have a protective effect on stroke and coronary heart disease (Ness & Powles, 1997) and some types of cancer (van't Veer et al., 2000). Similarly, physical activity has been found to be widely beneficial to health and health-related quality of life (Penedo & Dahn, 2005). Finally, alcohol consumption has been shown to increase the risk of cancer and cancer-related death (Praud et al., 2016). These behaviours (sleep, unhealthy food intake, fruit and vegetable consumption, physical activity and alcohol intake) are integral to improving population health and therefore, if PC is shown to influence these behaviours, then these thought processes will be a valuable target in health behaviour interventions.

Findings from the systematic reviews and meta-analyses reported in this thesis provide promising support for the extended PCH. In Chapter 2, a positive association was found between PC and health-risk behaviours, and more specifically, brooding and health-risk behaviours. In, Chapter 3, an association was found between higher levels of worry and brooding and longer SOL, shorter TST and poorer sleep quality, indicating a consistent association with disturbed sleep. However, neither of these reviews allowed the full extended model outlined in Chapter 1 to be tested. From these reviews, it is unknown whether PC moderates the association between stress and health behaviours, or whether these effects would disappear if stress levels were accounted for. This aspect is integral to the model outlined in Chapter 1. It was therefore important to empirically test whether, in addition to directly predicting health behaviours, the association between PC and health behaviours is still apparent when stress is included in the analytical model and whether PC moderates the association between stress and health behaviours.

Furthermore, there are several variables which are predictive of both PC and health behaviours and therefore should be included as covariates when rigorously testing the full model. Neuroticism is a personality trait which consists of high emotionality, negative affectivity and worry (McCrae & Costa, 1987). As such, it has some degree of conceptual overlap with PC (Smith & Alloy, 2009) and neuroticism has been found to predict less physical activity (Rhodes & Smith, 2006), more emotional eating (Elfhag & Morey, 2008) and poorer sleep (Duggan, Friedman, McDevitt, & Mednick, 2014). Therefore, it is advisable to control for this variable when investigating the association between PC and health behaviour outcomes. Likewise, research suggests that physical activity (Caspersen, Pereira, & Curran, 2000) and diet quality (Hiza, Casavale, Guenther, & Davis, 2013) differ across age and sex and there is also evidence that alcohol use (Erol & Karpyak, 2015) and sleeping patterns (Krishnan & Collop, 2006) differ in males and females. Sleep patterns have been shown to change across the life span (Ohayon et al., 2004) and there is evidence that a higher body mass index (BMI) is associated with poorer sleep (Vorona et al., 2005). Hence, age, sex and BMI are also likely to influence a number of health behaviour outcomes. Thus, in order to fully test the extended PCH, these predictors should be included in analytical models.

4.1.1 Aims and Hypotheses

The aim of the study was to investigate the cross-sectional and prospective relationships between stress, trait PC (worry, brooding and reflection) and health behaviours across a three-month period. The secondary aim was to assess the predictive utility of each component of trait PC (worry, brooding and reflection) when these variables were included within the same model. A final aim was to test whether associations between PC and health behaviours, and interactions between PC and stress on health behaviours, remained when demographics (age, sex and BMI) and neuroticism were included within the statistical models.

4.1.1.1 Hypothesis 1

Worry (H1a) and brooding (H1b) will be positively associated with Time 1 health-risk behaviours (greater consumption of unhealthy snack foods and alcohol).

Worry (H1c) and brooding (H1d) will be negatively associated with Time 1 health-promoting behaviours (lower consumption of fruit and vegetables, lower levels of physical activity and poorer sleep parameters).

Reflection will be associated with Time 1 health-risk behaviours (H1e) and Time 1 health-promoting behaviours (H1f).

4.1.1.2 Hypothesis 2

Worry (H2a) and brooding (H2b) will be positively associated with Time 2 health-risk behaviours.

Worry (H2c) and brooding (H2d) will be negatively associated with Time 2 health-promoting behaviours.

Reflection will be associated with Time 2 health-risk behaviours (H2e) and Time 2 health-promoting behaviours (H2f).

4.1.1.3 Hypothesis 3

Positive associations between Time 1 stress and Time 1 health-risk behaviours will be moderated by worry (H3a) and brooding (H3b) such that these associations will be stronger as levels of worry and brooding increase.

Negative associations between Time 1 stress and Time 1 health-promoting behaviours will be moderated by worry (H3d) and brooding (H3e) such that these associations will be stronger as levels of worry and brooding increase.

Positive (H3e) associations between Time 1 stress and Time 1 health-risk behaviours will be moderated by reflection.

Negative (H3f) associations between Time 1 stress and Time 1 health-promoting behaviours will be moderated by reflection.

4.1.1.4 Hypothesis 4

Positive associations between *average* stress and change in health-risk behaviours (from Time 1 to Time 2) will be moderated by worry (H4a) and brooding (H4b) such that these associations will be stronger as levels of worry and brooding increase.

Negative associations between *average* stress and change in health-promoting behaviours (from Time 1 to Time 2) will be moderated by worry (H4c) and brooding (H4d) such that these associations will be stronger as levels of worry and brooding increase.

Positive (H4e) associations between *average* stress and change in health-risk behaviours (from Time 1 to Time 2) will be moderated by reflection.

Negative (H4f) associations between *average* stress and change in health-promoting behaviours (from Time 1 to Time 2) will be moderated by reflection.

4.1.1.5 Hypothesis 5

Worry, brooding and reflection will individually predict unique variance in Time 1 health-risk behaviours and health-promoting behaviours (H5a).

Worry, brooding and reflection will individually predict unique variance in the change in health-risk and health-promoting behaviours (from Time 1 to Time 2) (H5b).

4.2 Method

4.2.1 Participants

Five hundred and sixty-two participants completed the baseline (Time 1) survey and, of these, 336 completed the follow-up (Time 2) survey, representing a 40% attrition rate. An a-priori sample size calculation suggested that, based upon an expected effect size of 0.1, power of 0.8 and alpha of .05, the minimum required sample to detect significant effects was 387 participants. At Time 1, the mean age of participants was 27.7 years (*SD* = 10.4; range 17-80 years). Mean BMI was 23.8 (*SD* = 5.4). Regarding sex, 78.7% of participants were female, 20.7% were male, 2 participants chose not to disclose their sex (selected the ‘prefer not to say’ option), one participant reported having transitioned from female to male (they were coded as being male in analyses) and data was missing for 7 participants (did not select any response option). Four hundred and ninety-three participants were British and 68 reported another nationality, data was missing for one participant. Participants were predominantly of White ethnicity (81.0%). Most participants were full-time (31.0%) or part-time employed (10.1%) or students (51.6%). Only 7.1% of participants were educated to below A Level grade; 43.4% had received A-Level qualifications as their highest level of education so far. Twenty-nine percent had completed an undergraduate degree (2.8% had completed a foundation degree). A further 17.6% had completed postgraduate degrees. All demographics refer to the baseline (Time 1) sample.

Participants were recruited via posters and participant databases at the University of Leeds, social media, and Call for Participants and Prolific Academic websites. Participants were not eligible for the study if they were under 16, not resident in the UK or if they were not fluent in English. Due to website rules, participants recruited through Prolific Academic were paid £2.50 after completing each survey. All other participants received either a £5 voucher or study credits if they completed both surveys.

4.2.2 Design

A longitudinal survey design was employed in which all variables (aside from trait variables) were measured at Time 1 and then again at 3 month follow-up (Time 2). Trait variables (worry, brooding, reflection and neuroticism) were only measured at Time 1 as these were measured at a trait level and therefore expected to remain stable over time. In completing the surveys, participants completed predictor variables prior to outcome variables.

4.2.3 Measures

4.2.3.1 Neuroticism

Neuroticism was measured using 10 items from the International Personality Item Pool (Goldberg et al., 2006). International Personality Item Pool scales have been validated in the Eugene Springfield community sample (Goldberg, 2008). Items included ‘I panic easily’ and ‘I have frequent mood swings’. Responses range from 1 (‘very inaccurate’) to 5 (‘very accurate’). General standardised instructions for personality measures were also taken from the website (see appendix C). Five items were reversed scored (e.g. ‘I feel comfortable with myself’) so that higher scores represented higher levels of neuroticism. Items were summed to produce a total neuroticism score (α = .88).

4.2.3.2 Trait Perseverative Cognition

Worry was measured using the 16-item Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990). Items include ‘my worries overwhelm me’ and ‘many situations make me worry’. Responses were rated on a 5-point scale (1 = ‘not at all typical of me’, 5 = ‘very typical of me’). Five items were reverse scored (e.g. ‘I do not tend to worry about things’) so that a higher score represented a higher level of trait worry (α = .94). See appendix D for full details. This measure has previously been shown to be reliable and valid (van Rijsoort et al., 1999).

Brooding was measured using 5 items from the Ruminative Responses Scale (RRS; Treynor, Gonzalez, & Nolen-Hoeksema, 2003). See appendix E for full details. Responses ranged from 1-4 and options consisted of ‘almost never’, ‘sometimes’, ‘often’ and ‘almost always’ (α = .81). Reflection was measured using 5 items from the RRS (Treynor et al., 2003). Responses ranged from 1-4 and options consisted of ‘almost never’, ‘sometimes’, ‘often’ and ‘almost always’ (α = .80). See appendix F for full details. Psychometric analysis by Treynor et al. (2003) supported the two-factor model (brooding and reflection) and found them to be differentially predictive of depression.

4.2.3.3 Stress

Perceived stress in the past month was measured using the 10-item Perceived Stress Scale (Cohen, 1988). Items included ‘in the last month, how often have you felt difficulties were piling up so high that you could not overcome them?’ and ‘in the last month, how often have you been upset because of something that happened unexpectedly?’ Responses range from 0 (‘never’) to 4 (‘very often’). Four items were reversed scored (e.g. ‘In the last month, how often have you felt that things were going your way?’) so that a higher score represented a higher level of perceived stress (Time 1, α = .89; Time 2, α = .90). See appendix G for full details. The reliability and construct validity of this measure has been supported in previous research (Roberti, Harrington, & Storch, 2006).

4.2.3.4 Unhealthy Snacking

Ten types of unhealthy snack foods (sugared squash/still soft drinks (not including fruit juice); sugared fizzy drinks; sausages, pies or burgers; chips, potato crisps; savoury snacks; ice cream; cakes/other sweet pastries; sweet biscuits; chocolate confectionary and sugared confectionary) were listed and participants were asked to indicate the frequency of consuming these particular snacks in the past month (‘never’, ‘less than once a month’, ‘less than once a week’, ‘once a week’, ‘2-4 days a week’, ‘5-6 days a week’, ‘once a day, everyday’, ‘2-3 times a day, everyday’, ‘more than 3 times a day. Everyday’). Brown, Ogden, Vogele, and Gibson (2008) used this measure in children but the food types and response options were deemed equally applicable to self-report in adults here. See appendix H for full details. Responses were coded 0-9 and summed such that higher scores represented more unhealthy snacking (Time 1, α = .79; Time 2, α = .78). This measure was also adapted for use in adults by Cropley et al. (2012).

4.2.3.5 Fruit and Vegetables

Fruit and vegetable consumption were measured using a quantity-frequency measure created for this study. Participants were asked (in separate items), in a typical week in the past month, how many days each week they ate fruit and vegetables. Responses options ranged from 0-7 days. They were then asked (again in separate items) how many portions of fruit and vegetables they consumed on days when they did eat fruit and vegetables. A link to a website was provided which informed participants of what a portion of different types of fruits and vegetables consists of (http://www.nhs.uk/Livewell/5ADAY/Pages/Portionsizes.aspx). The number of days that each fruit and vegetable was eaten was multiplied by the portions of each fruit and vegetable typically eaten on these days to provide an outcome variable of the portions of fruit and vegetables eaten in a typical week in the past month.

4.2.3.6 Physical Activity

The Leisure Time Exercise Questionnaire (Godin & Shephard, 1985), which has been validated in healthy adults, was used to assess physical activity. Participants were asked how many times per week, in a typical 7-day period in the past month, they engaged in various activities for more than 15 minutes in their free time. The categories were ‘strenuous exercise (heart beats rapidly)’, ‘moderate exercise (not exhausting)’ and ‘mild exercise (light effort)’. Example activities were provided but some of the suggested example activities were removed due to expected lack of relevance to the sample (e.g. yodelling). As per the original scoring instructions, the number of weekly episodes of strenuous activity was multiplied by 9, moderate activity was multiplied by 5 and light activity was multiplied by 3. These products were then summed to produce a weekly exercise score. Participants were also asked to indicate how often in the same time-period they engaged in any regular activity long enough to work up a sweat. Responses options were ‘often’, ‘sometimes’ or ‘never/rarely’ (coded 1-3). This was reverse scored and then summed with the weekly exercise score to produce a total physical activity score, used in analyses. See appendix I for full details.

4.2.3.7 Alcoholic Drinks

Alcohol consumption items were adapted from Stockwell et al. (2004). This was a quantity-frequency measure which asked participants to indicate how often they drank in the past month (‘everyday’, ‘5-6 days per week’, ‘3-4 days per week’, ‘1-2 days per week’, ‘2-3 days per month’, ‘about one day a month’, ‘less often’, ‘don’t drink’ or ‘prefer not to say’) and then to indicate how many standard drinks they usually had on days when they were drinking (‘13 or more drinks’, ’11-12 drinks’, ‘7-10 drinks’, ‘5-6 drinks’, ‘3-4 drinks’, ‘1-2 drinks’, ‘didn’t drink’ or ‘prefer not to say’). A link was provided explaining what a standard drink represents (http://www.drinkaware.ie/facts/what-is-a-standard-drink). Responses were coded to provide an estimate of the number of drinks consumed in that month. The estimated number of drinking days per month was calculated. For example, every day was coded as 28 (7 days a week multiplied by 4 to represent a typical 4-week month) whereas 3-4 days per week was coded as 14 (the median of 3.5 x 4). Less often than one day per month was estimated at 0.5 and non-drinkers were coded as 0. The number of drinks consumed on drinking days was coded as the median of the response options (e.g. ‘5-6 drinks’ = 5.5). The number of drinking days per month was multiplied by the number of drinks consumed on drinking days to provide an estimate of alcohol units consumed that month. As drinking guidelines refer to weekly units, this number was then divided by 4 to provide an outcome of units consumed per week in a typical 4-week month. Weekly drinking was the outcome variable included in analyses.

4.2.3.8 Sleep

Sleep items were taken from the Pittsburgh Sleep Quality Index (PSQI;Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Three single-items of interest were taken from this measure. These related to SOL, TST in hours and minutes and then a rating of sleep quality (‘very good’ = 1, ‘fairly good’ = 2, ‘fairly bad’ = 3, ‘very bad’ =4). These questions referred to ‘the majority of days and nights in the past month’. See appendix J for full details. Higher scores refer to longer SOL, more sleep time and lower levels of sleep quality. The PSQI has shown good test-retest reliability and has been found to be predictive of sleep log data in a previous study (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002), more so than the Epworth Sleepiness Scale (Buysse et al., 2008).

4.2.4 Procedure

Participants accessed a link to the online survey. In the first survey, participants were provided with study information and were asked to provide their consent. In the Time 1 survey, participants were first asked to provide demographic details (e.g., age, sex, height, weight and education). The following measures were completed in this order: neuroticism, worry, brooding and reflection, perceived stress in the past month, sleep duration, sleep onset latency, sleep quality, physical activity, snack food intake, fruit and vegetable consumption and alcohol. Note that smoking behaviour was measured but there were very few smokers recruited and therefore this outcome could not be analysed whilst maintaining an adequate degree of statistical power. At the end of the survey, participants were informed that a researcher would contact them in three months’ time to complete the second part of the study. Time 1 surveys were completed from June 2016 to October 2016.

Three months after the first survey, participants were contacted by email with a link to the second survey. The same health behaviours were measured in the same order. Participants read a study debrief at the end of the survey. Time 2 surveys were completed from September 2016 to January 2017. Ethical approval was granted by the University of Leeds, School of Psychology Ethics Committee (Ethics number: 16-0158, date of approval 02.06.16).

4.2.5 Method of Analysis

All analyses were conducted using SPSS. In the simplest tests of hypothesis 1 (a-f) and 2 (a-f), correlational analyses were first carried out to assess whether PC was associated with health behaviours and health outcomes cross-sectionally and prospectively.

In a further test of hypothesis 1 (a-f), hierarchical multiple regression analyses were conducted to assess whether, when accounting for stress, PC variables predicted health behaviours cross-sectionally. These models also tested whether PC moderated an association between stress and health behaviours, in a test of hypothesis 3 (a-f). Hierarchical multiple linear regressions using the enter method were conducted to test the relationships specified in the extended PCH model for variables measured at Time 1. At step 1, worry, brooding or reflection were added to the model. At step 2, perceived stress was entered. Worry, brooding or reflection were examined as moderators of the relationship between stress and health behaviour outcomes. Therefore, at step 3, the interaction between perceived stress and worry, brooding or reflection were added to the model. In a more thorough test of hypothesis 1 (a-f) and 3 (a-f), the model is identical apart from, at step 1, age, sex, BMI and neuroticism were entered to assess whether PC added any predictive value to the model in addition to the variables which were expected to be predictive of several health behaviours.

Similarly, to test hypothesis 2 (a-f) and 4 (a-f), the same models were tested for Time 2 health behaviour outcomes but average stress across the two time-points was instead used (hypotheses 2 and 4). Again, models were tested with and without demographics and neuroticism. Average stress across the two time-points (mean of stress at Time 1 and 2), as opposed to a change in stress was used as there was little variation in stress responses across the time-points. Here, the interaction between *average* stress and worry, brooding or reflection was added to the model. At step 1, the Time 1 dependent variable was added (i.e. baseline behaviour) and, as such, by including this as a covariate, the outcome became *change* in behaviour from Time 1 to Time 2. Standardised betas from the final step of this model are represented in Table 4.12, Table 4.13 and Table 4.14 alongside R^2 and F Change statistics.

Finally, to assess whether different PC variables predicted unique variance in Time 1 and 2 health behaviours (hypothesis 5 a-b), all PC variables were entered into the same hierarchical multiple regression model simultaneously (which also accounted for stress, and average stress in the case of prospective analyses, and the interaction terms between these and PC predictors), this was described as the competition model. In keeping with the other analyses, these models were tested with and without demographics and neuroticism. However, here, PC was always added at step 1 so that the predictive utility of the combined PC predictors alone could be assessed. Therefore, in the first step of the cross-sectional model, worry, brooding and reflection were added. In the second step of this model either, age, sex, BMI and neuroticism were added, or, in models not including demographics and neuroticism, stress was added at the second, rather than third step. In the final step, the interaction between stress and brooding, stress and worry and stress and reflection were added. Like in the previous prospective analyses, the Time 1 dependent variable was added at step 1 so that the outcome became change in the health behaviour from Time 1 to Time 2, and average stress was used in place of Time 1 stress. These models are depicted in Table 4.17 and Table 4.18.

Standardised betas from the final steps of these model are represented in the relevant tables alongside R^2 and F Change statistics. The Hayes PROCESS Macro was used to decompose any significant interactions between PC and stress in all analyses. Analyses were conducted separately for worry, brooding and reflection (apart from when assessing hypothesis 5 a-b). Simple slopes are reported as 1 SD below the mean (low), the mean (medium) and 1 SD above the mean (high).

4.3 Results

4.3.1 Attrition Analyses

A Multivariate Analysis of Variance (MANOVA) was conducted on continuous Time 1 variables to compare those who completed both surveys (completers) to those who only completed survey 1 (drop-outs). The MANOVA was statistically significant, F (14, 465) = 1.87, p = .03. Main effects of completion status were found on age (completers: M = 28.62, SD = 10.50; drop-outs: M = 26.35, SD = 10.10), F (1, 469) = 4.08, p = .04, worry (completers: M = 56.90, SD = 14.32; drop-outs: M = 55.29, SD = 13.87), F (1, 469) = 4.20, p = .04, and fruit and vegetable consumption, (completers: M = 29.06, SD = 20.30; drop-outs: 32.16, SD = 26.21), F (1, 469) = 4.72, p = .03, but not on BMI, neuroticism, brooding, reflection, stress, SOL, TST, sleep quality, physical activity or alcohol. For categorical Time 1 variables (sex, nationality, ethnicity, employment status and education), chi-square analyses were conducted, and no significant differences were found between completers and drop-outs on these variables (p > .05).

4.3.2 Analysis of Missing Data

The percentage of missing data was analysed across Time 1 and Time 2. Missing value analysis was conducted on the full dataset before totals had been computed. Less than 1% of data was missing overall at both time points. An expectation maximisation chi-square test was used to assess whether data was missing completely at random (Little, 1988) and this was found to be non-significant at Time 1 (all participants), χ^2 (df = 3201) = 3227.42, p = .37, and Time 2 (completers only), χ^2 (df = 5384) = 5494.33, p = .14, indicating that data was missing completely at random. When conducting analyses, listwise deletion is used and therefore, the sample size varied per analysis. Based on a minimum required sample size of 387 participants (see section 4.2.1), all models are underpowered (see Table 4.6 to Table 4.18 for sample sizes per analytical model). Listwise deletion has been found to be an unbiased method of dealing with missing data when data is missing completely at random (Kang, 2013).

4.3.3 Descriptive Statistics and Correlations

Descriptive statistics and Pearson's correlations between the study variables are reported in Table 4.1. As correlations between PC measures were not high (all are below .7), analysing these variables as individual predictors was justified. As expected, neuroticism was significantly positively correlated with all PC variables (although much less so with reflection) which confirms that it is necessary to control for this variable when analysing PC. Worry was significantly correlated with longer SOL at Time 1 (r = .23, p < .001) and 2 (r =.15, p < .01), poorer sleep quality at Time 1 (r = .28, p < .001) and 2 (r = .24, p < .001), and more unhealthy snacking at Time 1 (r = .21, p < .001) and 2 (r = .17, p < .01). Worry was not significantly correlated with TST at Time1 or 2, physical activity at Time 1 or 2, fruit and vegetable intake at Time 1 or 2, or alcohol consumption at Time 1 or 2. Brooding was significantly correlated with longer sleep onset latency at Time 1 (r = .22, p < .001) and Time 2 (r = .19, p < .001), shorter TST at Time 1 (r = -.14, p < .05), and poorer sleep quality at Time 1 (r = .24, p < .001) and Time 2 (r = .23, p < .001), less physical activity at Time 1 (r = -.13, p < .01) and more unhealthy snacking at Time 1 (r = .25, p < .001) and Time 2 (r = .20, p < .001). Brooding was not significantly correlated with TST at Time 2, physical activity at Time 2 or fruit and vegetable or alcohol consumption at either time-point. Reflection was significantly correlated with longer SOL (r = .13, p < .05) and poorer sleep quality (r = .12, p < .05) at Time 1. Reflection was not significantly correlated with Time 2 SOL or poorer sleep quality, or TST, physical activity, unhealthy snacking, fruit and vegetable intake or alcohol consumption at either Time 1 or Time 2. Time 1 stress was significantly correlated with longer Time 1 SOL (r = .29, p < .001), shorter TST (r = -.19, p < .01), poorer sleep quality (r = .40, p < .001) more unhealthy snacking (r = .18, p < .01) and lower fruit and vegetable intake (r = -.11, p < .05) but was not significantly correlated with physical activity or alcohol consumption at Time 1 (p > .05). Average stress also significantly predicted longer SOL (r = .25, p < .001), shorter TST (r = -.15, p < .01), poorer sleep quality (r = .34, p < .001) and more unhealthy snacking (r = .16, p < .01) at Time 2, and was not significantly correlated with Time 2 physical activity, fruit and vegetable intake or alcohol consumption (p > .05).

Table 4.1 Descriptive Statistics and Pearson's Correlations between Study Variables[a]

	N	*M (SD)*	1	2	3	4	5	6	7	8	16
1. Worry	549	27.71 (10.39)	-								
2. Brooding	558	10.96 (3.63)	.60***	-							
3. Reflection	558	9.70 (9.70)	.27***	.53***	-						
4. Age	562	27.71 (10.39)	-.11*	-.09	-.10	-					
5. Sex[b]	553	n/a	.11*	.02	-.02	-.08	-				
6. BMI	548	23.76 (5.36)	-.02	.11*	-.07	.30***	-.05	-			
7. Neuroticism	555	29.84 (8.20)	.68***	.60***	.32***	-.09	.06	.05	-		
8. Perceived Stress T1[c]	548	19.50 (7.36)	.67***	.67***	.42***	-.06	.07	-.01	.70***	-	
9. SOL (minutes) T1	541	38.88 (44.64)	.23***	.22***	.13*	-.05	.05	-.00	.26***	.29***	-
10. TST (minutes) T1	552	436.13 (84.34)	-.05	-.14*	-.11	-.28***	.04	-.10	-.15**	-.19**	-
11. Sleep Quality T1	560	2.27 (0.73)	.28***	.24***	.12*	.11*	-.04	.06	.33***	.40***	-
12. Physical Activity T1[d]	561	48.26 (37.09)	-.10	-.13*	-.03	-.11*	-.03	-.12*	-.14*	-.11	-
13. Unhealthy Snacks T1	545	26.37 (8.55)	.21***	.25***	.09	-.14*	-.10	-.03	.22***	.18**	-

14. Fruit and Vegetable Portions (per week) T1[e]	562	30.31 (22.89)	-.10	-.07	-.01	.15**	.09	-.01	-.07	-.11*	-
15. Alcohol Units T1	562	6.14 (9.13)	-.04	-.02	.06	-.16**	.02	-.07	.00	-.04	-
16. Average Perceived Stress[c]	320	19.65 (6.95)	.69***	.67***	.39***	-.10	.09	.03	.71***	.93***	-
17. SOL (minutes) T2	328	38.08 (35.19)	.15**	.19***	.03	-.12*	.04	.01	.23***	-	.25***
18. TST (minutes) T2	335	432.12 (76.37)	.00	-.10	-.08	-.26***	.10	-.10	-.10	-	-.15**
19. Sleep Quality T2	334	2.19 (0.70)	.24***	.23***	.10	-.04	.01	-.04	.28***	-	.34***
20. Physical Activity T2	331	49.25 (41.39)	.00	-.04	-.07	-.03	-.06	.01	-.10	-	-.03
21. Unhealthy Snacks T2	330	24.15 (8.07)	.17**	.20***	.09	-.14**	-.08	-.07	.17**	-	.16**
22. Fruit and Vegetable Portions (per week) T2	334	28.20 (15.56)	-.07	-.08	-.02	.06	.10	-.06	-.09	-	-.06
23. Alcohol Units (per week) T2	336	4.67 (6.30)	-.00	-.01	.03	-.13*	-.03	-.02	.06	-	.003

Note. *** Correlation is significant at the .001 level, **significant at the .01 level, * significant at the .05 level, [a]Sample size, means and SDs refer to the whole sample at Time 1, correlations are for completers only, [b]1 = male, 2 = female, point biserial correlation, [c]Perceived stress at T1 was only correlated with T1 outcomes and average stress was correlated with T2 outcomes only, [d]Physical activity scores at Time 1 had extreme outliers which were truncated to 2 SDs above the mean, [e]Time 1 weekly Fruit and Vegetables portions had extreme outliers at the upper end which were truncated to 2 SDs above the mean.

4.3.4 Multicollinearity

Multicollinearity diagnostics (Table 4.2) revealed an issue with multicollinearity between PC variables, stress and interaction terms as Variance Inflation Factor (VIF) statistics were above 10 (Alin, 2010) and tolerance statistics were below 0.2 (Weisburd & Britt, 2007). Therefore, continuous variables were standardised prior to being entered into regression models. As can be seen from Table 4.2, standardising these variables reduced multicollinearity statistics to acceptable levels. However, although there is no definite cut-off for multicollinearity statistics, it has been suggested that tolerance statistics below 0.4 may still be problematic (Allison, 1999) which suggests that multicollinearity remained an issue for worry, brooding and average stress in the prospective models. Note that, for brevity, statistics reported in Table 4.2 relate to one outcome only (SOL), as they differed little across health behaviour outcomes. Multicollinearity statistics for the other outcomes are reported in appendix K.

Table 4.2 Multicollinearity Statistics

	Non-Standardised		Standardised	
	Tolerance	VIF	Tolerance	VIF
		Cross-Sectional		
Age	0.88	1.13	0.88	1.13
Sex[a]	0.93	1.07	0.93	1.07
BMI	0.87	1.15	0.87	1.15
Neuroticism	0.41	2.45	0.41	2.45
Worry	0.09	11.39	0.40	2.49
Brooding	0.05	19.09	0.36	2.77
Reflection	0.08	12.43	0.64	1.56
Stress	0.04	22.44	0.37	2.68
Stress x Worry	0.02	57.63	0.55	1.81
Stress x Brooding	0.02	55.41	0.46	2.16
Stress x Reflection	0.03	30.11	0.74	1.35
		Prospective		
Time 1 Dependent Variable	0.90	1.11	0.90	1.11
Age	0.90	1.11	0.90	1.11
Sex[a]	0.93	1.07	0.93	1.07
BMI	0.88	1.13	0.88	1.13
Neuroticism	0.41	2.45	0.41	2.45
Worry	0.08	12.00	0.38	2.60

Brooding	0.05	20.33	0.38	2.62
Reflection	0.07	13.83	0.67	1.49
Average Stress	0.05	21.07	0.38	2.67
Average Stress x Worry	0.02	57.81	0.54	1.86
Average Stress x Brooding	0.02	57.07	0.47	2.15
Average Stress x Reflection	0.03	31.67	0.72	1.39

Note. Statistics reported are for SOL Time 1 (cross-sectional) and Time 2 (prospective), [a]Sex was not standardized as this variable is dichotomous.

4.3.5 Cross-sectional Regression Models

4.3.5.1 Models without Demographics and Neuroticism

In the worry models (Table 4.3), stress significantly predicted longer SOL, β = .22, *p* = .004, shorter TST, β = -.27, *p* < .001, and poorer sleep quality, β = .40, *p* < .001, in accordance with the significant correlations reported in Table 4.1. In the brooding models, the associations between stress and longer SOL, β = .27, *p* < .001, shorter TST, β = -.17, *p* = .02, and poorer sleep quality, β = .46, *p* < .001, also remained. This was also the case in the reflection models (SOL: β = .29, *p* < .001, TST: β = -.16, *p* = .01, sleep quality: β = .43, *p* < .001). However, the associations between stress and unhealthy snacking and fruit and vegetable intake (see Table 4.1) were reduced to non-significance in the worry and brooding models. In the reflection models, stress still predicted more unhealthy snacking, β = .18, *p* = .004, and lower fruit and vegetable intake, β = -.13, *p* = .04.

Worry predicted more unhealthy snacking, β = .16, *p* = .04. However, significant associations between worry and SOL and sleep quality, reported in Table 4.3, were reduced to non-significance in these models and worry also did not predict TST, physical activity, fruit and vegetable intake or alcohol consumption and there were no significant interactions between worry and stress on any health behaviour outcomes.

As can be seen from Table 4.4, brooding significantly predicted unhealthy snacking, β = .25, *p* = .001, and moderated the association between stress and unhealthy snacking, β = -.14, *p* = .02. This interaction is depicted in Figure 4.1.

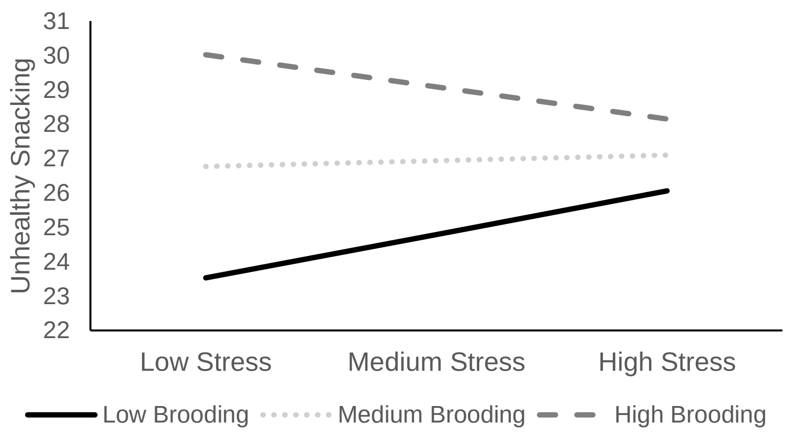

Figure 4.1 Simple Slopes of the Moderating Effect of Trait Brooding on the Associations between Perceived Stress and Unhealthy Snacking Cross-Sectionally

Analyses in Hayes PROCESS Macro revealed that, at low levels of brooding there was a positive association between stress and unhealthy snacking, β = 1.25, p = .10, at medium levels of brooding there was a smaller positive association between stress and snacking, β = 0.16, p = .80, and at high levels of brooding, there was a negative association between stress and unhealthy snacking, β = -.92, p = .25. Although none of these slopes were significant, entering brooding as the predictor and stress as the moderator, revealed that, at low stress, brooding predicted more unhealthy snacking, β = 3.25, $p < .001$, this was also true at medium levels of stress, β = 2.15, p = .01, although the association was weaker. At high levels of stress, this association was still positive but non-significant, β = 1.05, p = .15. Therefore, brooding predicts more snacking at low and medium levels of stress but at high levels of stress, there appears to be no relationship between brooding and snacking.

However, associations between brooding and SOL, TST, sleep quality and physical activity, reported in Table 4.1, were no longer significant in these models, nor did brooding predict fruit and vegetable or alcohol consumption. There were no other significant interactions between brooding and stress on any other health behaviour outcomes.

Table 4.5 demonstrates that in these models, significant associations between reflection and SOL and sleep quality (see Table 4.1) were no longer significant in these models, nor did reflection significantly predict TST, physical activity, unhealthy snacking, fruit and vegetable intake or alcohol consumption and there were no significant interactions between reflection and stress on any health behaviour outcomes.

Table 4.3 Hierarchical Regressions of Cross-sectional Associations between Worry and Stress on Health Behaviours

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Worry	.10	.12	-.00	-.05	.16*	-.03	-.04
R^2	.05	.00	.07	.01	.04	.01	.00
ΔF	17.22***	0.77	25.44***	2.32	13.36***	2.95	0.69
Perceived Stress	.22**	-.27***	.40***	-.06	.07	-.09	-.01
R^2	.08	.05	.16	.01	.04	.01	.00
ΔR^2	.03	.04	.09	.00	.00	.00	.00
ΔF	9.42**	14.62***	33.02***	0.74	0.67	1.23	0.02
Worry x Stress	.07	-.08	-.02	-.03	-.02	.04	-.02
R^2	.09	.05	.16	.01	.04	.01	.00
ΔR^2	.00	.01	.00	.00	.00	.00	.00
ΔF	1.56	2.08	0.21	0.36	0.18	0.56	0.07

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: n = 302; TST: n = 316; Sleep Quality: n = 317; Physical Activity: n = 319; Unhealthy Snacks: n = 308; Fruit and Vegetables: n =; Alcohol: n = 319.

Table 4.4 Hierarchical Regressions of Cross-Sectional Associations between Brooding and Stress on Health Behaviours

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Brooding	.02	-.01	-.09	-.09	.25** (.001)	.03	.01
R^2	.05	.02	.05	.02	.06	.00	.00
ΔF	15.42***	6.37*	17.88***	5.10*	18.63***	0.84	0.13
Perceived Stress	.27***	-.17*	.46***	-.04	.02	-.12	-.04
R^2	.08	.04	.17	.02	.06	.01	.00
ΔR^2	.04	.02	.11	.00	.00	.01	.00
ΔF	11.96**	5.15*	42.78***	0.26	0.15	2.80	0.31
Brooding x Stress	.09	-.09	.08	-.03	-.14*	.01	.01
R^2	.09	.04	.17	.02	.07	.01	.00
ΔR^2	.01	.01	.01	.00	.02	.00	.00
ΔF	2.73	2.31	2.35	0.26	5.87*	0.04	0.01

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: n = 305; TST: n = 319; Sleep Quality: n = 320; Physical Activity: n = 322; Unhealthy Snacks: n = 312; Fruit and Vegetables: n = 322; Alcohol: n = 322.

Table 4.5 Hierarchical Regressions of Cross-Sectional Associations between Reflection and Stress on Health Behaviours

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Reflection	-.01	-.03	-.07	.01	.03	.03	.09
R^2	.02	.01	.01	.00	.01	.00	.00
ΔF	5.01*	3.76	4.34*	0.24	2.10	0.09	1.12
Perceived Stress	.29***	-.16**	.43***	-.11	.18**	-.13*	-.07
R^2	.08	.03	.16	.01	.03	.01	.01
ΔR^2	.07	.02	.15	.01	.03	.01	.00
ΔF	22.31***	7.22**	56.71***	3.48	8.81**	4.35*	1.38
Reflection x Stress	.08	-.06	.06	.05	-.09	.05	-.00
R^2	.09	.04	.17	.01	.04	.02	.01
ΔR^2	.01	.00	.00	.00	.01	.00	.00
ΔF	2.19	1.05	1.23	0.66	2.81	0.93	0.00

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: n = 307; TST: n = 321; Sleep Quality: n = 322; Physical Activity: n = 324; Unhealthy Snacks: n = 313; Fruit and Vegetables: n = 324; Alcohol: n = 324.

4.3.5.2 Models with Demographics and Neuroticism

In the worry models containing demographics and neuroticism at step 1 (Table 4.6), stress significantly predicted longer SOL, β = .17, p = .05, shorter TST, β = -.22, p = .01, and poorer sleep quality, β = .34, $p < .001$, in accordance with the significant correlations reported in Table 4.1. In the brooding models, the associations between stress and longer SOL, β = .20, p = .03, and poorer sleep quality remained, β = .38, $p < .001$, but stress no longer predicted shorter TST. This was also the case in the reflection models (SOL: β = .20, $p < .01$, sleep quality: β = .35, $p < .001$). Stress did not significantly predict physical activity, physical activity, fruit and vegetable intake or alcohol consumption in either the worry (Table 4.6), brooding (Table 4.7) or reflection (Table 4.8) models.

When demographics and neuroticism were included in the model, worry no longer significantly predicted unhealthy snacking. Worry also did not significantly predict SOL, TST, sleep quality, physical activity, unhealthy snacking, fruit and vegetable or alcohol consumption and there were no significant interactions between worry and stress on any health behaviour outcomes. It can also be seen that, at step 2, worry did not significantly increase the predictive utility of the model for any of the health behaviour outcomes, as indicated by the F change statistics (Table 4.6).

Brooding still significantly predicted unhealthy snacking, β = .22, $p < .01$, and moderated the association between stress and unhealthy snacking, β = -.12, $p < .04$, depicted in Figure 4.1. Brooding still did not significantly predict SOL, TST, sleep quality, physical activity, fruit and vegetable or alcohol consumption, there were no other significant interactions between stress and brooding, and brooding did not significantly increase the ability of the model to predict any of these outcomes (Table 4.7).

In these models, reflection still did not significantly predict SOL, TST, sleep quality, physical activity, unhealthy snacking, fruit and vegetable or alcohol consumption and there were no significant interactions between reflection and stress on any health behaviour outcomes (Table 4.8). It can also be seen that, at step 2, reflection did not significantly increase the predictive utility of the model for any of the health behaviour outcomes.

Table 4.6 Hierarchical Regressions of Cross-Sectional Associations between Demographics, Neuroticism, Worry and Stress on Health Behaviours

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Age	-.02	-.24***	.15**	-.11	-.12*	.15*	-.16**
Sex	.02	.03	-.06	-.05	-.14*	.11	.01
BMI	.02	-.01	.01	-.10	-.01	-.11	-.02
Neuroticism	.11	-.13	.15	-.07	.09	.05	.07
R^2	.07	.10	.14	.04	.06	.04	.03
F	5.56***	7.77***	12.13***	3.14*	4.92**	2.96*	2.13
Worry	.06	.15	-.04	-.02	.12	-.05	-.08
R^2	.08	.10	.15	.04	.07	.04	.03
ΔR^2	.00	.00	.01	.00	.01	.01	.00
ΔF	1.45	1.20	1.77	0.15	2.78	1.94	1.28
Perceived Stress	.17*	-0.22**	.34***	-.03	.03	-.11	-.03
R^2	.09	.12	.20	.04	.07	.05	.03
ΔR^2	.01	.11	.05	.00	.00	.00	.00
ΔF	4.54*	8.12**	18.19***	0.17	0.08	1.49	0.14
Worry x Stress	.08	-0.05	-.04	-.01	-.02	.05	-.02

R^2	.10	.13	.20	.04	.07	.05	.03
ΔR^2	.08	.00	.00	.00	.00	.00	.00
ΔF	1.81	0.68	0.51	0.02	0.14	0.69	0.09

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 287; TST: *n* = 299; Sleep Quality: *n* = 300; Physical Activity: *n* = 302; Unhealthy Snacks: *n* =292; Fruit and Vegetables: *n* = 302; Alcohol: *n* = 302.

Table 4.7 Hierarchical Regressions of Cross-Sectional Associations between Demographics, Neuroticism, Brooding and Stress on Health Behaviours

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Age	-.02	-.26***	.12*	-.12	-.09	.17**	-.16**
Sex	.01	.03	-.07	-.04	-.12*	.10	.01
BMI	.01	-.02	.01	-.09	-.03	-.08	-.01
Neuroticism	.14	-.07	.15*	-.05	.10	.03	.05
R^2	.08	.10	.14	.04	.06	.04	.03
F	5.83***	8.59***	11.92***	3.16*	5.02**	3.04*	2.16
Brooding	-.03	-.01	-.13	-.10	.22**	-.01	-.03
R^2	.08	.11	.14	.05	.08	.04	.03
ΔR^2	.00	.00	.00	.01	.02	.00	.00
ΔF	1.29	1.44	0.55	2.09	5.93*	0.61	0.46
Stress	.20*	-.15	.38***	-.00	-.03	-.12	-.05
R^2	.09	.12	.20	.05	.08	.05	.03
ΔR^2	.02	.01	.06	.00	.00	.01	.00
ΔF	4.83*	3.01	21.61***	0.00	0.13	1.91	0.35

Brooding x Stress	.09	-.05	.08	-.01	-.12*	.01	.02
R^2	.10	.12	.20	.05	.10	.05	.03
ΔR^2	.08	.00	.01	.00	.01	.02	.00
ΔF	2.68	0.90	2.11	0.03	4.12*	0.01	0.11

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 290; TST: *n* = 302; Sleep Quality: *n* = 303; Physical Activity: *n* = 305; Unhealthy Snacks: *n* = 295; Fruit and Vegetables: *n* = 305; Alcohol: *n* = 305.

Table 4.8 Hierarchical Regressions of Cross-Sectional Associations between Demographics, Neuroticism, Reflection and Stress on Health Behaviours

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Age	-.02	-.26***	.13*	-.12*	-.11	.16**	-.16**
Sex	.01	.03	-.08	-.04	-.14*	.12*	-.00
BMI	.01	-.02	-.01	-.10	-.01	-.10	-.01
Neuroticism	.14	-.08	.13	-.08	.14	.03	.02
R^2	.08	.10	.14	.04	.06	.04	.03
F	5.90***	8.49***	11.80***	3.43**	4.90**	3.01*	2.21
Reflection	-.03	-.04	-.09	-.01	.01	.02	.08
R^2	.08	.11	.14	.04	.06	.04	.03
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	0.18	1.62	0.00	0.05	0.02	0.00	0.92
Stress	.20*	-.14	.35***	-.05	.08	-.14	-.08
R^2	.10	.12	.19	.04	.07	.05	.03
ΔR^2	.02	.01	.06	.00	.00	.01	.00
ΔF	6.02*	3.06	21.62***	0.36	0.85	3.01	1.03

Reflection x Stress	.08	-.03	.05	.05	-.09	.06	-.01
R^2	.10	.12	.20	.05	.07	.05	.03
ΔR^2	.01	.00	.00	.00	.01	.00	.00
ΔF	2.02	0.33	0.92	0.77	2.47	1.12	0.01

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 292; TST: *n* = 304; Sleep Quality: *n* = 305; Physical Activity: *n* = 307; Unhealthy Snacks: *n* =297; Fruit and Vegetables: *n* = 307; Alcohol: *n* = 307.

4.3.6 Prospective Regression Models

4.3.6.1 Models without Demographics and Neuroticism

In the worry model (Table 4.9), average stress predicted longer SOL, β = .27, $p <$ .001, shorter TST, β = -.14, p = .04, and poorer sleep quality, β = .17, p = .01, which is in broad agreement with the correlational analyses (Table 4.1) and cross-sectional regression models. In the brooding model (Table 4.10), average stress only predicted longer SOL, β = .15, p = .03, and in the reflection model, average stress again predicted longer SOL, β = .19, p = .001, and poorer sleep quality, β = .14, p = 01, (Table 4.11).

Worry significantly predicted shorter SOL, β = -.15, p = .03. This association with SOL is in the opposite direction to the correlation reported, which is indicative of multicollinearity (Alin, 2010) and therefore, these findings should be interpreted with caution. Neither brooding or reflection predicted any health behaviour outcomes prospectively and neither brooding, worry or reflection significantly interacted with average stress to predict any health behaviour outcomes.

Table 4.9 Hierarchical Regressions of Prospective Associations between Worry and Average Stress on Health Behaviours

	SOL (T2)	TST (T2)	Sleep Quality (T2)	Physical Activity (T2)	Unhealthy Snacking (T2)	Fruit and Vegetables (T2)	Alcohol (T2)
Baseline DV	.49***	.54***	.50***	.54***	.68***	.53***	.43***
R^2	.27	.31	.31	.29	.48	.28	.19
F	110.04***	135.34***	135.57***	124.54***	275.26***	122.02***	70.85***
Worry	-0.15*	.13	-.05	.07	.03	-.01	-.00
R^2	.28	.31	.31	.29	.49	.28	.19
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	.81	0.35	1.57	1.80	1.63	0.10	0.14
Average Stress	.27***	-.14*	.17*	-.03	.02	-.02	.01
R^2	.31	.32	.32	.29	.49	.28	.19
ΔR^2	.04	.01	.01	.00	.00	.00	.00
ΔF	15.21***	4.25*	6.08*	0.22	0.03	0.06	0.00
Worry x Average Stress	-.06	.04	-.01	-.04	-.05	-.01	-.05
R^2	.32	.32	.32	.29	.49	.28	.19

ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	1.61	0.76	0.08	0.56	1.18	0.01	1.00

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 292; TST: *n* = 308; Sleep Quality: *n* = 308; Physical Activity: *n* = 308; Unhealthy Snacks: *n* = 295; Fruit and Vegetables: *n* = 311; Alcohol: *n* = 312.

Table 4.10 Hierarchical Regressions of Prospective Associations between Brooding and Average Stress on Health Behaviours

	SOL (T2)	TST (T2)	Sleep Quality (T2)	Physical Activity (T2)	Unhealthy Snacking (T2)	Fruit and Vegetables (T2)	Alcohol (T2)
Baseline DV	.45***	.55***	.50***	.54***	.68***	.58***	.43***
R^2	.25	.31	.31	.28	.49	.34	.19
F	97.01***	139.59***	140.88***	122.21***	285.49***	163.35***	72.01***
Brooding	.00	.03	.03	.06	.03	-.03	-.02
R^2	.26	.31	.32	.28	.49	.34	.19
ΔR^2	.01	.00	.01	.00	.00	.00	.00
ΔF	3.75	0.13	4.54*	0.55	0.63	0.68	.00
Average Stress	.15*	-.07	.12	-.03	.02	.00	.02
R^2	.27	.31	.33	.28	.49	.34	.19
ΔR^2	.01	.00	.01	.00	.00	.00	.00
ΔF	4.96*	1.26	3.10	0.16	0.25	0.00	0.09
Brooding x Average Stress	-.01	-.01	.02	-.01	-.05	-.02	.02

R^2	.27	.31	.33	.28	.49	.34	.19
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	0.02	0.08	0.19	0.07	1.19	0.27	0.14

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 297; TST: *n* = 312; Sleep Quality: *n* = 312; Physical Activity: *n* = 312; Unhealthy Snacks: *n* =300; Fruit and Vegetables: *n* = 314; Alcohol: *n* = 316.

Table 4.11 Hierarchical Regressions of Prospective Associations between Reflection and Average Stress on Health Behaviours

	SOL (T2)	TST (T2)	Sleep Quality (T2)	Physical Activity (T2)	Unhealthy Snacking (T2)	Fruit and Vegetables (T2)	Alcohol (T2)
Baseline DV	.46***	.55***	.51***	.53***	.69***	.54***	.42***
R^2	.25	.31	.31	.28	.48	.30	.17
F	96.99***	143.24***	143.07***	120.02***	280.89***	132.23***	66.72***
Reflection	-.09	-.00	-.01	-.07	-.00	-.01	-.01
R^2	.25	.32	.32	.28	.48	.30	.17
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	0.45	0.26	0.64	1.72	0.09	0.14	0.00
Average Stress	.19**	-.05	.14*	.04	.04	-.02	.01
R^2	.28	.32	.33	.28	.49	.30	.17
ΔR^2	.03	.00	.02	.00	.00	.00	.00
ΔF	12.04**	1.04	6.98**	0.54	0.76	0.12	0.02
Reflection x Average Stress	-.07	-.02	-.04	-.03	-.01	.02	.04

R^2	.28	.32	.33	.28	.49	.30	.18
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	1.92	0.15	0.70	0.31	0.05	0.25	0.49

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 297; TST: *n* = 313; Sleep Quality: *n* = 313; Physical Activity: *n* = 313; Unhealthy Snacks: *n* = 300; Fruit and Vegetables: *n* = 315; Alcohol: *n* = 317.

4.3.6.2 Models with Demographics and Neuroticism

In the worry model (Table 4.12), average stress predicted longer SOL, β = .23, p = .003, shorter TST, β = -.15, p = .05, and poorer sleep quality, β = .17, p = .02, which is in broad agreement with the correlational analyses (Table 4.1) and cross-sectional regression models. In the brooding model, stress did not significantly predict any of these variables (Table 4.13). In the reflection models, stress significantly predicted longer SOL, β = .18, p = .01, and poorer sleep quality, β = .16, p = .02 (Table 4.14).

Worry predicted shorter SOL, β = -.19, p = .01 (Table 4.12). As in the model excluding demographics and neuroticism, this association with SOL is in the opposite direction to the correlation reported, indicating multicollinearity (Alin, 2010) and suggesting that these findings should be interpreted with caution. Neither brooding or reflection significantly predicted any health behaviour outcomes prospectively, nor did they increase the predictive utility of any of the models. Neither brooding, worry nor reflection significantly interacted with average stress to predict any health behaviour outcomes.

Table 4.12 Hierarchical Regressions of Prospective Associations between Demographics, Neuroticism, Worry and Average Stress on Health Behaviours

	SOL (T2)	TST (T2)	Sleep Quality (T2)	Physical Activity (T2)	Unhealthy Snacking (T2)	Fruit and Vegetables (T2)	Alcohol (T2)
Baseline DV	.46***	.51***	.52***	.54***	.68***	.57***	.41***
R^2	.27	.30	.31	.28	.49	.33	.18
F	100.08***	126.78***	128.53***	111.04***	267.40***	142.23***	66.06***
Age	-.09	-.09	-.08	.05	-.02	.00	-.07
Sex	-.00	.11*	-.01	-.00	-.03	.05	-.04
BMI	-.06	.00	-.04	.07	-.04	-.01	.02
Neuroticism	.12	-.04	-.01	-.08	.05	-.08	.15
R^2	.30	.32	.32	.28	.50	.33	.20
ΔR^2	.04	.02	.02	.01	.01	.00	.01
ΔF	3.49**	2.13	1.65	0.61	0.91	0.50	1.09
Worry	-.19*	.15	-.04	.12	.02	.06	-.06
R^2	.31	.33	.32	.29	.50	.33	.20
ΔR^2	.00	.00	.00	.01	.00	.00	.00
ΔF	1.70	1.15	0.08	3.60	0.36	0.83	0.82
Average Stress	.23**	-.15*	.17*	.00	.00	.02	-.07
R^2	.33	.34	.34	.29	.50	.33	.20
ΔR^2	.02	.01	.01	.00	.00	.00	.00
ΔF	8.85**	3.64	5.23*	0.00	0.00	0.05	0.85

Worry x Average Stress	-.05	.06	.01	-.04	-.05	.01	-.05
R^2	.33	.34	.34	.29	.50	.33	.20
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	0.91	1.42	0.01	0.61	1.24	0.06	0.96

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 278; TST: *n* = 291; Sleep Quality: *n* = 291; Physical Activity: *n* = 291; Unhealthy Snacks: *n* =280; Fruit and Vegetables: *n* = 294; Alcohol: *n* = 295.

Table 4.13 Hierarchical Regressions of Prospective Associations between Demographics, Neuroticism, Brooding and Average Stress on Health Behaviours

	SOL (T2)	TST (T2)	Sleep Quality (T2)	Physical Activity (T2)	Unhealthy Snacking (T2)	Fruit and Vegetables (T2)	Alcohol (T2)
Baseline DV	.44***	.51***	.51***	.53***	.68***	.64***	.41***
R^2	.24	.31	.31	.27	.49	.41	.18
F	86.96***	130.50***	129.29***	109.68***	276.46***	205.93***	66.83***
Age	-.07	-.09	-.07	.03	-.02	-.01	-.09
Sex	-.01	.09	.01	-.03	-.02	.05	-.05
BMI	.01	-.01	-.05	.06	-.04	.01	.02
Neuroticism	.01	-.00	-.02	-.08	.07	-.07	.15*
R^2	.26	.33	.32	.28	.50	.41	.19
ΔR^2	.02	.02	.02	.01	.01	.00	.01
ΔF	1.76	1.94	1.78	0.64	0.98	0.54	1.07
Brooding	.00	.01	.05	.07	-.00	.01	-.08
R^2	.26	.33	.33	.28	.50	.41	.20
ΔR^2	.00	.00	.01	.00	.00	.00	.01
ΔF	0.74	0.09	2.74	1.16	0.05	0.12	2.06
Average Stress	.15	-.09	.12	.02	.01	.04	-.06
R^2	.27	.33	.33	.28	.50	.41	.20
ΔR^2	.01	.00	.01	.00	.00	.00	.00
ΔF	3.49	1.26	2.16	0.06	0.01	0.26	0.53

Brooding x Average Stress	-.01	-.00	.03	-.02	-.04	-.01	.04
R^2	.27	.33	.33	.28	.50	.41	.20
ΔR^2	.00	.00	.00	.00	.00	.00	.00
ΔF	0.02	0.00	0.39	0.19	0.76	0.03	0.51

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 282; TST: *n* = 295; Sleep Quality: *n* = 295; Physical Activity: *n* = 295; Unhealthy Snacks: *n* =284; Fruit and Vegetables: *n* = 298; Alcohol: *n* = 299.

Table 4.14 Hierarchical Regressions of Prospective Associations between Demographics, Neuroticism, Reflection and Average Stress on Health Behaviours

	SOL (T2)	TST (T2)	Sleep Quality (T2)	Physical Activity (T2)	Unhealthy Snacking (T2)	Fruit and Vegetables (T2)	Alcohol (T2)
Baseline DV	.44***	.51***	.51***	.52***	.68***	.58***	.40***
R^2	.24	.30	.31	.27	.49	.34	.17
F	87.30***	128.26***	130.81***	107.28***	271.97***	155.11***	61.91***
Age	-.07	-.09	-.07	.03	-.03	-.00	-.08
Sex	-.02	.10*	-.02	-.03	-.04	.05	-.03
BMI	-.00	-.01	-.04	.05	-.05	.01	.01
Neuroticism	.03	.01	-.02	-.04	.06	-.07	.15*
R^2	.26	.32	.32	.27	.50	.35	.18
ΔR^2	.02	.02	.02	.01	.01	.00	.01
ΔF	1.78	1.97	1.75	0.63	1.03	0.46	1.02
Reflection	-.11	.00	-.04	-.07	-.01	-.01	-.02
R^2	.26	.32	.32	.28	.50	.35	.18
ΔR^2	.01	.00	.00	.00	.00	.00	.00
ΔF	2.87	0.07	0.09	1.30	0.10	0.00	0.27
Average Stress	.18*	-.09	.16*	.06	.01	.05	-.10
R^2	.28	.33	.34	.28	.50	.35	.19
ΔR^2	.02	.00	.01	.00	.00	.00	.00
ΔF	6.13*	1.53	5.29*	0.74	0.05	0.42	1.72

Reflection x Average Stress	-.08	-.00	-.04	-.03	-.02	.03	.04
R^2	.29	.33	.34	.28	.50	.35	.19
ΔR^2	.01	.00	.00	.00	.00	.00	.00
ΔF	2.27	0.00	0.61	0.38	0.23	0.41	0.67

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 283; TST: *n* = 296; Sleep Quality: *n* = 296; Physical Activity: *n* = 296; Unhealthy Snacks: *n* = 285; Fruit and Vegetables: *n* = 299; Alcohol: *n* = 300.

4.3.7 Cross-Sectional and Prospective Competition Models

4.3.7.1 Models without Demographics and Neuroticism

Table 4.15 shows that higher levels of brooding, $\beta = .26$, $p = .003$, but not worry or reflection, predicted more unhealthy snacking at Time 1. Brooding also still significantly interacted with stress to predict unhealthy snacking, $\beta = -.18$, $p = .02$. There were no other significant direct or moderator effects involving PC on any other health behaviour outcome, when the three types of PC were considered simultaneously. Step 1 of the model (containing all 3 PC variables) was significant in predicting SOL, sleep quality and unhealthy snacking. Stress predicted longer SOL, $\beta = .21$, $p = .02$, shorter TST, $\beta = -.24$, $p = .01$, and worse sleep quality, $\beta = .46$, $p < .001$.

Table 4.16 demonstrates that, at Time 2, worry predicted shorter SOL, $\beta = -.19$, $p = .02$. As the correlation between worry and Time 2 SOL was positive, it is possible that multicollinearity may have caused the direction to have reversed, so this association should be interpreted with caution. There were no other significant prospective associations between worry, brooding and reflection and health behaviour outcomes and there were no significant interactions with average stress. In the prospective competition models, average stress only predicted longer SOL, $\beta = .29$, $p < .001$.

Table 4.15 Hierarchical Regressions of Assessing the Unique Variance of Worry, Brooding and Reflection in Predicting Cross-Sectional Health Behaviours (without demographics and neuroticism)

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Worry	.10	.12	.02	-.02	.09	-.02	-.02
Brooding	-.01	-.01	-0.10	-.08	.26**	.06	-.04
Reflection	.00	-.04	-.04	.03	-.06	-.01	.10
R^2	.06	.02	.08	.02	.07	.01	.01
F	6.48***	0.02	9.13***	1.54	7.04***	0.76	0.82
Stress	.21*	-.24**	.46***	-.03	-.01	-.13	-.04
R^2	.08	.05	.17	.02	.07	.01	.01
ΔR^2	.02	.03	.09	.00	.00	.01	.00
ΔF	6.53*	8.79**	32.78***	0.14	0.01	1.72	0.24
Worry x Stress	.01	-.05	-.10	-.00	.09	.06	-.02
Brooding x Stress	.07	-.04	.12	-.07	-.18*	-.06	.03
Reflection x Stress	.05	-.01	.02	.07	-.02	.09	-.01
R^2	.09	.05	.18	.02	.09	.02	.01
ΔR^2	.01	.01	.01	.00	.02	.01	.00

ΔF	1.29	0.74	1.32	0.50	2.44	0.88	0.05

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 296; TST: *n* = 310; Sleep Quality: *n* = 311; Physical Activity: *n* = 313; Unhealthy Snacks: *n* = 303; Fruit and Vegetables: *n* = 313; Alcohol: *n* = 313.

Table 4.16 Hierarchical Regressions of Assessing the Unique Variance of Worry, Brooding and Reflection in Predicting Prospective Health Behaviours (without demographics and neuroticism)

	SOL T2	TST T2	Sleep Quality T2	Physical Activity T2	Unhealthy Snacking T2	Fruit and Vegetables T2	Alcohol T2
Baseline DV	.49***	.54***	.50***	.55***	.68***	.57***	.43***
R^2	.27	.32	.31	.30	.49	.33	.18
F	108.33***	139.26***	135.48***	126.39***	274.28***	147.72***	68.11***
Worry	-.19*	.14	-.06	.04	.05	.01	-.01
Brooding	.07	-.01	.05	.08	.03	-.03	.02
Reflection	-.11	.01	-.02	-.09	-.01	-.01	-.02
R^2	.29	.32	.32	.31	.49	.33	.18
ΔR^2	.02	.00	.01	.01	.00	.00	.00
ΔF	2.62	0.42	1.70	1.61	0.67	0.23	0.08
Average Stress	.29***	-.14	.15	-.02	-.01	.00	.01
R^2	.33	.33	.33	.31	.49	.33	.18
ΔR^2	.03	.01	.01	.00	.00	.00	.00
ΔF	13.29***	3.25	3.71	0.15	0.01	0.00	0.00
Worry x Average Stress	-.10	.07	-.03	-.05	-.02	.00	-.11

Brooding x Average Stress	.08	-.04	.06	.01	-.05	-.04	.05
Reflection x Average Stress	-.11	-.03	-.06	-.04	.02	.04	.04
R^2	.34	.33	.33	.31	.49	.33	.19
ΔR^2	.01	.00	.00	.00	.00	.00	.01
ΔF	2.03	0.47	0.45	0.56	0.49	0.17	0.90

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 288; TST: *n* = 303; Sleep Quality: *n* = 303; Physical Activity: *n* = 303; Unhealthy Snacks: *n* = 291; Fruit and Vegetables: *n* = 306; Alcohol: *n* = 307.

4.3.7.2 Models with Demographics and Neuroticism

Table 4.17 shows that higher levels of brooding, β = .23, *p* = .02, but not worry or reflection, predicted more unhealthy snacking at Time 1. There were no other significant direct or moderator effects involving PC on any other health behaviour outcome, when the three types of PC were considered simultaneously. Step 1 of the model (containing all 3 PC variables) was significant in predicting SOL, sleep quality and unhealthy snacking. Stress predicted shorter, TST β = -.21, *p* = .02, and worse sleep quality, β = .39, *p* < .001. Despite step 3 improving the predictive validity of the model, stress did not significantly predict SOL.

Table 4.18 demonstrates that, at Time 2, worry β = -.24, *p* = .003, and reflection β = -.14, *p* = .02, predicted shorter SOL prospectively, and this was the only outcome in which step 2 increased the predictive utility of the model. As the correlation between worry and Time 2 SOL was positive, it is possible that multicollinearity may have caused the direction to have reversed, so this association should be interpreted with caution. Worry was also found to predict longer TST prospectively, β = .16, *p* = .04. Average stress predicted longer SOL, β = .26, *p* = .002, and there was a significant interaction between average stress and reflection, β = -.13, *p* = .03. However, when decomposed, this interaction was non-significant, β = -1.68, *p* = .17, so was not explored further. This was confirmed by running a regression model which consisted solely of reflection, average stress and the interaction term, and this again was found to be non-significant. Average stress did not predict any other health behaviour outcomes prospectively within the competition model.

Earlier, it was proposed that the negative association between worry and shorter SOL, despite a positive correlation between the two, indicated remaining multicollinearity issues. As this relationship was reported again here and a misleading interaction emerged between average stress and reflection, there appears to be issues with the prospective SOL model which could be attributed to multicollinearity. This is supported by the fact that, despite standardisation, tolerance statistics were still low for some variables in the prospective model (see Table 4.2). Although this problem is only apparent for the SOL model, multicollinearity should be considered an issue across all prospective models.

Table 4.17 Hierarchical Regressions of Assessing the Unique Variance of Worry, Brooding and Reflection in Predicting Cross-Sectional Health Behaviours (with demographics and neuroticism)

	SOL	TST	Sleep Quality	Physical Activity	Unhealthy Snacking	Fruit and Vegetables	Alcohol
Worry	.06	.16	-.02	.00	.08	-.03	-.06
Brooding	-.02	-.01	-.11	-.09	.23*	.04	-.08
Reflection	-.01	-.03	-.04	.01	-.06	-.01	.11
R^2	.06	.02	.08	.02	.06	.01	.01
F	6.29***	2.10	8.54***	1.66	5.96**	0.94	0.80
Age	-.02	-.24***	.14*	-.11	-.09	.16**	-.15*
Sex	.02	.02	-.06	-.03	-.14*	.12*	.01
BMI	.02	-.01	.02	-.09	-.03	-.10	-.01
Neuroticism	.11	-.13	.16*	-.05	.07	.04	.08
R^2	.08	.11	.15	.04	.09	.04	.03
ΔR^2	.02	.09	.07	.03	.03	.03	.03
ΔF	1.17	6.86***	5.76***	2.11	2.35	2.53*	1.98
Stress	.18	-.20*	.39***	-.00	-.03	-.13	-.05
R^2	.09	.12	.21	.04	.09	.05	.04
ΔR^2	.01	.02	.06	.00	.00	.01	.00
ΔF	3.99*	5.57*	20.59***	0.00	0.21	1.58	0.27
Worry x Stress	.03	-.04	-.11	.02	.06	.09	-.04
Brooding x Stress	.06	-.01	.12	-.06	-.14	-.09	.06
Reflection x Stress	.05	-.00	.01	.06	-.03	.11	-.03

R^2	.10	.13	.22	.05	.11	.06	.04
ΔR^2	.01	.00	.01	.00	.02	.01	.00
ΔF	1.12	0.22	1.24	0.34	1.57	1.23	0.20

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 283; TST: *n* = 295; Sleep Quality: *n* = 296; Physical Activity: *n* = 298; Unhealthy Snacks: *n* = 288; Fruit and Vegetables: *n* = 298; Alcohol: *n* = 298.

Table 4.18 Hierarchical Regressions of Assessing the Unique Variance of Worry, Brooding and Reflection in Predicting Prospective Health Behaviours (with demographics and neuroticism)

	SOL T2	TST T2	Sleep Quality T2	Physical Activity T2	Unhealthy Snacking T2	Fruit and Vegetables T2	Alcohol T2
Baseline DV	.46***	.50***	.51***	.55***	.68***	.62***	.41***
R^2	.27	.30	.30	.28	.49	.39	.18
F	98.84***	125.56***	125.95***	113.01***	266.57***	187.02***	63.94***
Worry	-.24**	.16*	-.07	.08	.03	.05	-.06
Brooding	.08	-.03	.09	.09	.01	.00	-.03
Reflection	-.14*	.02	-.06	-.08	-.01	-.01	-.02
R^2	.29	.31	.32	.29	.50	.39	.18
ΔR^2	.02	.00	.31	.01	.00	.00	.00
ΔF	3.13*	0.64	2.24	1.48	0.79	0.14	0.04
Age	-.10	-.09	-.07	.05	-.01	-.01	-.08
Sex	-.02	.10*	-.00	-.02	-.02	.06	-.06
BMI	-.08	.01	-.06	.05	-.04	-.02	.02
Neuroticism	.13	-.04	-.01	-.09	.05	-.08	.15
R^2	.33	.33	.33	.30	.50	.40	.20
ΔR^2	.04	.02	.01	.01	.00	.01	.02
ΔF	3.60**	1.96	1.10	0.96	0.46	0.71	1.44
Average Stress	.26**	-.13	.15	.01	-.01	.02	-.05
R^2	.35	.33	.34	.30	.50	.40	.20
ΔR^2	.02	.01	.01	.00	.00	.00	.00
ΔF	9.23**	2.52	3.04	0.00	0.02	0.06	0.41

Worry x Average Stress	-.08	.10	-.02	-.04	-.02	.01	-.12
Brooding x Average Stress	.09	-.06	.06	-.00	-.03	-.02	.08
Reflection x Average Stress	-.13*	-.01	-.05	-.04	-.00	.04	.03
R^2	.36	.34	.34	.31	.50	.40	.21
ΔR^2	.02	.01	.00	.00	.00	.00	.01
ΔF	2.13	0.74	0.37	0.55	0.36	0.15	0.97

Note. All standardised regression coefficients are from the final step in the analyses, * significant at the .05 level, **significant at the .01 level, ***significant at the .001 level. SOL: *n* = 283; TST: *n* = 295; Sleep Quality: *n* = 296; Physical Activity: *n* = 298; Unhealthy Snacks: *n* =288; Fruit and Vegetables: *n* = 298; Alcohol: *n* = 298.

4.4 Discussion

The aim of this study was to investigate the cross-sectional and prospective relationships between stress, trait PC and health behaviours across a three-month period. In summary, there was support for associations between trait worry, brooding and reflection and some health-risk behaviours both cross-sectionally and prospectively. However, in the full theoretical model which included stress, neuroticism and relevant demographic covariates, only the cross-sectional association between brooding and unhealthy snacking remained significant. Therefore, support for hypotheses 1-4 can be considered very limited. There was also only very partial support for the hypothesis that PC would moderate the association between stress and health behaviours (hypotheses 3 and 4), as only brooding was found to moderate the association between stress and unhealthy snacking, and only cross-sectionally (H2b). There was also limited support for hypothesis 5 (a-b) as, when PC predictors were entered into models simultaneously, only the significant prediction of unhealthy snacking by brooding (and its significant moderation of the association between stress and unhealthy snacking) remained. As there was little difference between models including and excluding demographics and neuroticism, the latter will be discussed as this was the most rigorous test of the extended PCH.

Worry, brooding and reflection were predictive of longer SOL and poorer sleep quality cross-sectionally. Furthermore, these associations were also found prospectively for brooding. Only brooding predicted shorter TST, and only cross-sectionally. These findings are broadly consistent with the Chapter 3 review and meta-analysis of PC and sleep outcomes in which it was found that there were small- to medium-sized associations between worry and brooding and sleep quality, SOL and TST. Also, it is worth noting that, despite research indicating that reflection may be an adaptive form of repetitive thinking (Smith & Alloy, 2009; Treynor et al., 2003), this variable did not have a protective effect here but instead predicted poorer sleep quality. In the Chapter 3 review and meta-analysis, the association between reflection and sleep outcomes could not be meta-analysed as only one study investigated this, although findings were broadly in agreement. Querstret et al. (2017) found that after a mindfulness intervention, levels of affective rumination and problem-solving pondering (which is conceptually similar to reflection) were reduced and sleep quality increased. Nevertheless, this was the only health-risk behaviour significantly predicted by reflection which suggests that it may play a less significant role in health-risk behaviours than worry and brooding. However, none of these associations remained significant in the full model, suggesting that these associations may be better explained by demographic variables, neuroticism or stress. It should also be noted that there are issues with self-reported sleep measurements, as sleep duration tends to be overestimated compared to objectively measured sleep (Lauderdale et al., 2008) and some research has found that the PSQI is limited in its ability to predict actigraphy- and polysomnography-measured sleep (Backhaus et al., 2002; Buysse et al., 2008; Grandner, Kripke, Yoon, & Youngstedt, 2006). As well, the type of sleep assessment was found to moderate the association between PC and sleep in the Chapter 3 meta-analysis, with a stronger association being found in studies measuring sleep quality via self-report as opposed to actigraphy, as the effect size doubled for self-reported sleep, indicating a substantial negative reporting bias. Future studies should continue to include known predictors of sleep in analytical models assessing the relationships between PC and sleep outcomes and, where possible measuring sleep via polysomnography, which has not yet been used in studies testing the associations between PC and sleep to date.

Worry and brooding were associated with more unhealthy snacking both cross-sectionally and prospectively. However, the only association that remained in the full model was the significant prediction of unhealthy snacking by brooding and this remained significant when worry and reflection were added simultaneously, suggesting that brooding explains unique variance in unhealthy snacking. These findings are consistent with Cropley et al. (2012) who reported an association between affective rumination and unhealthy food choice. However, interaction effects revealed a slightly more complex relationship between brooding and unhealthy snacking. Brooding significantly moderated the association between stress and unhealthy snacking such that brooding predicted more snacking at low and medium levels of stress but at high levels of stress, there was no relationship between brooding and snacking. Furthermore, the association between brooding and unhealthy snacking was strongest at low levels of stress and weaker at medium levels. This indicates that brooding is most detrimental to eating behaviour when stress levels are low, which is contrary to the theory that these variables will have additive, negative effects on health behaviour.

However, if considered from the viewpoint that together, high brooding and high stress will have additive, detrimental effects on the physiological stress system, these findings may make more sense within the context of existing research. In this study, stress was significantly correlated with more unhealthy snacking cross-sectionally and this finding is consistent with an existing body of research evidence that stress increases eating and especially of unhealthy foods (Adam & Epel, 2007; Conner, Fitter, & Fletcher, 1999; Newman et al., 2007; O'Connor et al., 2008).

Nonetheless, in what they termed the stress-eating paradox, Stone and Brownell (1994) found that at high levels of stress, eating reduced dramatically which is consistent with the body's fight or flight response mechanism (see section 1.2, Chapter 1). It is possible that, even at low levels of stress, high brooders are still experiencing the physiological stress response, due to stress-related cognitions and, as such display the typical increase in unhealthy eating in response to stress. However, at high levels of stress, eating is reduced in all participants, regardless of brooding. At medium levels, a mixture between the two extremes is witnessed, with low brooders experiencing a moderate amount of stress and high brooders experiencing quite substantial amounts of stress due to the additive effects of stress and brooding. This is only supposition but may partially explain the moderating effect of stress and brooding on unhealthy snacking witnessed in this study.

Brooding was the only PC predictor significantly correlated with physical activity and this association was only significant cross-sectionally and was not significant in the full model. This reflects findings reported in Chapter 2 which suggested that brooding is a stronger predictor of health-risk behaviour than worry or reflection. Within the existing literature, one study has reported an association between health worry and reduced physical activity (Li et al., 2009) but others have found associations between health worry and more physical activity (Bernat et al., 2015; Ferrer, Portnoy, et al., 2013). Overall mixed support for an association between PC and physical activity may reflect the mixed association between stress and this health behaviour (Stults-Kolehmainen & Sinha, 2014), with research suggesting that physical activity has been shown to increase alongside stress, possibly due to its use as a coping mechanism (Cairney et al., 2014).

Neither PC nor stress predicted alcohol consumption. The absence of any association with alcohol consumption is surprising given the findings from the systematic review and meta-analysis (Chapter 2) in which an association between overall PC and greater alcohol consumption was evidenced. The only significant predictor of alcohol emerged as age (cross-sectionally) and neuroticism (prospectively), with younger and more neurotic individuals drinking more. This might indicate that PC is not a significant predictor of alcohol intake when these variables are accounted for. Equally, fruit and vegetable intake was only predicted by age, with older adults consuming more, and only cross-sectionally. This variable had to be truncated due to extreme outliers, perhaps indicating some difficulty in accurately estimating fruit and vegetable intake, which research has suggested may be prone to a substantial social approval bias (Miller, Abdel-Maksoud, Crane, Marcus, & Byers, 2008). However, it may also again reflect findings from the systematic review and meta-analysis (Chapter 2) that PC is not predictive of health-promoting behaviours. The limited evidence in this area is mixed as Cropley et al. (2012) found no association between rumination and healthy foods, including fruits and vegetables whereas Ferrer, Bergman, et al. (2013) found that health worry predicted higher fruit and vegetable intake.

There were limitations of this study which should be taken into consideration when interpreting the findings. It should first be noted that due to assessing relationships between various components of PC and numerous health behaviours, within varied statistical models, a substantial number of analyses were conducted, increasing the likelihood of committing a type I error. It is reassuring that some findings were consistent across a number of models, but even so, findings should be interpreted with a degree of caution. As well, the findings indicated that multicollinearity was an issue in the prospective models. This suggests that the coefficients in these models may be unreliable and limits the inferences that can be made from them. Even after standardising these variables, multicollinearity remained which highlights the difficulty in teasing apart stress-related thinking from the experience of stress. In this sense, at a prospective level, the hypotheses could not be reliably tested. Naturalistic studies employing multiple daily measurements and objective measures, such as that by Weise et al. (2013), may be better able to assess temporal associations between stress, stress-related cognitions and health behaviour outcomes.

On a related note, it is argued that global retrospective measurements such as those employed in this study are limited by recall bias and do not adequately capture how behaviour changes across time and situations on a day-to-day basis (Shiffman, Stone, & Hufford, 2008). It is suggested that future studies employ ecological momentary assessment methodology such as daily diaries in order to better understand the temporal associations between these variables and overcome issues associated with global retrospective reporting. Daily level measurement may be especially important within this context as it has been shown in the literature (Ottaviani et al., 2016; Verkuil et al., 2007) and within this thesis (Chapters 2 and 3) that state measurements of PC are differentially predictive of health and health behaviour outcomes than trait PC, so studies investigating the association between trait PC and health behaviours do not provide the full picture. The measurement time-scales in the current study did not enable measurement of state PC for comparison against trait measures as there are no existing validated and reliable measures which assess PC in the past week/month.

In conclusion, these findings support the association between PC and health-risk behaviours and poorer sleep found in the systematic reviews and meta-analyses presented in previous chapters and demonstrate an association between brooding, worry and, to a lesser extent reflection, and health-risk behaviours both cross-sectionally and prospectively. However, in a full model including demographic predictors, neuroticism and stress, only a cross-sectional association between brooding and unhealthy snacking remained significant and there was only one instance of PC moderating the association between stress and health behaviour, therefore providing limited supported for the full theoretical model. The moderating effect of brooding on the association between stress and unhealthy snacking was somewhat anomalous with the theoretical model outlined as these variables do not appear to have additive negative effects on the behaviour. Although an explanation for this is proposed, future research should explore this further, especially considering the limited amount of research in this area. It is also suggested that future research addresses the limitations of this study by investigating these associations using daily diary methodology and by employing state as well as trait measures of PC.

Chapter 5
Stress, Perseverative Cognition and Health Behaviour: A Daily Diary Study

5.1 Introduction

As outlined in Chapter 1, it is proposed that there may be an indirect pathway between PC and health outcomes via health behaviours, described as the extended PCH. This proposal is supported by the fact that PC has been shown to activate the same physiological pathways that account for the negative effects of stress on health (Ottaviani et al., 2016), and stress has both a direct relationship with health (Heraclides et al., 2009; Marniemi et al., 2002; Steptoe & Kivimäki, 2012) and an indirect relationship via health behaviours (Chida et al., 2008; Corbin et al., 2013; Kouvonen et al., 2005; O'Connor et al., 2008; Segerstrom & Miller, 2004; Stults-Kolehmainen & Sinha, 2014). It is suggested that components of PC, brooding, reflection and worry, will moderate the associations between stress on health-promoting and health-risk behaviours as evidence suggests that PC prolongs the stress response (Brosschot et al., 2006; Ottaviani et al., 2016; Verkuil et al., 2010), and this physiological stress response is theorised to account for the negative association between stress and health behaviours (see section 1.3)

Research presented in this thesis so far goes some way in supporting the extended PCH. The systematic review and meta-analysis of the association between PC and health behaviours (Chapter 2) suggested an association between PC and more health-risk behaviours (although not less health-promoting behaviours), and the association with health-risk behaviour appeared to be mostly explained by brooding. However, it was difficult to assess the association between PC and individual categories of health behaviours, due to the small number of studies in each. Also, there were very few studies measuring reflection and only one study measured general worry, rather than health worry specifically. Thus, a need was identified for studies to investigate the association between different types of PC (worry, brooding and reflection) and stress-sensitive health behaviours individually. It was also identified that few studies (8/17) had used validated measures of PC or assessed outcomes prospectively and it was suggested that future studies address these shortcomings. In Chapter 3, an association was also found between higher levels of general PC, brooding and worry and longer SOL, shorter TST and poorer sleep quality, indicating a consistent association with disturbed sleep. However, neither of these reviews allowed the full extended model outlined in Chapter 1 to be tested.

Thus, in Chapter 4, in addition to assessing the direct association between trait PC (worry, brooding and reflection) and multiple health behaviours, this association was tested when stress and other known covariates and predictors of health behaviours were included in an analytical model (e.g. age, sex, BMI and neuroticism), and the moderating effect of PC on associations between stress and health behaviours was tested. This study found support for associations between trait worry, brooding and reflection and some health-risk behaviours both cross-sectionally and prospectively. However, in the full theoretical models which included stress, neuroticism and relevant demographic covariates, only the cross-sectional association between brooding and unhealthy snacking remained significant. Also, contrary to the theory put forward in Chapter 1, brooding was the only significant moderator of a stress and health behaviour relationship. It was found that at low stress, brooding predicted more unhealthy snacking, but not at high stress. Therefore, there is only partial support for the extended PCH so far.

In the review of PC and sleep reported in Chapter 3, whether PC was measured at a trait or state level moderated the association between PC and longer SOL such that this relationship was stronger for trait compared to state PC (SOL: state r = -.13, trait r = -.20). However, measures of state PC were fewer and measures were less likely to be validated. Verkuil et al. (2007) found that trait worry only accounted for 24% of the variance in daily worry and Ottaviani et al. (2016) found that state and trait PC predicted differing physiological outcomes. This suggests that (1) state and trait PC may predict health behaviour outcomes differently and, (2) state and trait PC may contain elements unique to one another. It may seem counterintuitive for state and trait PC to predict different outcomes if they represent the same underlying construct, however, trait PC may characterise a personality trait in which an individual is predisposed to engage in PC under a variety of circumstances whereas even individuals low in trait PC may engage in PC under certain environmental conditions. Thus, at a state level, the content of the repetitive thoughts, their frequency or duration, or the distress associated with them may differ as a function of how customary these thought patterns are for that individual. This could explain differing physiological responses to state and trait PC. It is therefore suggested that, to more fully understand the relationship between PC and health behaviours within the context of the extended PCH, it is vital to test the association between both state and trait PC and health behaviours. As yet, only the association with trait PC has been empirically tested within this thesis.

In both reviews (see Chapters 2 and 3), a need was identified for more prospective and diary studies (see sections 2.4 and 3.4). In the full extended PCH tested in Chapter 4, PC did not predict health behaviours prospectively. However, daily diary studies allow researchers to capture prospective associations which are closer in time and to better capture everyday real-world behaviours and participant's recent states more accurately than measures using global retrospective recall methods (Shiffman et al., 2008). Shiffman et al. (2008) cite research which suggests that the error inherent in retrospective recall is systematically biased. For instance, when in a negative mood, participants are more likely to recall negative information (Kihlstrom, Eich, Sandbrand, & Tobias, 2000). Therefore, it is useful to avoid relying on memory when capturing behaviours and mood states and this limited reliance on memory is a strength of daily diary methodology. Also, when collecting daily diary data, it is possible to collect data at the level of the individual and at the level of the (sample) population, thus creating a hierarchical structure within the data and enabling multilevel modelling analyses. This type of analysis is valuable in addressing the ecological fallacy. That is, the error that can occur when inferences from population (ecological) level data are applied at the level of the individual (Piantadosi, Byar, & Green, 1988). Such methodology would allow the extended PCH to be tested more thoroughly, at both a state (daily) and trait level.

Additionally, the type of stress measured may play an important role within the theoretical model outlined in Chapter 1 (the extended PCH). DeLongis et al. (1982) emphasised the importance of the hassles and strains of daily life in measuring stress and how it contributes to health status. They termed these everyday stresses and strains daily hassles and argued that a life-events approach to measuring stress is insufficient alone. The Hassles Scale, a 117-item checklist of hassles, was found to be more predictive of psychological symptoms than life events (Kanner, Coyne, Schaefer, & Lazarus, 1981). However, despite the utility of this measure, an open-ended method of measuring daily hassles, as employed by numerous daily diary studies (Conner et al., 1999; O'Connor et al., 2008; Stone & Brownell, 1994) avoids constraining responses to a predetermined checklist of events which may be irrelevant to participants or miss events crucial to their daily life. The use of the validated Perceived Stress Scale (Cohen, 1988) was appropriate for use in Chapter 4 as this measure refers to a monthly time-period. However, it is an asset of employing daily diary methodology in the current study that it is possible to test how PC interacts with a state/daily measure of stress on health behaviours. If similar associations are found between trait brooding and stress on unhealthy snacking, for example, then it can be inferred that this is not limited to one measure of stress.

5.1.1 Aims and Hypotheses

The aim of this research was to assess the within- and between-person relationships between daily hassles, state and trait PC and health behaviours at a daily level, in order to test the extended PCH outlined in Chapter 1 (see Figure 1.2). The use of daily diary methodology enables hypotheses to be tested at the level of the individual (within-person, level 1) and at the level of the sample (between-person, level 2). It also enables investigation of how between-person variables interact with within-person daily variation to contribute to daily health behaviours (cross-level interactions).

As noted in Chapter 4, the construct of rumination overlaps considerably with neuroticism (Smith & Alloy, 2009). This was supported by findings reported in Chapter 4, in which neuroticism was shown to be highly correlated with brooding and worry. It was therefore deemed necessary to include this variable as a covariate in analyses of the direct associations between state (daily) and trait PC and health behaviours (hypotheses 1 and 3).

5.1.1.1 Hypothesis 1

Trait worry (H1a) and trait brooding (H1b) will be positively associated with health-risk behaviours (greater consumption of unhealthy snack foods and alcohol and more time spent sitting).

Trait worry (H1c) and trait brooding (H1d) will be negatively associated with health-promoting behaviours (lower consumption of fruit and vegetables, lower levels of physical activity and poorer sleep parameters).

Trait reflection will be associated with health-risk behaviours (H1e) and health-promoting behaviours (H1f).

5.1.1.2 Hypothesis 2

Positive associations between daily hassles and health-risk behaviours will be moderated by trait worry (H2a) and trait brooding (H2b) such that these associations will be stronger as levels of worry and brooding increase.

Negative associations between daily hassles and health-promoting behaviours will be moderated by trait worry (H2c) and trait brooding (H2d) such that these associations will be stronger as levels of worry and brooding increase.

Positive associations between daily hassles and health-risk behaviours will be moderated by trait reflection (H2e).

Negative associations between daily hassles and health-promoting behaviours will be moderated by trait reflection (H2f).

5.1.1.3 Hypothesis 3

Daily worry (H3a) and daily brooding (H3b) will be positively associated with health-risk behaviours.

Daily worry (H3c) and daily brooding (H3d) will be negatively associated with health-promoting behaviours.

5.2 Method

5.2.1 Participants

Participants were recruited via the University of Leeds Participant Pool, an email participant pool used by staff and students at the university, and via posters, social media advertisements and word of mouth. Participants were excluded from participating if they were not fluent in English or were under 18. Sample size was not calculated a-priori as there was a short window of time in which to recruit participants (as data collection formed part of an undergraduate dissertation project) and therefore, the decision was made to simply recruit as many participants as possible during a 2-month period. A total of 329 participants were recruited to the study and completed a total of 2063 evening diaries and 2117 morning diaries. Of these, 273 completed 4 or more eligible evening diaries and were therefore included in data analysis. A cut-off of 4 diaries was decided upon prior to analysis to allow sufficient daily comparisons for within-person analyses. This equated to 1645 evening diaries and 1095 diaries in which a morning diary could be matched to the previous evening's diary. First and second year undergraduate Psychology students recruited from the University of Leeds were granted credits for their participation and were entered into prize draws for shopping vouchers. All other participants were simply entered into the prize draws for shopping vouchers. Ethical approval was granted from the University of Leeds, School of Psychology ethics committee (reference: 16-0291, date of approval: 02.11.16).

The mean age of participants included in analysis (those that completed 4 or more diaries) was 20.2 years (*SD* = 4.11), with a range from 18-55. Mean BMI was 22.04 (*SD* = 4.04). Ninety-three percent of participants were female and 7% were male. Ninety-one percent were British and 9% reported another nationality. Ninety-one percent of participants reported White ethnicity. Most participants were university students (93%). Ninety percent of participants were educated to A Level grade; 71% had completed an undergraduate degree or foundation degree. A further 2% had completed postgraduate degrees.

5.2.2 Design

This was a daily diary study in which comparisons were made both within- and between-participants across 7 consecutive days (twice daily). Evening diaries captured daily stressors, PC and health behaviours and morning diaries captured variables relating to the previous night's sleep. As such, sleep outcomes were prospective and other outcomes were cross-sectional. Diaries were completed online using Online Surveys (https://www.onlinesurveys.ac.uk/).

5.2.3 Measures

5.2.3.1 Trait Measures

Neuroticism was measured using 10 items (α = .82) from the International Personality Item Pool website (see Chapter 4, section 4.2.3.1 and Appendix C for further details). Higher scores indicated higher levels of trait neuroticism. Trait worry was measured using the 16-item (α = .92) Penn State Worry Questionnaire (Meyer et al., 1990) and higher scores indicated higher levels of worry (see Chapter 4, section 4.2.3.2 and Appendix D for further details). Trait brooding was measured using 5 items (α = .78) from the brooding subscale of the Ruminative Responses Scale (RRS; Treynor et al., 2003) (see Chapter 4, section 4.2.3.2 and Appendix E for further details). Trait reflection was measured using the 5-item (α = .78) reflection subscale from the RRS (Treynor et al., 2003) (see Chapter 4, section 4.2.3.2 and Appendix F for further details). In both, higher scores relate to higher levels of these constructs.

5.2.3.2 Morning Diary

Participants were asked to report how long they slept in total (total sleep time, TST) and how long it took them to fall asleep (sleep onset latency, SOL). Sleep quality was assessed with one item whereby participants were asked to rate from 1 to 5 (‘not at all’ to ‘very’) how tired they felt that morning. Higher scores refer to longer SOL, more sleep time and lower levels of sleep quality. Single-item measures were used to reduce participant burden. These items are adapted for daily use from the Pittsburgh Sleep Quality Index (Buysse et al., 1989). See Appendix L for full details.

5.2.3.3 Evening Diary

As per O'Connor et al. (2008), participants were provided with a definition of a daily hassle and given an example. They were then asked to provide a description of each daily hassle experienced (a free type box was provided) and were then asked to rate the intensity of this hassle from 1 to 5 (‘not at all intense’ to ‘very intense’). Participants could list up to 6 daily hassles. See Appendix M for full details. Hassles per day were calculated by multiplying the total number of hassles by their average intensity.

Participants were asked to report how often they worried and ruminated. Descriptions and examples of worry and rumination were provided for participants. Daily worry and rumination questions were adapted from Zoccola, Dickerson, and Yim (2011). These were, ‘today, how often did you worry or focus on negative things that may occur or happen to you in the future?' (see appendix N) and 'today, how often did you ruminate or dwell over negative things that happened to you or upset you in the past (including today)?' (see appendix O). 'how often' was added to both items to measure the frequency of these thoughts and 'including today' was added to the rumination item to emphasise to participants that rumination over that day's events was relevant. Unlike Zoccola et al. (2009) yes/no response, here, a 5-point scale ('never' to 'very often') was used to again capture the frequency of these thoughts. Zoccola et al.'s (2009) measure did not distinguish between brooding and reflection but the wording demonstrates a closer affinity with brooding, as the focus is on dwelling and negativity rather than problem-solving or reinterpretation (Smith & Alloy, 2009). As such, this item is considered to represent daily brooding here. Also added was 'if you worried/ruminated today, how intense were these worries?' rated on a 5-point scale ('not at all' to 'very'). Worry and brooding per day were calculated by multiplying the total number of each by their average intensity, respectively.

Like O'Connor et al. (2008), participants reported the number of between-meal snacks they ate that day (see appendix P). These were coded as high, medium and low fat and sugar by pairs of researchers (dissertation students who assisted in data collection). Due to time constraints, pairs of researchers worked in pairs rather than double-coding independently. If discrepancies could not be resolved through discussion, the lead researcher was contacted to assist in the decision-making process. In line with NHS guidelines, high fat snacks were categorised as containing 17.5g of fat or more per 100g. High sugar snacks were categorised as containing 22.5g or more of sugar per 100g, as per NHS guidelines. A grocery website was used to obtain this information and, where a brand of food item was not specified, generic items were agreed upon across the group of coders. The total number of high fat and high sugar snacks consumed per day were calculated. Participants were also asked to indicate the portions of fruit and vegetables they had eaten that day to assess healthy food choice. The same website link was provided as in Chapter 4 so that participants could confirm what constitutes as a portion of fruit and vegetables (http://www.nhs.uk/Livewell/5ADAY/Pages/Portionsizes.aspx).

In regard to alcohol use, participants were asked to report how many pints of beer, cider or lager they had consumed that day, how many standard sized glasses of wine (175ml), how many shots of spirits of liqueur (25ml), and if they had consumed any other alcohol and if so, how much. This information was then converted into alcohol units using the Drinkaware alcohol unit calculator (https://www.drinkaware.co.uk/understand-your-drinking/unit-calculator) by the same pairs of researchers. Note that smoking behaviour was measured but there were very few smokers recruited and therefore this outcome could not be analysed whilst maintaining an adequate degree of statistical power.

Physical activity was measured using the International Physical Activity Questionnaire – Short Form (IPAQ-SF) (Craig et al., 2003), which was adapted for daily use by substituting the period of reference from the last 7 days to 'today' (see appendix Q). Participants were asked to report, in hours and minutes how long they had spent engaging in vigorous and moderate activity that day and how long they had spent walking. In accordance with standardised use of the IPAQ-SF, participants were asked to only include this information if they had spent more than 10 minutes engaging in these activities, and a description of vigorous and moderate activity was provided. Additionally, to assess sedentary behaviour, also from the IPAQ-SF, participants were asked to indicate for how long they had spent sitting that day (this was not limited to more than 10 minutes). As the standard scoring system for the IPAQ-SF is based upon weekly activity, these items were used as single-item measures with the minutes of activity (or sitting) as the outcomes. This also allowed for assessing whether different types of physical activity are associated with PC.

5.2.4 Procedure

Participants attended a session at the School of Psychology in which they provided informed consent and completed the background survey. The following day (or the following Monday if the initial session was on a Friday), participants were emailed a link to the morning diary (6am) to be completed upon awakening and an evening diary (7pm) to be completed before bed. These diary emails were sent for 7 consecutive days. After the final day, participants were debriefed via email.

5.2.5 Method of Analysis

Data was excluded from analysis if less than 4 days of diaries were completed, to provide sufficient data for within-person analyses, if morning diaries were completed after 12pm and if evening diaries were completed after 2am as backfilled diaries are potentially less accurate (Shiffman et al., 2008). Multilevel analyses were conducted using HLM7 software. Significant interactions were decomposed using Kristopher Preacher's online utility (http://www.quantpsy.org/interact/hlm2.htm).

5.2.5.1 Treatment of Missing Data

The percentage of missing data was analysed across the final dataset (participants completing 4 or more evening diaries). Missing value analysis was conducted on the full dataset before totals had been computed. Less than 1% of data was missing overall. An expectation maximisation chi-square test was used to assess whether data was missing completely at random (Little, 1988) across the level 2 file (trait variables and demographics) and both level 1 files (morning and evening diaries). These tests were found to be non-significant for the level 2 dataset, χ^2 (*df* = 554) = 580.39, *p* = .21, and evening data, χ^2 (*df* = 227) = 152.97, *p* = .99, confirming that data was missing completely at random. As levels of missing data were minimal and missingness was random, an expectation maximization method was used to impute missing data (Horton & Kleinman, 2007). As this method is only appropriate for continuous data, this left one data point missing at level 2 (on sex) which was subject to listwise deletion when running analyses. However, the morning data was not found to be missing completely at random χ^2 (*df* = 15) = 66.83, *p* < .001. Note that missing analysis was conducted on the morning diary data when complete missing days had been removed (that is, where a diary day was missed completely) so that the analysis was equivalent to the evening diary analysis, where only completed days were analysed. As the percentage of missing data was minimal and estimation maximization was not possible as the data was not missing at random, complete case analysis was used.

5.3 Results

5.3.1 Attrition Analyses

A Multivariate Analysis of Variance (MANOVA) was conducted on continuous variables to compare those who completed 4 or more daily diaries (completers) to those who completed less than 4 daily diaries (drop-outs). The MANOVA was statistically significant, F (6, 285) = 2.94, p = .01. Main effects of completion status were found on worry (completers: M = 56.30, SD = 11.65; drop-outs: M = 51.07, SD = 13.72) but not on age, BMI, neuroticism, brooding or reflection (p > .05). For categorical variables (sex, nationality, ethnicity, employment status and education), chi-square analyses were conducted, and significant differences were found on sex, χ^2 (df = 1) = 15.57, p < .001, and educational status, χ^2 (df = 4) = 10.75, p = .03, across dropouts and completers. Dropouts consisted of a higher percentage of male participants and were more highly educated, compared to completers. No significant differences were found across nationality, ethnicity or employment status (p > .05).

5.3.2 Descriptive Statistics

Descriptive statistics for the multilevel modelling dataset which excluded sleep outcomes are reported in Table 5.1 , descriptive statistics for the sleep dataset are included in Table 5.2. As can be seen, predictor means and standard deviations (daily hassles, daily worry, daily brooding, neuroticism, trait worry, trait brooding and trait reflection) vary little between these datasets. Note that these files were analysed separately due to the differential treatment of missing data for the morning and evening diary datasets (see 5.2.5.1).

Table 5.1 Descriptive Statistics for the Daily (Level 1) and Between-Person (Level 2) Measures (Without Sleep)

	Level 1					Level 2			
Predictor	Mean	SD	Minimum	Maximum	Predictor	Mean	SD	Minimum	Maximum
Daily Hassles	5.47	4.40	0.00	29.00	Neuroticism	28.29	6.56	11.00	47.00
Daily Worry Frequency	2.82	1.15	1.00	5.00	Trait Worry	55.83	11.80	26.00	80.00
Daily Brooding Frequency	2.37	1.19	1.00	5.00	Trait Brooding	10.23	3.19	5.00	19.00
Daily High Fat Snack Total	0.82	0.82	0.00	4.00	Trait Reflection	8.94	3.13	5.00	20.00
Daily High Sugar Snack Total	0.71	0.73	0.00	3.00					
Daily Fruit Portions	1.27	1.24	0.00	8.00					
Daily Vegetable Portions	2.00	1.40	0.00	8.00					
Daily Alcoholic Units	1.16	3.12	0.00	37.70					
Daily Minutes of Vigorous Activity[a]	11.73	30.45	0.00	184.00					

Daily Minutes of Moderate Activity[a]	11.73	38.69	0.00	235.00
Daily Minutes Walking[a]	71.95	80.82	0.00	341.00
Daily Minutes Sitting[b]	402.85	184.82	31.00	1320.00

Note. Level 1: n = 1638, Level 2: n = 272. [a]Due to extreme outliers at the upper end, vigorous physical activity, moderate physical activity and walking were truncated to 2 SDs above the mean, [b]due to extreme outliers at the lower end, sitting was truncated to 2 SDs below the mean.

Table 5.2 Descriptive Statistics for the Daily (Level 1) and Between-Person (Level 2) Measures (Sleep Only)

		Level 1					Level 2		
Predictor	Mean	SD	Minimum	Maximum	Predictor	Mean	SD	Minimum	Maximum
Daily Hassles	5.64	4.45	0.00	28.00	Neuroticism	28.25	6.51	11.00	47.00
Daily Worry Frequency	2.85	1.16	1.00	5.00	Trait Worry	55.56	11.81	26.00	80.00
Daily Brooding Frequency	2.36	1.19	1.00	5.00	Trait Brooding	10.28	3.25	5.00	19.00
Sleep Onset Latency[a] (minutes)	32.44	37.84	0.00	190.00	Trait Reflection	9.17	3.28	5.00	20.00
Total Sleep Time (minutes)	456.00	105.68	0.00	750.00					
Sleep Quality	3.08	1.13	1.00	5.00					

Note. Level 1: n = 1090, Level 2: n = 208. [a]Due to extreme outliers at the upper end, SOL was truncated to 2 SDs above the mean.

5.3.3 Daily Hassles, Trait PC and Health Behaviours

To test hypothesis 1, the cross-level associations between trait PC (worry, brooding and reflection) and level 1 health behaviours were analysed, whilst co-varying for neuroticism (Table 5.3). To test hypothesis 2, the cross-level interactions between level 1 daily hassles and level 2 trait PC (worry, brooding and reflection) on level 1 health behaviours were analysed (Table 5.4)

5.3.3.1 Hypothesis 1

Multilevel models testing hypothesis 1, that trait PC (worry and brooding) would be associated with more health-risk (greater consumption of unhealthy snack foods and alcohol and more time spent sitting) and less health-promoting behaviours (lower consumption of fruit and vegetables, lower levels of physical activity and poorer sleep parameters), are reported below in Table 5.3. It was predicted that reflection would predict health-risk and health-promoting behaviours, but the direction was not specified.

Table 5.3 Between-Person Effects of Trait Worry, Brooding and Reflection on Health Behaviours

	β	B	*SE*	t	*p*
Intercept: High Fat Snacks	β00	0.82	0.03	27.35	<.001
Level 2 Slope: Worry – High Fat Snacks	β01	0.01	0.00	1.71	.09
Level 2 Slope: Neuroticism – High Fat Snacks	β02	-0.01	0.01	-1.33	.19
Intercept: High Sugar Snacks	β00	0.70	0.03	27.82	<.001
Level 2 Slope: Worry – High Sugar Snacks	β01	-0.00	0.00	-0.22	.83
Level 2 Slope: Neuroticism – High Sugar Snacks	β02	-0.01	0.01	-1.06	.29
Intercept: Fruit	β00	1.26	0.05	22.97	<.001
Level 2 Slope: Worry – Fruit	β01	0.00	0.00	0.70	.49
Level 2 Slope: Neuroticism – Fruit	β02	-0.01	0.01	-0.79	.43
Intercept: Vegetables	β00	1.99	0.06	34.22	<.001
Level 2 Slope: Worry – Vegetables	β01	0.01	0.01	1.30	.19
Level 2 Slope: Neuroticism – Vegetables	β02	-0.01	0.01	-1.44	.15
Intercept: Vigorous Activity	β00	11.84	1.06	11.14	<.001
Level 2 Slope: Worry – Vigorous Activity	β01	-0.04	0.11	-0.33	.74
Level 2 Slope: Neuroticism – Vigorous Activity	β02	-0.33	0.19	-1.77	.08

Intercept: Moderate Activity	β00	11.92	1.20	9.95	<.001
Level 2 Slope: Worry – Moderate Activity	β01	-0.23	0.15	-1.52	.13
Level 2 Slope: Neuroticism – Moderate Activity	β02	0.25	0.25	0.98	.33
Intercept: Walking	β00	71.71	2.97	24.17	<.001
Level 2 Slope: Worry – Walking	β01	0.32	0.32	1.01	.31
Level 2 Slope: Neuroticism – Walking	β02	-1.42	0.55	-2.57	.01
Intercept: Sitting	β00	401.85	8.77	45.82	<.001
Level 2 Slope: Worry – Sitting	β01				
Level 2 Slope: Neuroticism – Sitting	β02	1.16	1.66	0.70	.48
Intercept: Alcohol	β00	1.18	0.10	12.16	<.001
Level 2 Slope: Worry – Alcohol	β01	0.00	0.01	0.28	.78
Level 2 Slope: Neuroticism – Alcohol	β02	-0.01	0.02	-0.26	.79
Intercept: SOL	β00	32.60	1.59	20.46	<.001
Level 2 Slope: Worry – SOL	β01	0.17	0.15	1.08	.28
Level 2 Slope: Neuroticism – SOL	β02	0.51	0.28	1.83	.07
Intercept: TST	β00	457.03	3.92	116.54	<.001

Level 2 Slope: Worry – TST	β01	0.21	0.45	0.47	.64
Level 2 Slope: Neuroticism – TST	β02	-0.56	0.68	-0.82	.42
Intercept: Sleep Quality	β00	3.09	0.05	63.64	<.001
Level 2 Slope: Worry – Sleep Quality	β01	0.00	0.00	0.52	.60
Level 2 Slope: Neuroticism – Sleep Quality	β02	0.01	0.01	0.99	.32
Intercept: High Fat Snacks	β00	0.82	0.03	27.23	<.001
Level 2 Slope: Brooding – High Fat Snacks	β01	0.01	0.01	0.68	.50
Level 2 Slope: Neuroticism – High Fat Snacks	β02	-0.00	0.01	-0.79	.43
Intercept: High Sugar Snacks	β00	0.70	0.03	27.94	<.001
Level 2 Slope: Brooding – High Sugar Snacks	β01	0.01	0.01	1.58	.12
Level 2 Slope: Neuroticism – High Sugar Snacks	β02	-0.01	0.00	-2.14	.03
Intercept: Fruit	β00	1.26	0.05	22.96	<.001
Level 2 Slope: Brooding – Fruit	β01	0.00	0.02	0.06	.95
Level 2 Slope: Neuroticism – Fruit	β02	-0.00	0.01	-0.50	.62
Intercept: Vegetables	β00	1.99	0.06	34.14	<.001
Level 2 Slope: Brooding – Vegetables	β01	-0.01	0.02	-0.49	.62

Level 2 Slope: Neuroticism – Vegetables	β02	-0.00	0.01	-0.52	.60
Intercept: Vigorous Activity	β00	11.85	1.06	11.17	<.001
Level 2 Slope: Brooding – Vigorous Activity	β01	0.47	0.31	1.50	.14
Level 2 Slope: Neuroticism – Vigorous Activity	β02	-0.47	0.17	-2.80	.01
Intercept: Moderate Activity	β00	11.93	1.20	9.95	<.001
Level 2 Slope: Brooding – Moderate Activity	β01	0.96	0.49	1.96	.05
Level 2 Slope: Neuroticism – Moderate Activity	β02	-0.19	0.26	-0.75	.46
Intercept: Walking	β00	71.72	2.95	24.27	<.001
Level 2 Slope: Brooding – Walking	β01	1.92	1.04	1.85	.07
Level 2 Slope: Neuroticism – Walking	β02	-1.53	0.55	-2.80	.01
Intercept: Sitting	β00	401.86	8.78	45.78	<.001
Level 2 Slope: Brooding – Sitting	β01	0.52	2.63	0.20	.84
Level 2 Slope: Neuroticism – Sitting	β02	0.40	1.50	0.27	.79
Intercept: Alcohol	β00	1.17	0.10	12.19	<.001
Level 2 Slope: Brooding – Alcohol	β01	-0.03	0.03	-0.83	.41
Level 2 Slope: Neuroticism – Alcohol	β02	0.00	0.02	0.23	.82

Intercept: SOL	β00	32.59	1.59	20.46	<.001
Level 2 Slope: Brooding – SOL	β01	0.70	0.51	1.37	.17
Level 2 Slope: Neuroticism – SOL	β02	0.50	0.24	2.08	.04
Intercept: TST	β00	456.99	3.90	117.24	<.001
Level 2 Slope: Brooding – TST	β01	-2.88	1.21	-2.38	.02
Level 2 Slope: Neuroticism – TST	β02	0.34	0.60	0.57	.57
Intercept: Sleep Quality	β00	3.09	0.05	64.55	<.001
Level 2 Slope: Brooding – Sleep Quality	β01	0.04	0.02	2.54	.01
Level 2 Slope: Neuroticism – Sleep Quality	β02	0.00	0.01	0.09	.93
Intercept: High Fat Snacks	β00	0.82	0.03	27.24	<.001
Level 2 Slope: Reflection – High Fat Snacks	β01	-0.01	0.01	-0.79	.43
Level 2 Slope: Neuroticism – High Fat Snacks	β02	-0.00	0.01	-0.28	.78
Intercept: High Sugar Snacks	β00	0.70	0.03	27.80	<.001
Level 2 Slope: Reflection – High Sugar Snacks	β01	-0.00	0.01	-0.10	.92
Level 2 Slope: Neuroticism – High Sugar Snacks	β02	-0.00	0.00	-1.40	.16
Intercept: Fruit	β00	1.26	0.05	23.01	<.001

Level 2 Slope: Reflection – Fruit	β01	0.02	0.02	0.99	.32
Level 2 Slope: Neuroticism – Fruit	β02	-0.01	0.01	-0.74	.46
Intercept: Vegetables	β00	1.99	0.06	34.14	<.001
Level 2 Slope: Reflection – Vegetables	β01	0.01	0.02	0.66	.51
Level 2 Slope: Neuroticism – Vegetables	β02	-0.01	0.01	-1.00	.32
Intercept: Vigorous Activity	β00	11.83	1.06	11.18	<.001
Level 2 Slope: Reflection – Vigorous Activity	β01	0.48	0.34	1.40	.16
Level 2 Slope: Neuroticism – Vigorous Activity	β02	-0.44	0.16	-2.69	.01
Intercept: Moderate Activity	β00	11.89	1.19	10.01	<.001
Level 2 Slope: Reflection – Moderate Activity	β01	0.98	0.42	2.33	.02
Level 2 Slope: Neuroticism – Moderate Activity	β02	-0.12	0.23	-0.50	.61
Intercept: Walking	β00	71.71	2.97	24.13	<.001
Level 2 Slope: Reflection – Walking	β01	-0.42	1.05	-0.40	.69
Level 2 Slope: Neuroticism – Walking	β02	-1.04	0.52	-1.99	.05
Intercept: Sitting	β00	401.84	8.77	45.82	<.001
Level 2 Slope: Reflection – Sitting	β01	1.87	3.25	0.58	.57
Level 2 Slope: Neuroticism – Sitting	β02	0.25	1.50	0.17	.87

Intercept: Alcohol	β00	1.18	0.10	12.16	<.001
Level 2 Slope: Reflection – Alcohol	β01	-0.00	0.03	-0.13	.90
Level 2 Slope: Neuroticism – Alcohol	β02	-0.00	0.01	-0.14	.89
Intercept: SOL	β00	32.59	1.60	20.39	<.001
Level 2 Slope: Reflection – SOL	β01	-0.26	0.43	-0.61	.54
Level 2 Slope: Neuroticism – SOL	β02	0.71	0.24	2.96	.003
Intercept: TST	β00	457.03	3.94	116.13	<.001
Level 2 Slope: Reflection – TST	β01	-0.89	1.18	-0.75	.45
Level 2 Slope: Neuroticism – TST	β02	-0.21	0.52	-0.40	.69
Intercept: Sleep Quality	β00	3.09	0.05	63.73	<.001
Level 2 Slope: Reflection – Sleep Quality	β01	0.01	0.02	0.64	.52
Level 2 Slope: Neuroticism – Sleep Quality	β02	0.01	0.01	1.07	.29

As is demonstrated in Table 5.3, trait worry did not predict any health behaviour outcomes when co-varying for neuroticism. Trait brooding significantly predicted shorter TST (β_{01} = -2.88, p = .02) and poorer sleep quality (β_{01} = 0.04, p = .01). Trait reflection predicted more daily moderate activity (β_{01} = 0.98, p = .02).

5.3.3.2 Hypothesis 2

Multilevel models testing hypothesis 2, that associations between daily hassles and more health-risk and less health-promoting behaviours would be moderated by trait PC (worry, brooding and reflection) such that these associations would be stronger when levels of trait worry andbrooding were higher (and that reflection would moderate this association but no direction was specified), are reported below in Table 5.4.

Table 5.4 Trait Perseverative Cognition as a Moderator of the Within-Person Effects of Daily Hassles on Health Behaviours

	B	B	*SE*	t	*p*
Intercept: High Fat Snacks	β00	0.82	0.03	27.25	<.001
Level 1 Slope: Daily Hassles – High Fat Snacks	β10	0.02	0.01	2.53	.01
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – High Fat Snacks	β01	0.01	0.00	1.20	.23
Worry x Daily Hassles – High Fat Snacks	β11	0.00	0.00	1.04	.30
Intercept: High Sugar Snacks	β00	0.70	0.03	27.74	<.001
Level 1 Slope: Daily Hassles – High Sugar Snacks	β10	0.01	0.01	1.34	.17
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – High Sugar Snacks	β01	-0.00	0.00	-1.06	.29
Worry x Daily Hassles – High Sugar Snacks	β11	-0.00	0.00	-1.67	.10
Intercept: Fruit	β00	1.26	0.06	22.86	<.001
Level 1 Slope: Daily Hassles – Fruit	β10	0.00	0.01	0.37	.72
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Fruit	β01	0.00	0.01	0.25	.80
Worry x Daily Hassles – Fruit	β11	0.00	0.00	1.13	.26
Intercept: Vegetables	β00	1.98	0.06	34.11	<.001
Level 1 Slope: Daily Hassles – Vegetables	β10	-0.01	0.01	-0.85	.40

Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Vegetables	β01	0.00	0.01	0.64	.52
Worry x Daily Hassles – Vegetables	β11	0.00	0.00	0.51	.61
Intercept: Vigorous Activity	β00	11.84	1.07	11.09	<.001
Level 1 Slope: Daily Hassles – Vigorous Activity	β10	-0.12	0.17	-0.67	.50
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Vigorous Activity	β01	-0.14	0.09	-1.51	.13
Worry x Daily Hassles – Vigorous Activity	β11	0.03	0.02	1.73	.09
Intercept: Moderate Activity	β00	11.93	1.20	9.92	<.001
Level 1 Slope: Daily Hassles – Moderate Activity	β10	0.17	0.26	0.66	.51
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Moderate Activity	β01	-0.16	0.13	-1.19	.23
Worry x Daily Hassles – Moderate Activity	β11	0.03	0.03	1.07	.29
Intercept: Walking	β00	71.67	3.00	23.88	<.001
Level 1 Slope: Daily Hassles – Walking	β10	0.42	0.60	0.70	.48
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Walking	β01	-0.11	0.30	-0.36	.72
Worry x Daily Hassles – Walking	β11	-0.01	0.05	-0.19	.85

Intercept: Sitting	β00	401.87	8.78	45.78	<.001
Level 1 Slope: Daily Hassles – Sitting	β10	1.05	1.08	0.97	.33
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Sitting	β01	-0.31	0.77	-0.41	.68
Worry x Daily Hassles – Sitting	β11	0.11	0.08	1.43	.15
Intercept: Alcohol	β00	1.18	0.10	12.16	<.001
Level 1 Slope: Daily Hassles – Alcohol	β10	-0.07	0.03	-2.53	.01
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Alcohol	β01	0.00	0.01	0.21	.83
Worry x Daily Hassles – Alcohol	β11	0.00	0.00	0.15	.88
Intercept: SOL	β00	32.63	1.61	20.29	<.001
Level 1 Slope: Daily Hassles – SOL	β10	0.29	0.33	0.88	.38
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – SOL	β01	0.32	0.13	2.35	.02
Worry x Daily Hassles – SOL	β11	-0.02	0.02	-0.99	.32
Intercept: TST	β00	456.98	3.93	116.33	<.001
Level 1 Slope: Daily Hassles – TST	β10	-0.52	1.02	-0.51	.61
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – TST	β01	0.04	0.34	0.12	.90

Worry x Daily Hassles – TST	β11	-0.06	0.08	-0.70	.49
Intercept: Sleep Quality	β00	3.09	0.05	63.59	<.001
Level 1 Slope: Daily Hassles – Sleep Quality	β10	-0.01	0.01	-1.04	.30
Cross-Level Interaction with Worry					
Level 2 Slope: Worry – Sleep Quality	β01	0.01	0.00	1.16	.25
Worry x Daily Hassles – Sleep Quality	β11	-0.00	0.00	-1.19	.23
Intercept: High Fat Snacks	β00	0.82	0.03	27.19	<.001
Level 1 Slope: Daily Hassles – High Fat Snacks	β10	0.02	0.01	2.63	.01
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – High Fat Snacks	β01	0.00	0.01	0.39	.70
Brooding x Daily Hassles – High Fat Snacks	β11	-0.00	0.00	-0.71	.48
Intercept: High Sugar Snacks	β00	0.70	0.03	27.70	<.001
Level 1 Slope: Daily Hassles – High Sugar Snacks	β10	0.01	0.01	1.60	.11
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – High Sugar Snacks	β01	0.01	0.01	0.64	.53
Brooding x Daily Hassles – High Sugar Snacks	β11	-0.00	0.00	-2.21	.03
Intercept: Fruit	β00	1.26	0.05	22.94	<.001
Level 1 Slope: Daily Hassles – Fruit	β10	0.00	0.01	0.46	.65

Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Fruit	β01	-0.00	0.02	-0.17	.86
Brooding x Daily Hassles – Fruit	β11	-0.00	0.00	-0.35	.72
Intercept: Vegetables	β00	1.98	0.06	34.12	<.001
Level 1 Slope: Daily Hassles – Vegetables	β10	-0.01	0.01	-0.88	.38
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Vegetables	β01	-0.01	0.02	-0.76	.45
Brooding x Daily Hassles – Vegetables	β11	0.00	0.00	0.66	.51
Intercept: Vigorous Activity	β00	11.84	1.07	11.05	<.001
Level 1 Slope: Daily Hassles – Vigorous Activity	β10	-0.19	0.17	-1.15	.25
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Vigorous Activity	β01	0.03	0.29	0.09	.93
Brooding x Daily Hassles – Vigorous Activity	β11	0.19	0.06	2.97	.003
Intercept: Moderate Activity	β00	11.94	1.20	9.95	<.001
Level 1 Slope: Daily Hassles – Moderate Activity	β10	0.16	0.26	0.64	.52
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Moderate Activity	β01	0.78	0.40	1.95	.05
Brooding x Daily Hassles – Moderate Activity	β11	0.06	0.08	0.76	.45

Intercept: Walking	β00	71.68	3.00	23.88	<.001
Level 1 Slope: Daily Hassles – Walking	β10	0.50	0.61	0.82	.41
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Walking	β01	0.50	0.97	0.52	.60
Brooding x Daily Hassles – Walking	β11	-0.24	0.19	-1.26	.21
Intercept: Sitting	β00	401.87	8.78	45.77	<.001
Level 1 Slope: Daily Hassles – Sitting	β10	0.92	1.09	0.85	.40
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Sitting	β01	0.90	2.50	0.36	.72
Brooding x Daily Hassles – Sitting	β11	0.47	0.32	1.45	.15
Intercept: Alcohol	β00	1.18	0.10	12.18	<.001
Level 1 Slope: Daily Hassles – Alcohol	β10	-0.07	0.03	-2.65	.01
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Alcohol	β01	-0.02	0.03	-0.74	.46
Brooding x Daily Hassles – Alcohol	β11	0.01	0.01	1.86	.06
Intercept: SOL	β00	32.61	1.61	20.29	<.001
Level 1 Slope: Daily Hassles – SOL	β10	0.35	0.33	1.06	.29
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – SOL	β01	1.18	0.51	2.33	.02

Brooding x Daily Hassles – SOL	β11	-0.17	0.10	-1.72	.09
Intercept: TST	β00	457.00	3.90	117.31	<.001
Level 1 Slope: Daily Hassles – TST	β10	-0.65	1.01	-0.64	.52
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – TST	β01	-2.58	0.99	-2.62	.01
Brooding x Daily Hassles – TST	β11	0.39	0.32	1.22	.22
Intercept: Sleep Quality	β00	3.09	0.05	64.60	<.001
Level 1 Slope: Daily Hassles – Sleep Quality	β10	-0.01	0.01	-0.86	.39
Cross-Level Interaction with Brooding					
Level 2 Slope: Brooding – Sleep Quality	β01	0.04	0.01	2.82	.01
Brooding x Daily Hassles – Sleep Quality	β11	-0.01	0.00	-1.89	.06
Intercept: High Fat Snacks	β00	0.82	0.03	27.23	<.001
Level 1 Slope: Daily Hassles – High Fat Snacks	β10	0.02	0.01	2.60	.01
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – High Fat Snacks	β01	-0.01	0.01	-0.94	.35
Reflection x Daily Hassles – High Fat Snacks	β11	-0.00	0.00	-0.80	.42
Intercept: High Sugar Snacks	β00	0.70	0.03	27.68	<.001
Level 1 Slope: Daily Hassles – High Sugar Snacks	β10	0.01	0.01	1.35	.18

Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – High Sugar Snacks	β01	-0.00	0.01	-0.57	.57
Reflection x Daily Hassles – High Sugar Snacks	β11	-0.00	0.00	-0.43	.67
Intercept: Fruit	β00	1.26	0.05	22.98	<.001
Level 1 Slope: Daily Hassles – Fruit	β10	0.00	0.01	0.36	.72
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Fruit	β01	0.02	0.02	0.89	.37
Reflection x Daily Hassles – Fruit	β11	0.00	0.00	0.16	.87
Intercept: Vegetables	β00	1.98	0.06	34.09	<.001
Level 1 Slope: Daily Hassles – Vegetables	β10	-0.01	0.01	-0.81	.42
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Vegetables	β01	0.01	0.02	0.38	.71
Reflection x Daily Hassles – Vegetables	β11	-0.00	0.00	-0.13	.90
Intercept: Vigorous Activity	β00	11.83	1.07	11.05	<.001
Level 1 Slope: Daily Hassles – Vigorous Activity	β10	-0.15	0.18	-0.86	.39
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Vigorous Activity	β01	0.21	0.34	0.63	.53
Reflection x Daily Hassles – Vigorous Activity	β11	0.08	0.06	1.32	.19

Intercept: Moderate Activity	β00	11.90	1.19	10.00	<.001
Level 1 Slope: Daily Hassles – Moderate Activity	β10	0.18	0.26	0.69	.49
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Moderate Activity	β01	0.92	0.39	2.36	.02
Reflection x Daily Hassles – Moderate Activity	β11	0.02	0.08	0.24	.81
Intercept: Walking	β00	71.70	3.00	23.93	<.001
Level 1 Slope: Daily Hassles – Walking	β10	0.59	0.62	0.96	.34
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Walking	β01	-1.06	1.01	-1.05	.30
Reflection x Daily Hassles – Walking	β11	-0.27	0.19	-1.45	.15
Intercept: Sitting	β00	401.85	8.77	45.82	<.001
Level 1 Slope: Daily Hassles – Sitting	β10	1.11	1.10	1.01	.32
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Sitting	β01	2.03	3.07	0.66	.51
Reflection x Daily Hassles – Sitting	β11	-0.03	0.34	-0.08	.94
Intercept: Alcohol	β00	1.18	0.10	12.15	<.001
Level 1 Slope: Daily Hassles – Alcohol	β10	-0.07	0.03	-2.86	.01
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Alcohol	β01	-0.01	0.03	-0.22	.83

Reflection x Daily Hassles – Alcohol	β11	0.01	0.01	0.98	.33
Intercept: SOL	β00	32.62	1.63	20.03	<.001
Level 1 Slope: Daily Hassles – SOL	β10	0.42	0.32	1.31	.19
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – SOL	β01	0.17	0.47	0.37	.71
Reflection x Daily Hassles – SOL	β11	-0.28	0.10	-2.72	.01
Intercept: TST	β00	457.01	3.93	116.20	<.001
Level 1 Slope: Daily Hassles – TST	β10	-0.50	1.05	-0.48	.63
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – TST	β01	-1.02	1.14	-0.90	.37
Reflection x Daily Hassles – TST	β11	-0.01	0.27	-0.05	.96
Intercept: Sleep Quality	β00	3.09	0.05	63.57	<.001
Level 1 Slope: Daily Hassles – Sleep Quality	β10	-0.01	0.01	-0.56	.58
Cross-Level Interaction with Reflection					
Level 2 Slope: Reflection – Sleep Quality	β01	0.02	0.02	1.03	.31
Reflection x Daily Hassles – Sleep Quality	β11	-0.01	0.00	-3.30	.001

As can be seen in Table 5.4, trait worry did not significantly interact with daily hassles to predict any health behaviour outcomes. On the other hand, trait brooding significantly moderated the association between daily hassles and high sugar snacking (β_{11} = -0.00, *p* = .01) such that the association between daily hassles and less high sugar snacking became stronger as levels of trait brooding increased (see Figure 5.1). Simple slopes showed that at low levels of brooding (the mean - 1 SD), daily hassles were negatively associated with high sugar snacking, but this association was non-significant, β = -0.02, *p* = .14. At medium levels of brooding (the mean), daily hassles were negatively associated with more high sugar snacking and this association was slightly stronger than at low levels of brooding and there was a trend towards statistical significance, β = -0.03, *p* = .08. At high levels of brooding (the mean + 1 SD), there remained a negative association between daily hassles and high sugar snacking and this association was stronger than at medium levels of brooding and was also slightly more significant, although still not statistically significant, β = -0.05, *p* = .06.

In the same way, brooding moderated the association between daily hassles and vigorous activity (β_{11} = 0.15, *p* = .03). More numerous and intense daily hassles predicted more vigorous activity and this association was stronger as levels of trait brooding increased (see Figure 5.1). Simple slopes for brooding demonstrated that, at low levels of brooding, daily hassles significantly predicted more vigorous activity β = 1.16, *p* = .01. At medium levels of brooding, β = 1.77, *p* = .01, there was a slightly stronger association between daily hassles and more vigorous activity and, at high levels of brooding, this association was even stronger, β = 2.38, *p* = .01.

Trait reflection significantly moderated the association between daily hassles and SOL (β_{11} = -0.28, *p* = .01) such that SOL was shorter when daily hassles were high, and this association was stronger when levels of trait reflection were higher (see Figure 5.1). At low levels of reflection, daily hassles marginally predicted shorter SOL, β = -1.20, *p* = .05. At medium levels of reflection, the association between daily hassles and shorter SOL was stronger and more significant, β = -2.10, *p* = .02. At high levels of reflection, this association was stronger and more significant than at medium levels of reflection, β = -3.00, *p* = .01.

As well, trait reflection significantly moderated the association between daily hassles and sleep quality (β_{11} = -0.01, *p* = .02) such that higher daily hassles predicted better sleep quality and this association became stronger as levels of trait reflection increased (see Figure 5.1). At low levels of reflection, daily hassles significantly predicted better sleep quality, β = -0.05, *p* = .003. At medium levels of reflection, daily hassles more strongly and significantly predicted better sleep quality, β = -.08, *p* = .001. Finally, at high levels of reflection, daily hassles even more strongly predicted better sleep quality, β = -0.11, *p* = .001.

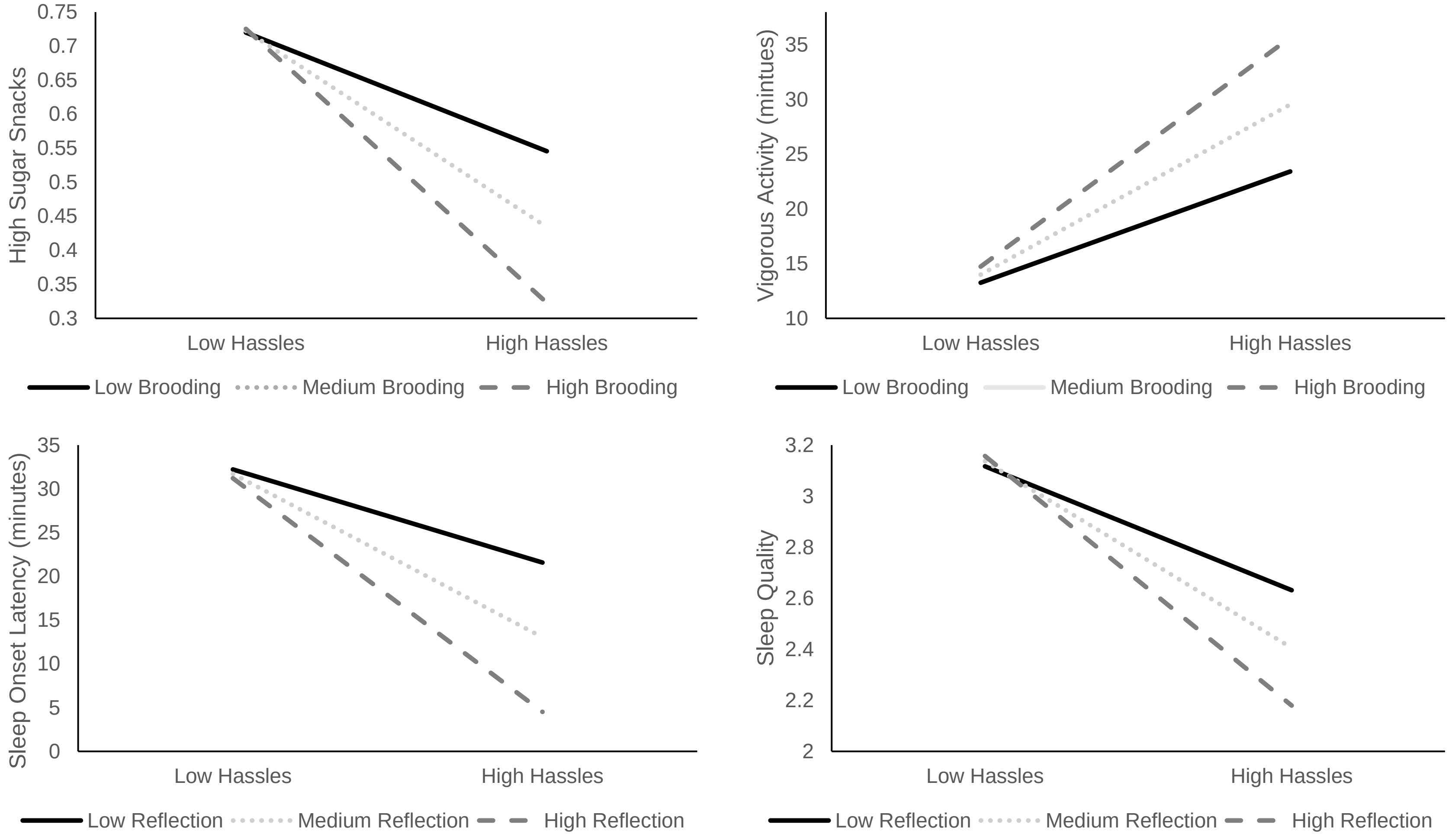

Figure 5.1 Simple Slopes of the Moderating Effects of Trait Perseverative Cognition on the Associations between Daily Hassles and Health Behaviour Outcomes

5.3.4 Daily PC and Health Behaviours

To test hypothesis 3, the level 1 associations between daily PC (worry and brooding) and level 1 health behaviours were analysed, whilst co-varying for neuroticism at level 2 (Table 5.5).

5.3.4.1 Hypothesis 3

Multilevel models testing hypothesis 3, that daily PC (worry and brooding) would be associated with more health-risk (greater consumption of unhealthy snack foods and alcohol and more time spent sitting) and less health-promoting behaviours (lower consumption of fruit and vegetables, lower levels of physical activity and poorer sleep parameters) are reported below in Table 5.5.

Table 5.5 Within-Person Effects of Daily Worry and Daily Brooding on Health Behaviours

	β	B	*SE*	t	*p*
Intercept: High Fat Snacks	β00	0.82	0.03	27.21	<.001
Level 1 Slope: Daily Worry – High Fat Snacks	β10	0.02	0.02	1.10	.27
Level 2 Slope: Neuroticism – High Fat Snacks	β01	-0.00	0.00	-0.54	.59
Intercept: High Sugar Snacks	β00	0.70	0.03	27.80	<.001
Level 1 Slope: Daily Worry – High Sugar Snacks	β10	0.02	0.02	1.14	.25
Level 2 Slope: Neuroticism – High Sugar Snacks	β01	-0.01	0.00	-1.47	.14
Intercept: Fruit	β00	1.26	0.05	22.95	<.001
Level 1 Slope: Daily Worry – Fruit	β10	-0.01	0.02	-0.48	.63
Level 2 Slope: Neuroticism – Fruit	β01	-0.00	0.01	-0.54	.59
Intercept: Vegetables	β00	1.99	0.06	34.10	<.001
Level 1 Slope: Daily Worry – Vegetables	β10	-0.02	0.03	-0.68	.50

Level 2 Slope: Neuroticism – Vegetables	β01	-0.01	0.01	-0.74	.46
Intercept: Vigorous Activity	β00	11.86	1.07	11.11	<.001
Level 1 Slope: Daily Worry – Vigorous Activity	β10	-2.18	0.76	-2.85	.01
Level 2 Slope: Neuroticism – Vigorous Activity	β01	-0.33	0.15	-2.23	.03
Intercept: Moderate Activity	β00	11.93	1.21	9.88	<.001
Level 1 Slope: Daily Worry – Moderate Activity	β10	-0.38	0.96	-0.40	.69
Level 2 Slope: Neuroticism – Moderate Activity	β01	0.01	0.22	0.04	.97
Intercept: Walking	β00	71.70	2.98	24.08	<.001
Level 1 Slope: Daily Worry – Walking	β10	-2.91	2.02	-1.44	.15
Level 2 Slope: Neuroticism – Walking	β01	-1.29	0.47	-2.71	.01
Intercept: Sitting	β00	401.85	8.78	45.77	<.001
Level 1 Slope: Daily Worry – Sitting	β10	13.21	3.93	3.36	<.001
Level 2 Slope: Neuroticism – Sitting	β01	0.63	1.40	0.45	.65

Intercept: Alcohol	β00	1.18	0.10	12.14	<.001
Level 1 Slope: Daily Worry – Alcohol	β10	-0.13	0.07	-1.82	.07
Level 2 Slope: Neuroticism – Alcohol	β01	-0.00	0.01	-0.04	.97
Intercept: SOL	β00	32.60	1.60	20.40	<.001
Level 1 Slope: Daily Worry – SOL	β10	1.66	1.28	1.30	.20
Level 2 Slope: Neuroticism – SOL	β01	0.69	0.24	2.81	.01
Intercept: TST	β00	457.07	3.94	116.03	<.001
Level 1 Slope: Daily Worry – TST	β10	-2.51	3.91	-0.64	.52
Level 2 Slope: Neuroticism – TST	β01	-0.34	0.52	-0.66	.51
Intercept: Sleep Quality	β00	3.09	0.05	63.64	<.001
Level 1 Slope: Daily Worry – Sleep Quality	β10	-0.01	0.03	-0.28	.78
Level 2 Slope: Neuroticism – Sleep Quality	β01	0.01	0.01	1.36	.17

Intercept: High Fat Snacks	β00	0.82	0.03	27.21	<.001
Level 1 Slope: Daily Brooding – High Fat Snacks	β10	0.02	0.02	1.00	.32
Level 2 Slope: Neuroticism – High Fat Snacks	β01	-0.00	0.00	-0.44	.66
Intercept: High Sugar Snacks	β00	0.70	0.03	27.80	<.001
Level 1 Slope: Daily Brooding – High Sugar Snacks	β10	0.02	0.02	0.89	.38
Level 2 Slope: Neuroticism – High Sugar Snacks	β01	-0.01	0.00	-1.33	.19
Intercept: Fruit	β00	1.26	0.05	22.95	<.001
Level 1 Slope: Daily Brooding – Fruit	β10	-0.00	0.03	-0.05	.96
Level 2 Slope: Neuroticism – Fruit	β01	-0.00	0.01	-0.51	.61
Intercept: Vegetables	β00	1.99	0.06	34.12	<.001
Level 1 Slope: Daily Brooding – Vegetables	β10	0.01	0.03	0.26	.80
Level 2 Slope: Neuroticism – Vegetables	β01	-0.01	0.01	-0.84	.41

Intercept: Vigorous Activity	β00	11.84	1.06	11.14	<.001
Level 1 Slope: Daily Brooding – Vigorous Activity	β10	-1.17	0.78	-1.51	.13
Level 2 Slope: Neuroticism – Vigorous Activity	β01	-0.35	0.16	-2.18	.03
Intercept: Moderate Activity	β00	11.95	1.21	9.88	<.001
Level 1 Slope: Daily Brooding – Moderate Activity	β10	-1.07	1.05	-1.02	.31
Level 2 Slope: Neuroticism – Moderate Activity	β01	0.04	0.22	0.21	.84
Intercept: Walking	β00	71.71	2.97	24.12	<.001
Level 1 Slope: Daily Brooding – Walking	β10	-6.87	1.63	-4.22	<.001
Level 2 Slope: Neuroticism – Walking	β01	-1.08	0.47	-2.30	.02
Intercept: Sitting	β00	401.84	8.78	45.77	<.001
Level 1 Slope: Daily Brooding – Sitting	β10	11.38	4.27	2.67	.01
Level 2 Slope: Neuroticism – Sitting	β01	0.55	1.40	0.39	.70

Intercept: Alcohol	β00	1.18	0.10	12.13	<.001
Level 1 Slope: Daily Brooding – Alcohol	β10	0.07	0.09	0.74	.46
Level 2 Slope: Neuroticism – Alcohol	β01	-0.01	0.01	-0.39	.70
Intercept: SOL	β00	32.57	1.60	20.41	<.001
Level 1 Slope: Daily Brooding – SOL	β10	2.09	1.30	1.61	.11
Level 2 Slope: Neuroticism – SOL	β01	0.67	0.23	2.87	.01
Intercept: TST	β00	457.03	3.94	116.08	<.001
Level 1 Slope: Daily Brooding – TST	β10	1.91	3.94	0.48	.63
Level 2 Slope: Neuroticism – TST	β01	-0.36	0.50	-0.73	.47
Intercept: Sleep Quality	β00	3.09	0.05	63.63	<.001
Level 1 Slope: Daily Brooding – Sleep Quality	β10	-0.02	0.04	-0.44	.66
Level 2 Slope: Neuroticism – Sleep Quality	β01	0.01	0.01	1.42	.16

Table 5.5 shows that more frequent and intense daily worry significantly predicted less daily vigorous activity (β_{10} = -2.18, p = .01), and predicted more time spent sitting (β_{10} = 13.21, $p < .001$). More frequent and intense daily brooding significantly predicted less daily walking (β_{10} = -6.87, $p < .001$) and more sitting (β_{10} = 11.38, p = .01).

5.4 Discussion

The aim of this study was to assess the within- and between-person relationships between daily hassles, state and trait PC and health behaviours at a daily level. The findings indicated that components of PC predict both health-risk and health-promoting behaviours and interact with daily hassles to contribute to health behaviour outcomes. Hypotheses 1a to 1d, that trait worry and brooding would predict more health-risk and less health-promoting behaviours, received limited support. The only significant association was between trait brooding and poorer sleep outcomes (TST and sleep quality). Hypothesis 1e, that trait reflection would predict health-risk behaviours, was not supported but hypothesis 1f, that trait reflection would predict health-promoting behaviours was partially supported, as trait reflection predicted more moderate daily activity. Hypothesis 2, that associations between daily hassles and more health-risk and less health-promoting behaviours would be stronger as levels of worry and brooding increased, was not supported as the direction of these interactions were opposite to those predicted. Daily hassles predicted less high sugar snacking and this association became stronger as levels of brooding increased, and an association between hassles and more vigorous activity increased in relation to increasing levels of trait brooding. Likewise, an association between hassles and shorter SOL and better sleep quality was strengthened by increasing levels of reflection. Hypothesis 3, that daily PC (worry and brooding) would be associated with more health-risk and less health-promoting behaviours, was again, partially supported. Both daily worry and daily brooding predicted more time spent sitting, daily worry predicted less vigorous activity and daily brooding predicted less daily walking. Therefore, there is support for an association between daily worry and more health-risk behaviour (H3a) and less health-promoting behaviour (H3c), and likewise for daily brooding (H3b and H3d), within the area of physical activity. Explanations for unsupportive and inconsistent findings will be considered.

Trait brooding predicted shorter TST and poorer sleep quality. These findings are broadly in line with the findings from the systematic review and meta-analysis of PC and sleep reported in Chapter 3 but diverge from these findings in that worry was not predictive of any sleep outcomes. However, in the meta-analysis, only direct associations were tested, whereas here, neuroticism was included within the model. It is possible that the association between worry and sleep may be explained by properties it shares with neuroticism such as negative affectivity. Furthermore, this study is notable for testing how PC measured the previous day relates to sleep measured the following morning. This overcomes the problem whereby measuring the two at the same time may lead to a mood state bias (Shiffman et al., 2008). This need was identified from the Chapter 3 PC and sleep systematic review and meta-analysis as few studies had tested this. More studies of this type may reveal divergences from the meta-analytic findings in which a large proportion of studies were cross-sectional.

Trait reflection significantly moderated the association between daily hassles and SOL such that SOL was shorter when daily hassles were high, and this association was stronger at higher levels of trait reflection. Trait reflection also significantly moderated the association between daily hassles and sleep quality such that higher daily hassles predicted better sleep quality and this association became stronger as levels of trait reflection increased. As noted in Chapter 4, it is hard to compare these findings to existing literature as, in the Chapter 3 review and meta-analysis, this type of PC was not included as there was only one study which investigated the association between a reflection-related predictor and a sleep outcome. In that study, Querstret et al. (2017) found that after a mindfulness intervention, levels of affective rumination and problem-solving pondering (which is conceptually similar to reflection) were reduced and sleep quality increased. This may appear to be in opposition to the current findings, but it is difficult to ascertain if the increase in sleep quality was attributable to a decrease in problem-solving pondering or affective rumination. Nevertheless, in the Chapter 4 survey study, reflection predicted longer SOL and poorer sleep quality cross-sectionally, which conflicts with the current findings. However, the results are not directly comparable as here, sleep quality was measured at a daily level and reflection is interacting with daily hassles. Given that reflection has been posited as an adaptive form of rumination (Smith & Alloy, 2009; Treynor et al., 2003), it is not altogether surprising that reflection was associated with better sleep quality. The increasing protective effect at higher levels of daily hassles may represent more effective use of reflection as a coping strategy as the level of environmental challenge increases. Overall, more research is needed on reflection and sleep outcomes to better understand the role of this type of PC in sleep.

More frequent and intense daily hassles significantly predicted more daily high fat snacking, which is consistent with several previous studies (Newman et al., 2007; Ng & Jeffery, 2003; O'Connor et al., 2008), but this was not moderated by any trait PC variables. Trait brooding significantly interacted with daily hassles on high sugar snacking such that there was an association between daily hassles and less high sugar snacking which increased in accordance with levels of trait brooding. In Chapter 4, trait brooding significantly moderated the association between stress and unhealthy snacking such that there was a positive association between stress and unhealthy snacking at low and medium levels of brooding but, at high levels of brooding, stress predicted less unhealthy snaking. In Chapter 4, the associations between stress and unhealthy snacking at low and medium levels of brooding were positive whereas the association here is negative at all levels of brooding. However, the measure of unhealthy snacking in Chapter 4 spanned a variety of foods, whereas here, snack foods are categorised by fat and sugar levels and only high sugar snacking, not high fat snacking was significantly moderated by brooding, with stress predicting high fat snacking irrespective of levels of any type of trait PC. This difference in the type of snacking may have contributed to the difference in findings.

The associations reported between both state and trait brooding and less unhealthy snacking may also be explained by the stress-eating paradox (Stone & Brownell, 1994), mentioned in Chapter 4, section 4.4. This theory suggests that, up to a point, stress increases eating, possibly due to physiological changes in reward sensitivity (Adam & Epel, 2007), but at high levels of stress, the opposite is true and decreased eating is witnessed. In Chapter 4, it was suggested that even at low levels of stress, brooding may exacerbate the physiological stress response, thus triggering unhealthy eating. However, at high levels of stress, this physiological response may plateau, reducing eating in all participants regardless of trait brooding. However, this theory does not fit as easily with the current findings because no positive association between daily hassles and high sugar snacking is seen at any level of brooding. It is to be noted that at low levels of stress, there is little difference in snacking at different levels of brooding. This suggests that, at a daily level, brooding may play less of a role in the stress-snacking association when stress levels are low. At high levels of daily hassles, it is clearer that higher levels of brooding predict less snacking, perhaps indicating that brooding and hassles are having a compound effect on the physiological stress response, inducing an appetite-suppressant response.

An alternative for the findings that trait and state brooding predicts less unhealthy snacking as levels of stress increase, is that brooding is generally predictive of less unhealthy eating. Although stress has been shown to be associated with increased unhealthy eating in several studies (Newman et al., 2007; Ng & Jeffery, 2003; O'Connor et al., 2008), a review by Gibson (2012) suggests that emotional or comfort eaters are actually in the minority (around 30%). As this area has never been systematically reviewed or subjected to meta-analysis, it is difficult to definitively ascertain the strength and direction of the association between these variables. In this way, if the association between stress and eating varies between individuals, it would not be unexpected for brooding to exacerbate a negative association between stress and snacking as research suggests that stress and brooding are physiologically similar processes (Ottaviani et al., 2016). Cropley et al. (2012) found an association between work-related affective rumination and unhealthy eating, but as noted in the introduction, the ecological fallacy can lead to erroneous assumptions about individuals on the basis of sample level data, and this study did not consider how stress interacted with rumination. Again, to date, there is too little research to draw firm conclusions regarding stress, brooding and eating behaviour.

Moreover, research suggests that other individual differences moderate the association between stress and eating behaviour. Differences have been found in eating patterns between men and women, with some studies finding that females are more likely to over-eat in response to stress (Mikolajczyk, El Ansari, & Maxwell, 2009; O'Connor et al., 2008), although others have failed to replicate this (Barrington, Beresford, McGregor, & White, 2014; Reichenberger et al., 2018). Eating styles also appear to be important moderators of this relationship. Wardle, Steptoe, Oliver, and Lipsey (2000) found that work stress only predicted higher fat and sugar intake in participants high in dietary restraint. O'Connor et al. (2008) also found a similar effect for emotional and external eating and disinhibition. It is arguable that, in failing to measure eating styles and account for sex, understanding of the associations between hassles, state and trait PC, and eating behaviour is limited. It is advised that future studies rectify this in order to better understand the complex relationships between these variables reported here and in the previous chapter.

Findings regarding physical activity were mixed. Trait reflection predicted more moderate activity. A protective effect of reflection on health behaviour is consistent within the context of the reflection literature which suggests that this coping style may be adaptive (Smith & Alloy, 2009; Treynor et al., 2003). However, the finding that hassles predicted more vigorous activity and that this association was stronger as levels of trait brooding increased, is less consistent with the extended PCH but there are no research findings from the literature for comparison. In Chapter 4, brooding was correlated with less physical activity cross-sectionally, but this association disappeared in the full model containing demographic variables, neuroticism and stress. These findings may reflect evidence that physical activity can be used as a coping mechanism (Cairney et al., 2014) and moderate and vigorous activity are more likely to represent formal exercise (such as going to the gym or running) rather than everyday activities such as walking.

On the other hand, more frequent and intense daily worry predicted lower daily vigorous activity and predicted more time spent sitting. These findings are consistent with one study that found an association between health worry and reduced physical activity (Li et al., 2009), although other research has found associations between cancer worry (Bernat et al., 2015) and health worry (Ferrer, Portnoy, et al., 2013) and more physical activity. Likewise, more frequent and intense daily brooding significantly predicted less daily walking and more sitting. These findings are more consistent with the association between brooding and less physical activity reported in Chapter 4, although it should be noted that this was a combined measure and so the differential association between brooding and different types of physical activity may have been concealed by this measure.

The lack of association between any trait or state PC predictors and daily drinking is consistent with findings reported in Chapter 4 that no trait PC variables predicted alcohol consumption but appears to contradict findings from the systematic review and meta-analysis in which an association between overall PC and greater alcohol consumption was evidenced. In the study most similar to this one, in a diary study of college student's drinking habits, Aldridge-Gerry et al. (2011) found that emotional rumination predicted more daily drinking. Including the current study, there are only two daily diary studies investigating these relationships, and only seven published studies in total, some of which include adolescent samples, so more research is needed in this area to better understand these relationships. There were also no associations found with fruit or vegetable consumption which reflects similar findings in Chapter 4 and that of Cropley et al. (2006) in which no association was found between rumination and healthy foods, including fruits and vegetables. Ferrer, Bergman, et al. (2013) found that health worry predicted higher fruit and vegetable intake, although health worry may qualitatively differ from general worry.

Another aim of this study was to test the association between both state and trait PC and health behaviours. Here, there was limited support for direct associations between trait PC and daily health behaviours (only brooding predicted poorer sleep and reflection predicted more moderate activity). However, trait PC did moderate associations between high sugar snacking, sleep quality, SOL and vigorous activity. State/daily PC (both worry and brooding) were fairly consistently associated with physical activity outcomes. Overall, it can be concluded that state and trait PC do appear to differentially relate to health behaviour outcomes. These findings are generally in accordance with those of Ottaviani et al. (2016), where it was found that state and trait PC predicted differing physiological outcomes, and those of Verkuil et al. (2007) who found that trait worry only accounted for 24% of the variance in daily worry. Similarly, in Chapter 3, whether PC was measured at a trait or state level moderated the association between PC and longer SOL and shorter TST such that this relationship was stronger for trait compared to state PC. Taken together, these findings suggest that (1) state and trait PC predict health and health behaviour outcomes differently and, (2) state and trait PC may contain elements unique to one another. Further psychometric analyses of state and trait measurements of PC could provide further insight.

There were a number of limitations of this research. First, due to assessing relationships between components of PC and health behaviours at a state and trait level, in addition to testing whether components of trait PC moderate the associations between daily hassles and health behaviours, a very large number of analyses were conducted. This increases the likelihood of producing chance or spurious findings. For instance, if a correction were made to the statistical threshold to account for the number of tests, many of these findings would be non-significant. It is reassuring that some of these findings seem to echo those from the reviews and from Chapter 4, but apart from where there is very high statistical significance (i.e. $p < .001$), many of these findings should be treated as indicative only until there is further confirmatory research evidence.

Second, despite employing daily diary methodology, this study may still have been subject to retrospective recall bias, as outcomes were only measured at two time-points in the day and may have been influenced by participant's emotional state when completing the diary. The outcomes may also simply have been biased due to memory limitations. A better way to utilise daily diary methodology is to measure thoughts, mood states and behaviours at multiple time-points throughout the day, such as in the study by Takano et al. (2014) in which repetitive thought and mood was measured at semi-random intervals throughout the day. However, these methods are most reliable when portable electronic devices are provided (as opposed to pen and paper methods) which is expensive and limits the number of participants that can be recruited at one time. Therefore, this method was not feasible here.

Third, there was no daily/state measure of reflection. Although reflection is of less interest within the scope of this thesis, as it is not considered to be a negative thought process, it would have perhaps been better to have captured reflection at a state level in order to have differentiated it from brooding. The wording of the measure was specific to brooding but it is possible that participants may have conflated daily brooding and reflection which could partially explain some of the unexpected findings. The measures of daily brooding and worry were chosen as they had previously been validated, which was vital for such a key measure. However, this validated measure did not include an item assessing reflection. As well, Brosschot and van der Doef (2006) found that the duration but not the frequency of worry was predictive of somatic symptoms. Here, only the frequency and intensity of daily worry and brooding were measured as it was thought that it would be too difficult for participants to recall for how many minutes each day they were worrying and brooding. A measure of duration is more feasible when multiple daily measurements are taken. In the study by Brosschot and van der Doef (2006), a daily pen and paper tally was made of worry episodes which may have made estimating duration at the end of the day easier. In future studies, it is suggested that multiple daily measurements of hassles, PC and health behaviours are taken and that this includes a state measure of reflection, and includes assessment of the duration of daily PC.

In conclusion, the findings from this study partially support the extended PCH as components of state and trait PC did predict both more health-risk and less health-promoting behaviours and interact with daily hassles to contribute to health behaviour outcomes, although not always in the predicted directions. Possible explanations for these findings have been discussed such as the stress-eating paradox (Stone & Brownell, 1994), use of physical activity as a coping mechanism (Stults-Kolehmainen & Sinha, 2014) and the adaptiveness of reflection (Smith & Alloy, 2009). It has also been acknowledged that the current study was limited in its use of daily diary methodology and may have failed to include key measures (i.e. eating styles and a measure of state reflection). In assessing these shortcomings, future studies may provide a clearer picture of the associations between stress, PC and daily health behaviours.

Chapter 6
General Discussion

6.1 Chapter Summary

In this chapter, the findings from across the systematic reviews and meta-analyses (Chapters 2 & 3) and original research findings (Chapters 4 & 5) will be considered within the context of the thesis aims. Secondly, the extended PCH proposed in Chapter 1 (Figure 1.2) will be reviewed in light of the evidence from this thesis. Thirdly, the strengths and limitations of the research presented in this thesis will be considered and suggestions will be made for how future research can improve and expand upon these findings. Finally, general conclusions will be offered.

6.2 Summary of the Thesis Findings

6.2.1 Aim I

The overarching aim of this thesis was to assess the extended PCH, that is, the theory that, in the same way as stress, there may be an additional indirect pathway between PC and health outcomes via health behaviours. Specifically, the first aim was '*to systematically review and meta-analyse the existing literature regarding PC and health behaviours in order to assess whether the theorised association between PC and health behaviour is supported by existing research, and to identify gaps in the existing literature'*. This aim was addressed in Chapters 2 and 3.

The findings from the Chapter 2 systematic review and meta-analysis were that there is a small-sized association between PC and health-risk, but not health-promoting behaviours. Health-risk behaviours spanned alcohol consumption, unhealthy eating and smoking. Primary findings from the Chapter 3 systematic review and meta-analysis were that there was a small-sized association between PC and poorer quality sleep, shorter sleep duration and longer sleep onset latency. The type of sleep assessment was found to moderate the association between PC and sleep, with a stronger association being found in studies measuring sleep quality via self-report as opposed to actigraphy, with the effect size doubling for self-reported sleep, indicating a substantial negative reporting bias. Gaps identified in these reviews included a lack of prospective and experimental studies, limited use of validated measures of PC in the Chapter 2 review and almost no studies investigating the association between: (1) general worry and health behaviours (apart from sleep), (2) reflection and sleep or, (3) any type of PC and eating behaviour or physical activity.

6.2.2 Aim II

The second aim was *'to empirically assess the cross-sectional and prospective associations between stress, PC and health behaviours to evaluate the extended PCH'*. This aim was addressed in Chapters 4 and 5. In the Chapter 4 study, employing survey methodology across a three-month period, there was support for associations between trait worry, brooding and reflection and some health-risk behaviours (e.g. poorer sleep, more unhealthy snacking and less physical activity) both cross-sectionally and prospectively. In the Chapter 5 seven-day diary study, findings indicated that components of PC predict both health-risk (snacking and time spent sitting) and health-promoting behaviours (physical activity) and interact with daily hassles to contribute to health behaviour outcomes, although some of these findings were not in the expected directions and, across both studies, there were a number of non-significant findings.

6.2.3 Aim III

The third aim was *'to assess the association between facets of PC (worry, brooding and reflection) and health behaviours'*. This aim was addressed in both systematic reviews and meta-analyses and in both empirical studies. In the Chapter 2 systematic review and meta-analysis, brooding was found to predict increases in health-risk, but not health-promoting behaviours, but measures of worry and reflection were not significantly associated with either. In the Chapter 3 systematic review and meta-analysis, brooding had a small-sized association with shorter sleep duration and longer sleep onset latency and a medium-sized association with poorer sleep quality. Worry had a small association with shorter sleep duration, longer sleep onset latency and poorer sleep quality. For all PC types, the strongest associations were with sleep quality. Therefore, across the reviews, brooding emerged as the stronger predictor of health behaviours.

In the Chapter 4 survey study, worry, brooding and reflection were predictive of longer SOL and poorer sleep quality cross-sectionally. Furthermore, these associations were also found prospectively for brooding. Only brooding predicted shorter TST, and only cross-sectionally. However, none of these associations remained significant in the full model (containing demographics, neuroticism, stress and interaction terms). Worry and brooding were associated with more unhealthy snacking both cross-sectionally and prospectively. However, the only association that remained in the full model was the significant prediction of unhealthy snacking by brooding and this remained significant when worry and reflection were added simultaneously, suggesting that brooding explains unique variance in unhealthy snacking. Brooding significantly moderated the association between stress and unhealthy snacking such that brooding predicted more snacking at low and medium levels of stress but at high levels of stress, there was no relationship between brooding and snacking. Furthermore, the association between brooding and unhealthy snacking was strongest at low levels of stress and weaker at medium levels. Brooding was the only PC predictor significantly correlated with physical activity and this association was only significant cross-sectionally and was not significant in the full model.

In the Chapter 5 diary study, trait brooding predicted poorer daily sleep outcomes (TST and sleep quality) and trait reflection predicted more moderate daily activity. Daily hassles predicted less high sugar snacking and this association became stronger as levels of brooding increased, and an association between hassles and more vigorous activity increased in relation to levels of trait brooding. Likewise, an association between hassles and shorter SOL and better sleep quality was strengthened by increasing levels of trait reflection. Both daily worry and daily brooding predicted more time spent sitting, daily worry predicted less vigorous activity and daily brooding predicted less daily walking. No associations were reported with daily drinking or with fruit or vegetable intake.

6.2.4 Aim IV

The fourth and final aim was *'to assess the associations between both trait and state PC and health behaviours.'* In the Chapter 2 systematic review and meta-analysis, there were too few studies in each category to enable comparison of state and trait PC. However, in the Chapter 3 systematic review and meta-analysis, the association between PC and longer SOL was stronger in studies measuring trait, as opposed to state PC. However, state PC measurements were more varied and less likely to be validated than trait measurements which could partially explain smaller effect sizes. All measurements of PC in the Chapter 4 survey study were at a trait level and therefore these findings only demonstrate associations between trait PC and health behaviours.

In the Chapter 5 diary study, both trait and state (daily) PC were measured, apart from reflection which was only measured at a trait level (due to no validated measure being available). Differences were found in the outcomes that state and trait PC predicted. Trait brooding predicted poorer daily sleep outcomes (TST and sleep quality) but no such association was found for state brooding. Trait brooding moderated an association between daily hassles and high sugar snacking, and hassles and vigorous activity, but no associations were found between daily brooding and high sugar snacking or vigorous activity. Both daily worry and daily brooding predicted more time spent sitting but this was not the case for trait worry and brooding. Similarly, daily worry predicted less vigorous activity and daily brooding predicted less daily walking, but no such associations were found between trait worry or brooding and these health behaviours.

6.3 The Extended Perseverative Cognition Hypothesis: Considering the Evidence

The findings from this thesis provide partial support for the hypothesis that in the original PCH (Brosschot et al., 2006), there may be scope for an additional route to pathogenic disease via poorer health behaviours (i.e. the extended PCH). In this conceptualisation, it was theorised that stress-related cognitions would influence health behaviours directly (the PCH) and moderate the effects of stressors on health behaviours, particularly those previously shown to be influenced by stress (the extended PCH). It was theorised that this would then have knock-on effects for health outcomes and disease processes.

On the one hand, several findings within this thesis wholly supported this proposal. Namely, the finding that, in previous research, PC was associated with increases in health-risk behaviours and that higher PC was associated with longer SOL, shorter TST and poorer quality sleep. Furthermore, studies from this thesis revealed that worry, brooding and reflection were predictive of longer SOL and poorer sleep quality cross-sectionally. Brooding also predicted these associations prospectively and was associated with shorter TST cross-sectionally. Also, in the survey study, brooding predicted more unhealthy snacking at low and medium levels of stress (although not at high stress). Likewise, in Chapter 5, trait brooding predicted poorer daily sleep outcomes (TST and sleep quality) and both daily worry and daily brooding predicted more time spent sitting, daily worry predicted less vigorous activity and daily brooding predicted less daily walking.

On the other hand, there were there were a number of non-significant findings (e.g. in the Chapter 4 and 5 studies, there were no significant associations with drinking or fruit and vegetable consumption) and there were findings which outright contradicted this theory, such as the finding in Chapter 5 that daily hassles predicted less high sugar snacking and this association became stronger as levels of brooding increased, and that an association between hassles and more vigorous activity increased in relation to levels of trait brooding. Likewise, trait reflection predicted more moderate activity and an association between hassles and shorter SOL and better sleep quality was strengthened by increasing levels of trait reflection. However, it was expected that reflection may have protective effects.

Therefore, support for the extended PCH seems to be undermined by some inconsistencies and subject to various caveats. One inconsistency reported was the inverse association between brooding and unhealthy snacking as stress levels increased found in the diary study. It was suggested in the Chapter 5 discussion that this may represent additive effects of stress and brooding, producing an appetite suppressant effect usually only found at high stress levels (Stone & Brownell, 1994). If this were the reason for this association between stress, brooding and eating, brooding would not be considered as a protective factor in the stress-eating relationship but instead a factor which compounds stress, altering its typical association with eating behaviour. Alternatively, it was suggested that, given the large number of analyses, chance findings could not be ruled out. However, considering that no previous study (apart from that reported in Chapter 4) has tested these associations, no firm conclusions can be drawn. Additionally, it was suggested that the finding that the association between daily hassles and more vigorous activity increased in line with levels of trait brooding might be explained by the use of physical activity as a coping mechanism. However, overall, these findings are broadly in opposition to the extended PCH. Taken together, the combined findings indicate that the pathway between PC and health behaviours is more complex than initially predicted.

Regarding caveats, the association between PC and health behaviours seems to differ across the type of PC, the type of health behaviour and whether PC is measured at a state or trait level. This supports the idea that while PC is useful as an overall construct, distinctions between its facets are also important and research findings from this thesis suggest that targeting different facets of PC would be more useful in modifying particular health behaviours. For instance, brooding emerged as the most significant predictor of unhealthy snacking and there is some evidence that reflection may confer protective benefits on sleep at times of stress, whereas the evidence points to detrimental influences of brooding and worry on sleep. Likewise, there is some suggestion from Chapters 3 and 5 that some behaviours are more strongly related to trait PC (e.g. sleep) whereas others are more influenced by state PC (e.g. physical activity). Again, the research is limited by the scarcity of studies in some areas and some conflicting findings but in general, the associations between different types of PC and different health behaviours does not appear to be homogenous, suggesting that the extended PCH may be too simplistic a model to adequately represent the relationships between these variables.

It could be argued that, while the model outlined in the original PCH (Brosschot et al., 2006) appears to be fairly consistently associated with poorer physical health parameters (Ottaviani et al., 2016), this is reflective of the relatively predictable ways in which the physiological stress system responds to psychological stress (Cannon, 1939; McEwen, 1998; Selye, 1950). In contrast to this, health behaviours may be more prone to vary both between and within individuals as behavioural responses to psychological factors are not fixed. This is echoed by research evidencing individual variations in eating behaviour and physical activity in response to stress (Gibson, 2012; Mikolajczyk et al., 2009; Stone & Brownell, 1994; Stults-Kolehmainen & Sinha, 2014). It could be argued that behavioural responses are more susceptible to the influence of individual differences under differing environmental circumstances and therefore, cumulatively, more research is needed in evidencing broad patterns of behaviour in response to any predictor. As such, although the findings from this thesis provide mixed support for the extended PCH, it is arguably too early to assess its utility given the scarcity of studies in this area.

Nevertheless, findings in the current thesis are partially supportive of the extended PCH and have implications from a population health perspective. From a brain-body point of view, PC may be important in the development of allostatic load. McEwen (1998) introduced the concept of allostatic load to capture the wear and tear the body experiences resulting from repeated and prolonged adaptation to environmental and psychosocial stressors. He proposed that the long-term impact of stress affects the body at cardiovascular, metabolic, neural, behavioural and cellular levels. Like basic homeostatic systems such as body temperature, the HPA axis, the autonomic nervous system and the cardiovascular, metabolic and immune systems protect the body by adapting to internal and external stress, known as allostasis. However, if the activation of these systems (allostasis) is repeated and prolonged, allostatic load will be experienced in the form of increased stress hormone, immune cell, brain activity and cardiovascular responses, ultimately, overtime leading to heightened risk of developing disease (McEwen, 1998, 2007). Numerous factors may contribute to the development of allostatic load including genes and early life experiences. Evidence from the systematic review and meta-analysis by Ottaviani et al. (2016) suggests that PC may also influence these physiological pathways to disease and now, there is evidence that PC may also influence behaviours which contribute significantly to health such as sleep, physical activity and eating behaviour. This is important as it suggests that interventions which are successful in reducing PC may have positive impacts on health directly and indirectly (via improved health behaviours). This positions PC as a viable and potentially rewarding intervention target for researchers wishing to improve various aspects of population health.

6.4 Strengths and Limitations of the Thesis

The research conducted in this thesis has various strengths. First, a testable theoretical model has been created, which advances research into stress and PC. Future research can use this model to structure hypotheses and can expand upon the model if research reveals further complexities within these associations. Moreover, if the direct association between PC and health behaviours had simply been tested, the support for this model would have been more considerable but also misleading. It is to the credit of this thesis that analytical models including stress, relevant covariates and interaction terms were tested, indicating that significant findings which did remain were more meaningful than direct associations alone.

Second, the existing literature was searched and synthesized rigorously and comprehensively via systematic reviews and meta-analyses. The findings from Chapter 2 have been published (Clancy et al., 2016) and as of publication of this thesis, this article is attracting a good citation rate, evidencing the quality of these findings and their significance to the field. Similarly, despite there being a great deal of research investigating an association between PC and sleep in non-clinical populations, this was the first time that this data had been subject to systematic review or meta-analysis. These findings may be especially significant to researchers and practitioners aiming to improve sleep, as associations were found between all types of PC and all sleep parameters, making PC a prime target for sleep interventions.

Third, the associations between various types of PC (worry, brooding and reflection, at both a state and trait level) and multiple health behaviours have been investigated, across both cross-sectional and prospective surveys and at a daily level, whilst testing interactions with stress. The breadth of this research has addressed a number of gaps in the existing literature and has provided a wealth of evidence for researchers in the field to draw inferences from and to build upon in future research. Despite focusing on a relatively niche area of health psychology, these findings have implications across a variety of research areas. These findings are of obvious relevance to health psychologists as the findings add to understanding of the psychological predictors of health behaviours. Also, within stress research these findings contribute to knowledge of how stress may influence health behaviours and, ultimately, health. Additionally, for researchers and practitioners interested in sleep, there is now review evidence that PC is a significant predictor of sleep disturbance. Finally, for clinical psychologists, these findings indicate that PC, which plays a part in anxiety in depression, is likely to influence health behaviours in these clinical populations.

However, despite the contribution of this thesis to our understanding of the associations between stress, PC and health behaviours, there are still some gaps in the literature which future research should address. The two prospective studies conducted for this thesis notwithstanding, the shortage of studies assessing prospective associations (identified in the Chapter 2 review) still remains. Furthermore, few of the studies included in the Chapter 2 review used validated measures of PC and there was a heavy reliance on single-item measures of this construct, meaning that conclusions that can be inferred from existing prospective studies are even more limited. Another issue is that measures used to assess PC and its components are heterogeneous, and across the reviews, varied from unvalidated single-item measures to a broad range of multi-item measures which, while often reported to be valid and reliable, may potentially be measuring slightly different constructs. This issue may contribute to some of the mixed findings within the literature.

There were also several limitations of this thesis which should be acknowledged. It was theorised within the extended PCH, via the PC-stress response pathway, there would be a direct impact on pathogenic states such as changes in somatic health outcomes and disease. This final pathway, between health behaviours and pathogenic states was not tested here. However, previous research has supported these associations. For example, associations have been reported between short sleep duration and poorer general, cardiovascular, metabolic, mental and immunologic health, as well as greater experience of pain and greater overall rates of mortality (Watson et al., 2015) and between sleep disturbance and markers of inflammation (Irwin et al., 2016). Consuming alcohol has been shown to increase the risk of cancer and cancer-related death (Praud et al., 2016) and high calorie, low nutrient foods combined with time spent sedentary contribute to a positive energy balance and obesity (Malik et al., 2013). A recent systematic review and meta-analysis has shown that greater time spent sedentary was associated with increased risk of diabetes, cardiovascular events, cardiovascular mortality and all-cause mortality (Wilmot et al., 2012) whereas engaging in physical activity has been shown to be beneficial for health (Penedo & Dahn, 2005). Hence, although the final pathway between health behaviours and pathogenic states was not tested here, existing literature supports these associations and it could be argued that, as a result of the existing body of research regarding health behaviours and health outcomes, evidencing an association with health behaviours is sufficient in testing the extended PCH.

There were also a number of methodological limitations across the thesis. First, some of the most consistent findings were in relation to eating behaviour but not all relevant covariates of eating behaviour were measured and accounted for in analyses. Differences have been found in eating patterns across gender (Mikolajczyk et al., 2009; O'Connor et al., 2008) and eating styles (O'Connor et al., 2008; Wardle et al., 2000). It is arguable that, in failing to measure eating styles and account for sex, understanding of the associations between hassles, state and trait PC, and eating behaviour is incomplete. It is advised that future studies rectify this in order to better understand the complex relationships between these variables. Second, a case was made for the use of daily diary methodology to overcome issues with global recall methods. However, the use of this methodology was somewhat limited. Daily diary methodology reduces the reliance on memory and therefore, limits retrospective recall bias (Shiffman et al., 2008). However, in Chapter 5, study variables were only measured at the beginning and the end of the day. A better way to utilise daily diary methodology is to measure thoughts, mood states and behaviours at multiple time-points throughout the day, such as in the study by Takano et al. (2014). Due to time and budget constraints, this method was not feasible here but would have been a more reliable way of collecting this data, and future studies should adopt this approach. Third, there was no daily/state measure of reflection and only the frequency and intensity of daily worry and brooding were measured. Brosschot and van der Doef (2006) found that the duration but not the frequency of worry was predictive of somatic symptoms. A measure of duration may be more feasible when multiple daily measurements are taken so that participants do not actively have to keep a tally of the time they have spent engaging in PC across the day.

In relation to the generalisability of the findings from this thesis, due to the use of convenience sampling methods, the findings from the empirical studies may be limited. Although a broad age range was recruited, participants were predominantly White British females educated to a high level (most were university students). Therefore, even when considering the UK population, the findings may not be representative of males, individuals of non-White ethnicity or those without a university-level education. Furthermore, Henrich, Heine, and Norenzayan (2010) argue that despite psychological research recruiting almost exclusively WEIRD samples (i.e. participants from Western, educated, industrialised, rich and democratic nations), such participants are highly unusual when compared to the rest of the world and there is growing evidence that findings from such samples are often not representative of other populations. Thus, it is suggested that, where possible, diverse and representative samples are included in future research in this area to assess the generalisability of the extended PCH.

Finally, as this thesis aimed to demonstrated relationships between components of PC and multiple health behaviours, at both a state and trait level, as well as to assess whether components of PC moderate associations between stress and health behaviours, a large number of analyses were conducted within the empirical chapters. Multiple testing increases the probability of committing a type I error (or detecting a false positive). As such, significant findings from Chapters 4 and 5 should be treated with caution until they are replicated by future research.

6.5 Future Research Directions

It is suggested that there are a number of ways in which future research can advance upon the current findings. First, one possibility that was not considered within this thesis is that the association between PC and health behaviours may be bi-directional with poorer health behaviours also influencing the likelihood of engaging in PC. There is some evidence of this in relation to sleep. A meta-analysis found that sleep disturbance was associated with an increased relative risk of suicidal ideation (Pigeon, Pinquart, & Conner, 2012), suggesting that poor sleep can lead to negative thought patterns. The direction of the relationship between PC and sleep could not be assessed in the Chapter 3 review as nearly all studies measured PC at the same time as or prior to measuring sleep. As such, it is possible that rather than PC influencing poorer sleep, poor sleep may lead to increased PC, or the two may interact in a damaging, bi-directional cycle. It is speculated that a bi-directional association between PC and health behaviours may also occur in individuals who have a tendency to worry or ruminate about their health, but nonetheless, engage in unhealthy behaviours. Engaging in unhealthy behaviours may then trigger further worry about health and/or brooding on engaging in the behaviour. Daily diary studies would be valuable in investigating these associations as they would allow for analysing both thought patterns and behaviours at one time point on thought patterns and behaviours at the next measurement interval. It is therefore suggested that future research assesses the potential bidirectional association between PC and health behaviours.

Second, while there are common and frequently used measures of worry and rumination, such as the Penn State Worry Questionnaire (Meyer et al. 1990) and the Ruminative Responses Scale (Treynor et al. 2003), a state level measure of PC which targets worry, brooding and reflection does not currently exist and the development and validation of such a measure would enable researchers to more reliably capture state PC in daily diary studies. Moreover, improved measurement specificity of PC and its components, including state and trait measures, could potentially lead to more consistent use of PC measures and would enable researchers to infer more meaningful conclusions from the cumulative literature.

Third, it is suggested that future studies include prospective analyses to better understand the relationship between PC and health behaviours over time, as the majority of the existing research is cross-sectional. Likewise, there were too few experimental studies to directly assess the causal associations between PC and health behaviours. Zoccola et al. (2009) used a stress induction procedure to test the impact of naturally-occurring rumination in response to a psychosocial stressor on SOL. They found that high stressor-specific (state) rumination predicted longer SOL (and this was higher in participants scoring highly on trait rumination). Similar studies with differing health behaviour outcomes would reveal whether PC (worry, brooding and reflection) are causally related to other detrimental health behaviours.

Finally, it is proposed that the primary way in which future research can advance the current findings is via the development of intervention studies which aim to reduce PC and improve health behaviour outcomes. Support for both the original PCH (Brosschot et al., 2006) and the extended PCH, indicates that development of interventions which reduce PC may be effective in improving health behaviours and health outcomes. Existing literature points to some potentially effective interventions. Querstret and Cropley (2013) systematically reviewed 19 studies which had tested an intervention to reduce rumination and/or worry and concluded that mindfulness-based and cognitive behavioural therapies may be useful in reducing these. Other methods such as a brief postpone worry intervention has been shown to significantly reduce daily worry and somatic symptoms (Brosschot & van der Doef, 2006; Jellesma et al., 2009). One study also found that writing about life goals reduced ruminative thinking and reduced the cortisol awakening response (Teismann, Het, Grillenberger, Willutzki, & Wolf, 2014). However, as these interventions have not specifically targeted health behaviours, their utility in the context of improving behavioural outcomes is unknown. Furthermore, given that associations between PC and health behaviours only appear to be small (apart from some associations with sleep), of more importance may be PC interventions that complement or form part of existing intervention packages designed to change behaviour via changes in other determinants of behaviour.

Some research has focused on improving sleep outcomes via a reduction in PC. Systematic review evidence suggests that, in patient samples, mindfulness-based stress reduction techniques are associated with better sleep by reducing worry (Winbush, Gross, & Kreitzer, 2007). Likewise, in healthy participants, interventions can be delivered online for periods as short as 4 weeks to improve sleep quality by reducing rumination (Querstret et al., 2017). Also, a self-compassion intervention has recently been found to improve sleep quality via reduced rumination (Butz & Stahlberg, 2018). A randomised control trial found that, compared to a waitlist control, a cognitive behavioural therapy-based intervention reduced psychological detachment from work and insomnia severity (Thiart, Lehr, Ebert, Berking, & Riper, 2015). On the other hand, despite a reduction in affective rumination, another cognitive behavioural therapy intervention was not found to improve sleep quality in a non-clinical population (Querstret et al., 2015). In an intervention termed stimulus-control training, which was similar to the postpone worry method in that a particular worry-period was identified and in this case, this period had to be at least 3 hours prior to bedtime, both worry and insomnia severity were reduced (McGowan & Behar, 2013). In participants reporting insomnia, a constructive worry intervention has been shown to be effective in reducing pre-sleep cognitive arousal (Carney & Waters, 2006). This procedure involved noting the participant’s three most prominent worries on a piece of paper before bed and writing down the next step for dealing with each of those worries. If these worries emerged during the night, participants were to reassure themselves that they had already been dealt with. Another study found this method to be effective, in conjunction with a sleep restriction method (when time in bed is restricted to previously identified TST), in reducing insomnia severity and worry (Jansson-Frojmark, Lind, & Sunnhed, 2012). Similarly, Digdon and Koble (2011) found positive effects on daily sleep and pre-sleep worry as a result of constructive worry, imagery distraction and gratitude interventions. The imagery distraction involved imagining pleasant and relaxing scenes before sleep and in the gratitude intervention, prior to going to sleep, participants wrote about recent positive experiences or a positive experience that they were anticipating in the near-future.

Therefore, there is emerging research which has tested whether reducing PC can improve sleep and a small number of interventions have been tested. However, no studies have explored whether a reduction in PC improves other health behaviours and, arguably, there is too little research at this point to definitively ascertain which methods are most suitable for reducing PC. The evidence to date is limited which makes it difficult to draw firm conclusions regarding the efficacy of particular interventions. Consequently, it is recommended that future research tests the effectiveness of interventions aimed at improving a variety of health behaviours via a reduction in PC.

6.6 Conclusions

The primary aim of this thesis was to investigate the extended PCH, that is, the theory that, in the same way as stress, there may be an additional indirect pathway between PC and health outcomes via health behaviours. In parallel to this, the aim was to also assess whether PC moderated associations between stress and health behaviours. Partial support was found for this theoretical model. Review evidence suggested that PC is associated with increases in health-risk, but not health-promoting behaviours. However, in regard to the association with types of PC, this was only found for brooding, but not worry or reflection. Nevertheless, an association was found between both worry and brooding and worse sleep outcomes (longer SOL, shorter TST and poorer sleep quality). The survey and diary studies supported direct associations with worse sleep, unhealthy snacking and less physical activity. Significant moderation of the stress-health behaviour relationship was also reported in some instances. However, there were a number of non-significant findings, some conflicting evidence and associations between PC and health behaviours appear to differ depending on the type of PC measured (including whether it is measured at a state or trait level), the type of health behaviour outcome and whether outcomes are cross-sectional or prospective. As such, the overall conclusion is that the extended PCH is a useful starting point for research into the relationship between PC and health behaviours, but the simplicity of the model may belie the complexity suggested by the research findings. This thesis has identified multiple areas in which future research can build upon these findings. For instance, there is a need for daily diary studies using multiple daily measurements which include testing bi-directional associations between PC and health behaviours, improved measurement specificity of PC and its components, experimental studies to test the causal effect of PC on health behaviours, and for intervention studies which test the impact of PC interventions on varied health behaviour outcomes.

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Appendices

Appendix A – Chapter 2 Forest Plots

	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Ferrer (2013b)	-0.156	-0.266	-0.042	-2.669	0.008
Bernat (2015)	-0.092	-0.183	-0.000	-1.960	0.050
Malmi (2010)	-0.057	-0.164	0.051	-1.040	0.299
Adrian (2014)	-0.030	-0.167	0.108	-0.424	0.672
Ferrer (2013a)	-0.007	-0.040	0.027	-0.388	0.698
Ciesla (2011)	-0.005	-0.113	0.102	-0.095	0.924
Dijkstra (2003)	0.020	-0.081	0.121	0.387	0.699
Aldridge-Gerry (2011)	0.042	-0.038	0.121	1.031	0.302
Swayampakala (2013)	0.043	-0.034	0.120	1.093	0.275
Willem (2011)	0.046	-0.098	0.187	0.621	0.535
Willem (2013)	0.066	-0.061	0.190	1.017	0.309
Frone (2015)	0.083	0.047	0.120	4.447	0.000
Dvorak (2010)	0.120	-0.155	0.378	0.854	0.393
Cropley (2012)	0.132	0.013	0.248	2.166	0.030
Li (2009)	0.155	0.132	0.179	12.755	0.000
Rutten (2011)	0.443	0.350	0.528	8.412	0.000
Harwell (2010)	0.495	0.341	0.623	5.691	0.000
	0.072	0.013	0.131	2.380	0.017

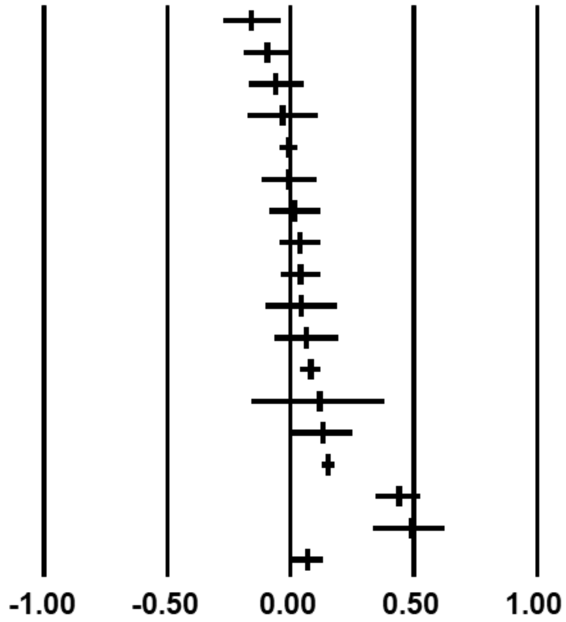

Figure A.1 Forest Plot of Correlations (*r*) between Overall PC (Excluding Reflection) and All Health Behaviours

	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Adrian (2014)	-0.110	-0.244	0.028	-1.559	0.119
Willem (2011)	-0.045	-0.187	0.098	-0.615	0.538
Cropley (2012)	0.020	-0.100	0.140	0.329	0.742
Willem (2013)	0.045	-0.081	0.171	0.701	0.483
	-0.016	-0.084	0.051	-0.473	0.636

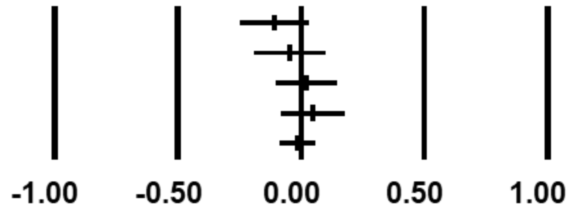

Figure A.2 Forest Plot of Correlations (*r*) between Reflection and All Health Behaviours

Appendix B – Chapter 3 Forest Plots

Study	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Van Laethem et al. (2016)	-0.001	-0.226	0.224	-0.008	0.993
Zoccola et al. (2009)	-0.009	-0.243	0.226	-0.074	0.941
Kocoglu et al. (2013)	-0.018	-0.104	0.068	-0.409	0.683
Omvik et al. (2007)	-0.081	-0.316	0.165	-0.640	0.522
Weise et al. (2013)	-0.084	-0.417	0.268	-0.462	0.644
McGowan et al. (2016)	-0.086	-0.135	-0.036	-3.403	0.001
Querstret et al. (2017)	-0.144	-0.332	0.054	-1.426	0.154
Åkerstedt et al. (2002)	-0.153	-0.179	-0.126	-11.171	0.000
Harvey et al. (2002)	-0.166	-0.395	0.082	-1.317	0.188
Baker et al. (2015)	-0.169	-0.346	0.020	-1.758	0.079
Hartz et al. (2013)	-0.170	-0.176	-0.164	-55.568	0.000
Jean-Louis et al. (2009)	-0.177	-0.235	-0.118	-5.776	0.000
Åkerstedt et al. (2012)	-0.178	-0.209	-0.147	-10.967	0.000
Carciofo et al. (2017)	-0.185	-0.282	-0.085	-3.582	0.000
Rodríguez-Muñoz et al. (2011)	-0.190	-0.219	-0.160	-12.360	0.000
Yan et al. (2014)	-0.190	-0.246	-0.133	-6.393	0.000
Bagley et al. (2015)	-0.193	-0.306	-0.075	-3.192	0.001
Thomsen et al. (2003)	-0.195	-0.363	-0.015	-2.118	0.034
Radstaak et al. (2014)	-0.195	-0.575	0.254	-0.847	0.397
Carney et al. (2006)	-0.210	-0.324	-0.089	-3.368	0.001
Takano et al. (2014)	-0.210	-0.335	-0.078	-3.088	0.002
Cropley et al. (2006)	-0.240	-0.419	-0.043	-2.378	0.017
Stoia-Caraballo et al. (2008)	-0.240	-0.348	-0.126	-4.047	0.000
Lin et al. (2017)	-0.259	-0.298	-0.220	-12.474	0.000
Yeh et al. (2015)	-0.263	-0.387	-0.129	-3.796	0.000
Huhtala et al. (2017)	-0.274	-0.444	-0.085	-2.808	0.005
Querstret et al. (2015)	-0.281	-0.396	-0.157	-4.339	0.000
Hairston and Shpitalni (2016)	-0.289	-0.362	-0.213	-7.174	0.000
Wicklow and Espie (2000)	-0.291	-0.642	0.161	-1.271	0.204
Takano et al. (2012)	-0.308	-0.427	-0.179	-4.532	0.000
Vahle-Hinz et al. (2014)	-0.322	-0.537	-0.066	-2.448	0.014
Cox et al. (2016)	-0.324	-0.416	-0.225	-6.149	0.000
MacNeil et al. (2017)	-0.329	-0.493	-0.144	-3.396	0.001
Van Laethem et al. (2015)	-0.331	-0.388	-0.270	-10.184	0.000
Cropley et al. (2015)	-0.332	-0.490	-0.153	-3.549	0.000
Annunziata et al. (2016)	-0.335	-0.483	-0.168	-3.819	0.000
Fichten et al. (2001)	-0.350	-0.461	-0.229	-5.387	0.000
Mitchell et al. (2012)	-0.355	-0.472	-0.226	-5.149	0.000
Kompier et al. (2012)	-0.380	-0.403	-0.356	-28.524	0.000
Querstret and Cropley (2012)	-0.380	-0.441	-0.316	-10.697	0.000
Slavish and Graham-Engeland (2015)	-0.380	-0.503	-0.242	-5.109	0.000
Joormann and Stöber (1999)	-0.420	-0.532	-0.294	-6.045	0.000
Liu et al. (2017)	-0.460	-0.504	-0.414	-17.047	0.000
Zawadzki et al. (2013)	-0.460	-0.559	-0.348	-7.261	0.000
Schmidt et al. (2011)	-0.461	-0.617	-0.270	-4.406	0.000
Doos Ali Vand et al. (2014)	-0.473	-0.545	-0.394	-10.292	0.000
Syrek and Antoni (2014)	-0.484	-0.605	-0.341	-5.980	0.000
Loft and Cameron (2014)	-0.490	-0.647	-0.293	-4.476	0.000
Barclay and Gregory (2010)	-0.520	-0.684	-0.306	-4.335	0.000
Syrek et al. (2017)	-0.530	-0.658	-0.372	-5.800	0.000
	-0.275	-0.308	-0.243	-15.755	0.000

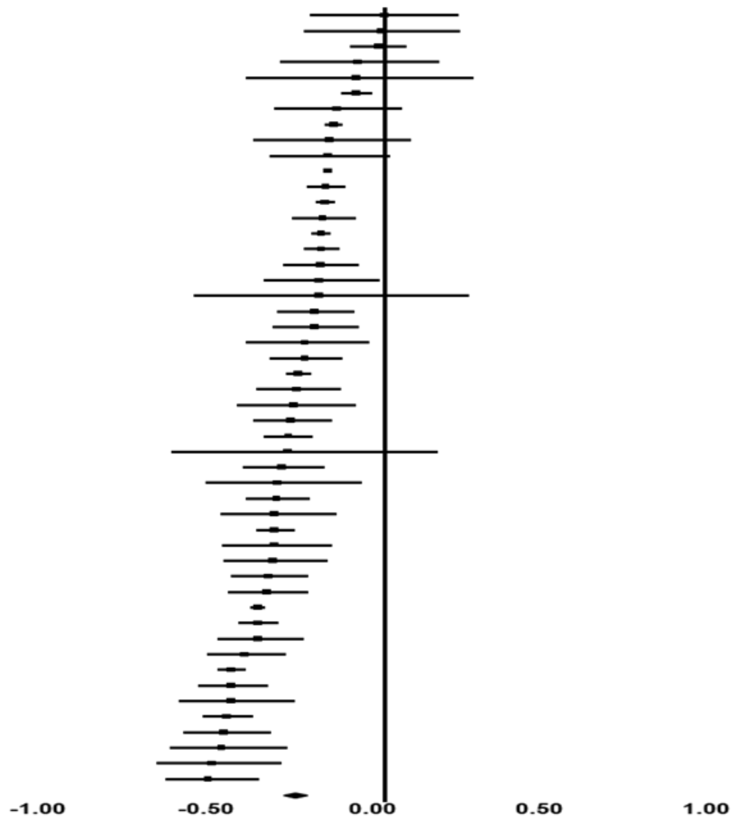

Figure B.1 Forest Plot of Correlations (*r*) between Overall PC and Sleep Quality

	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Tang and Harvey (2004)	0.043	-0.264	0.341	0.268	0.789
Zoccola et al. (2009)	-0.023	-0.257	0.213	-0.191	0.849
Omvik et al. (2007)	-0.024	-0.267	0.221	-0.193	0.847
Nota and Coles (2015)	-0.044	-0.259	0.176	-0.387	0.699
Takano et al. (2014)	-0.044	-0.173	0.086	-0.667	0.505
McGowan et al. (2016)	-0.082	-0.131	-0.033	-3.252	0.001
Baker et al. (2015)	-0.155	-0.333	0.034	-1.614	0.107
Van Laethem et al. (2016)	-0.172	-0.382	0.055	-1.487	0.137
Lin et al. (2017)	-0.180	-0.219	-0.141	-8.804	0.000
Weise et al. (2013)	-0.187	-0.493	0.161	-1.054	0.292
Stoia-Caraballo et al. (2008)	-0.200	-0.311	-0.084	-3.356	0.001
Thomsen et al. (2003)	-0.220	-0.386	-0.040	-2.391	0.017
Carciofo et al. (2017)	-0.251	-0.344	-0.153	-4.905	0.000
Yeh et al. (2015)	-0.290	-0.412	-0.158	-4.197	0.000
Wicklow and Espie (2000)	-0.300	-0.648	0.151	-1.314	0.189
Radstaak et al. (2014)	-0.740	-0.891	-0.441	-3.909	0.000
	-0.161	-0.216	-0.105	-5.598	0.000

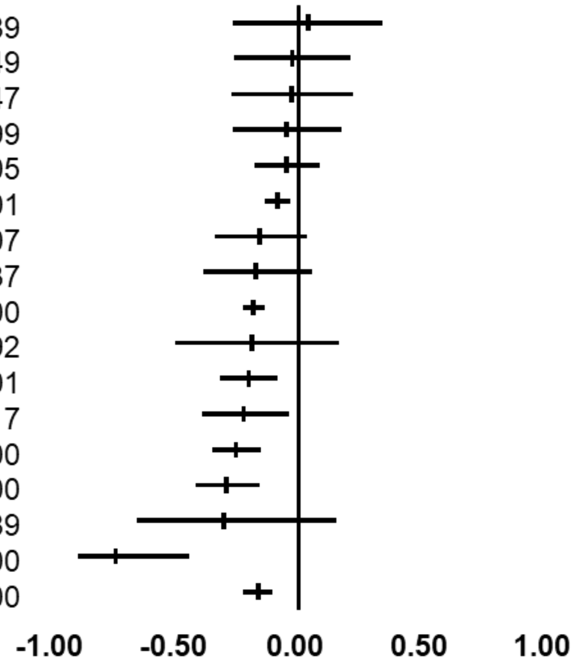

Figure B.2 Forest Plot of Correlations (*r*) between Overall PC and SOL

	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Omvik et al. (2007)	0.008	-0.234	0.249	0.064	0.949
Zoccola et al. (2009)	-0.028	-0.261	0.209	-0.225	0.822
Nota et al. (2016)	-0.070	-0.304	0.172	-0.563	0.574
Tang and Harvey (2004)	-0.075	-0.375	0.238	-0.465	0.642
Carciofo et al. (2017)	-0.083	-0.184	0.019	-1.589	0.112
McGowan et al. (2016)	-0.087	-0.136	-0.038	-3.476	0.001
Van Laethem et al. (2016)	-0.092	-0.311	0.136	-0.786	0.432
LaBrash et al. (2008)	-0.111	-0.247	0.030	-1.542	0.123
Fichten et al. (2001)	-0.134	-0.261	-0.001	-1.978	0.048
Bagley et al. (2015)	-0.140	-0.255	-0.021	-2.303	0.021
Baker et al. (2015)	-0.160	-0.338	0.029	-1.664	0.096
Yeh et al. (2015)	-0.161	-0.292	-0.024	-2.295	0.022
Cropley et al. (2006)	-0.210	-0.392	-0.012	-2.079	0.038
Lin et al. (2017)	-0.210	-0.249	-0.170	-10.189	0.000
Takano et al. (2014)	-0.234	-0.357	-0.102	-3.441	0.001
Kelly (2002)	-0.240	-0.361	-0.111	-3.604	0.000
Weise et al. (2013)	-0.244	-0.538	0.103	-1.387	0.165
Radstaak et al. (2014)	-0.250	-0.623	0.216	-1.055	0.291
Nota and Coles (2015)	-0.257	-0.450	-0.041	-2.322	0.020
	-0.149	-0.186	-0.112	-7.749	0.000

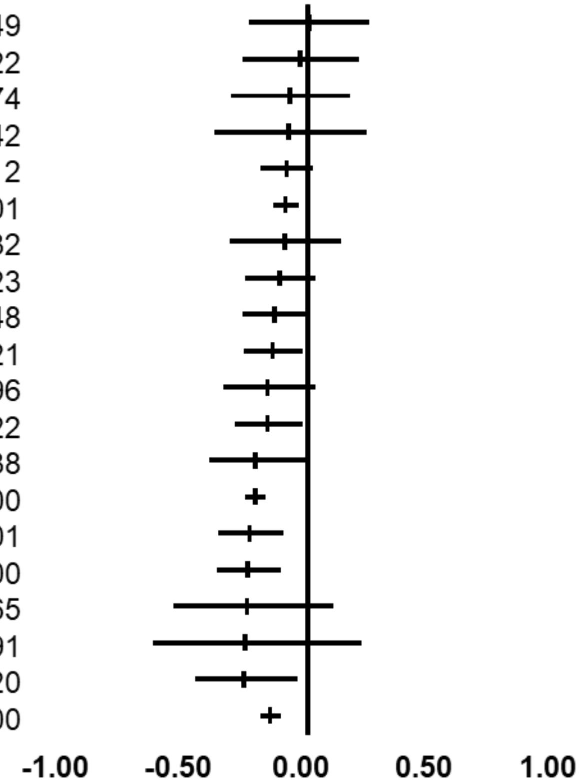

Figure B.3 Forest Plot of Correlations (*r*) between Overall PC and TST

Appendix C – Neuroticism Measure

Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex and age as yourself.

1. I often feel blue
2. I dislike myself
3. I am often down in the dumps
4. I have frequent mood swings
5. I panic easily
6. I rarely get irritated
7. I seldom feel blue
8. I feel comfortable with myself
9. I am not easily bothered by things
10. I am very pleased with myself

Response options: Very inaccurate, Moderately inaccurate, Neither accurate nor inaccurate, Moderately accurate, Very accurate

Appendix D – Penn State Worry Questionnaire

Rate each of the following statements on a scale of 1 (“not at all typical of me”) to 5 (“very typical of me”).

1. If I do not have enough time to do everything, I do not worry about it
2. My worries overwhelm me
3. I do not tend to worry about things
4. Many situations make me worry
5. I know I should not worry about things, but I just cannot help it
6. When I am under pressure I worry a lot
7. I am always worrying about something
8. I find it easy to dismiss worrisome thoughts
9. As soon as I finish one task, I start to worry about everything else I have to do
10. I never worry about anything
11. When there is nothing more I can do about a concern, I do not worry about it any more
12. I have been a worrier all my life
13. I notice that I have been worrying about things
14. Once I start worrying, I cannot stop
15. I worry all the time
16. I worry about projects until they are all done

Response options: 1 (not at all typical of me), 2, 3, 4, 5 (very typical of me)

Appendix E – Ruminative Responses Scale (Brooding)

People think and do many different things when they feel **down, sad or depressed**. Please read each of the items below and indicate whether you almost never, sometimes, often, or almost always think or do each one when you feel down, sad, or depressed. Please indicate what you generally do, not what you think you should do.

1. Think “What am I doing to deserve this?”
2. Think “Why do I always react this way?”
3. Think about a recent situation, wishing it had gone better
4. Think “Why do I have problems other people don’t have?”
5. Think “Why can’t I handle things better?”

Response options: Almost never, Sometimes, Often, Almost always

Appendix F – Ruminative Responses Scale (Reflection)

People think and do many different things when they feel **down, sad or depressed**. Please read each of the items below and indicate whether you almost never, sometimes, often, or almost always think or do each one when you feel down, sad, or depressed. Please indicate what you generally do, not what you think you should do.

1. Analyse recent events to try to understand why you are depressed
2. Go away by yourself and think about why you feel this way
3. Write down what you are thinking about and analyse it
4. Analyse your personality to try to understand why you are depressed
5. Go someplace alone to think about your feelings

Response options: Almost never, Sometimes, Often, Almost always

Appendix G – Perceived Stress Scale

The questions in this scale ask you about your feelings and thoughts **during the last month**. In each case, you will be asked to indicate *how often* you felt or thought a certain way.

1. In the last month, how often have you been upset because of something that happened unexpectedly?
2. In the last month, how often have you felt that you were unable to control the important things in your life
3. In the last month, how often have you felt nervous and “stressed”?
4. In the last month, how often have you felt confident about your ability to handle your personal problems?
5. In the last month, how often have you felt that things were going your way?
6. In the last month, how often have you found that you could not cope with all the things that you had to do?
7. In the last month, how often have you been able to control irritations in your life?
8. In the last month, how often have you felt that you were on top of things?
9. In the last month, how often have you been angered because of things that were outside of your control?
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

Response options: Never, Almost never, Sometimes, Fairly often, Very often

Appendix H – Chapter 4 Unhealthy Snacking Measure

On a **typical day in the past month**, how often did you have a serving of the following snacks in between breakfast, lunchtime and evening meals? (serving = normal portion for an adult)

1. Sugared squash/ still soft drinks (not including fruit juice)
2. Sugared fizzy drinks
3. Sausages, pies or burgers
4. Chips
5. Potato crisps
6. Savoury snacks
7. Ice cream
8. Cakes/ other sweet pastries
9. Sweet biscuits
10. Chocolate confectionery and sugared confectionery

Response options: Never / less than once a month; Less than once a week; Once a week; 2-4 days a week; 5-6 days a week; Once a day, everyday; 2-3 times a day, everyday; More than 3 times a day, everyday

Appendix I – Leisure Time Questionnaire

Considering a typical **7-day period (a week) in the past month**, how many times on average do you do the following kinds of exercise for **more than 15 minutes** during your **free time**?

1. **STRENUOUS EXERCISE (HEART BEATS RAPIDLY)** (i.e. running, jogging, hockey, football, soccer, squash, basketball, judo, roller skating, vigorous swimming, vigorous long distance bicycling). Times per week:

2. **MODERATE EXERCISE (NOT EXHAUSTING)** (i.e. fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming). Times per week:

3. **MILD EXERCISE (MINIMAL EFFORT)** (i.e. yoga, bowling, golf, easy walking). Times per week:

4. Considering a 7-day period (a week), during your leisure time in the past month, how often did you engage in any regular activity long enough to work up a sweat (heart beats rapidly)? Response options: Often, Sometimes, Never/Rarely

Appendix J – Chapter 4 Sleep Items

The following questions relate to your usual sleep habits **during the past month *only***. Your answers should indicate the most accurate reply for the ***majority* of days and nights in the past month**.

1. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?
2. During the past month, how many hours of *actual sleep* did you get at night?
3. During the past month, how would you rate your sleep quality overall?
   Response options: Very good, Fairly good, Fairly bad, Very bad

Appendix K – Chapter 4 Multicollinearity Tables

Table K. 1 Multicollinearity Statistics for TST

	Non-Standardised		Standardised	
	Tolerance	VIF	Tolerance	VIF
		Cross-Sectional		
Age	0.88	1.14	0.88	1.14
Sex[a]	0.95	1.06	0.95	1.06
BMI	0.88	1.14	0.88	1.14
Neuroticism	0.42	2.38	0.42	2.38
Worry	0.09	11.28	0.41	2.44
Brooding	0.05	18.98	0.36	2.75
Reflection	0.08	12.73	0.63	1.58
Stress	0.04	23.44	0.38	2.63
Stress x Worry	0.02	58.68	0.57	1.75
Stress x Brooding	0.02	56.19	0.46	2.16
Stress x Reflection	0.03	30.82	0.73	1.37
		Prospective		
TST T1	0.87	1.15	0.87	1.15
Age	0.84	1.19	0.84	1.19
Sex[a]	0.94	1.06	0.94	1.06
BMI	0.89	1.13	0.89	1.13

Neuroticism	0.41	2.42	0.41	2.42
Worry	0.08	12.78	0.39	2.56
Brooding	0.05	21.10	0.37	2.67
Reflection	0.07	14.39	0.66	1.51
Average Stress	0.04	22.47	0.37	2.70
Average Stress x Worry	0.02	63.67	0.54	1.87
Average Stress x Brooding	0.02	60.02	0.45	2.22
Average Stress x Reflection	0.03	32.70	0.72	1.40

Note. [a]Sex was not standardized as this variable is dichotomous

Table K. 2 Multicollinearity Statistics for Sleep Quality

	Non-Standardised		Standardised	
	Tolerance	VIF	Tolerance	VIF
		Cross-Sectional		
Age	0.88	1.14	0.88	1.14
Sex[a]	0.94	1.06	0.94	1.06
BMI	0.88	1.14	0.88	1.14
Neuroticism	0.42	2.40	0.42	2.40
Worry	0.09	11.13	0.40	2.48
Brooding	0.05	19.04	0.36	2.76
Reflection	0.08	12.74	0.63	1.58
Stress	0.04	22.65	0.38	2.63
Stress x Worry	0.02	57.23	0.56	1.80
Stress x Brooding	0.02	56.27	0.46	2.19
Stress x Reflection	0.03	30.87	0.72	1.38
		Prospective		
Sleep Quality T1	0.79	1.26	0.79	1.26
Age	0.87	1.16	0.87	1.16
Sex[a]	0.93	1.07	0.93	1.07
BMI	0.89	1.13	0.89	1.13
Neuroticism	0.41	2.46	0.41	2.46

Worry	0.08	12.42	0.39	2.59
Brooding	0.05	21.23	0.37	2.67
Reflection	0.07	14.33	0.66	1.51
Average Stress	0.05	21.25	0.36	2.80
Average Stress x Worry	0.02	61.31	0.51	1.96
Average Stress x Brooding	0.02	60.35	0.44	2.29
Average Stress x Reflection	0.03	32.67	0.71	1.41

Note. [a]Sex was not standardized as this variable is dichotomous

Table K. 3 Multicollinearity Statistics for Physical Activity

	Non-Standardised		Standardised	
	Tolerance	VIF	Tolerance	VIF
		Cross-Sectional		
Age	0.88	1.14	0.88	1.14
Sex[a]	0.94	1.06	0.94	1.06
BMI	0.88	1.14	0.88	1.14
Neuroticism	0.41	2.41	0.41	2.41
Worry	0.09	11.21	0.40	2.50
Brooding	0.05	19.10	0.36	2.77
Reflection	0.08	12.77	0.63	1.58
Stress	0.04	22.76	0.38	2.65
Stress x Worry	0.02	57.53	0.56	1.79
Stress x Brooding	0.02	56.39	0.46	2.18
Stress x Reflection	0.03	30.93	0.72	1.38
		Prospective		
Physical Activity T1	0.95	1.05	0.95	1.05
Age	0.89	1.13	0.89	1.13
Sex[a]	0.93	1.07	0.93	1.07
BMI	0.88	1.14	0.88	1.14
Neuroticism	0.41	2.42	0.41	2.42
Worry	0.08	12.58	0.39	2.59
Brooding	0.05	21.78	0.37	2.70

Reflection	0.07	14.38	0.66	1.50
Average Stress	0.05	20.91	0.37	2.69
Average Stress x Worry	0.02	61.17	0.51	1.95
Average Stress x Brooding	0.02	61.85	0.44	2.30
Average Stress x Reflection	0.03	32.69	0.71	1.40

Note. [a]Sex was not standardized as this variable is dichotomous

Table K. 4 Multicollinearity Statistics for Unhealthy Snacking

	Non-Standardised		Standardised	
	Tolerance	VIF	Tolerance	VIF
		Cross-Sectional		
Age	0.88	1.14	0.88	1.14
Sex[a]	0.93	1.08	0.93	1.08
BMI	0.88	1.13	0.88	1.13
Neuroticism	0.41	2.44	0.41	2.44
Worry	0.09	11.18	0.40	2.49
Brooding	0.05	19.02	0.36	2.79
Reflection	0.08	12.70	0.64	1.56
Stress	0.04	23.01	0.37	2.67
Stress x Worry	0.02	57.08	0.56	1.78
Stress x Brooding	0.02	56.11	0.46	2.19
Stress x Reflection	0.03	31.02	0.72	1.39
		Prospective		
Unhealthy Snacking T1	0.90	1.11	0.90	1.11
Age	0.89	1.13	0.89	1.13
Sex[a]	0.91	1.10	0.91	1.10
BMI	0.89	1.12	0.89	1.12
Neuroticism	0.41	2.46	0.41	2.46
Worry	0.08	12.92	0.37	2.71
Brooding	0.05	21.74	0.37	2.70

Reflection	0.07	14.12	0.68	1.47
Average Stress	0.05	21.62	0.37	2.69
Average Stress x Worry	0.01	67.21	0.47	2.11
Average Stress x Brooding	0.02	62.98	0.42	2.38
Average Stress x Reflection	0.03	32.22	0.72	1.39

Note. [a]Sex was not standardized as this variable is dichotomous

Table K. 5 Multicollinearity Statistics for Fruit and Vegetables

	Non-Standardised		Standardised	
	Tolerance	VIF	Tolerance	VIF
		Cross-Sectional		
Age	0.88	1.14	0.88	1.14
Sex[a]	0.94	1.06	0.94	1.06
BMI	0.88	1.14	0.88	1.14
Neuroticism	0.41	2.41	0.41	2.41
Worry	0.09	11.21	0.40	2.50
Brooding	0.05	19.10	0.36	2.77
Reflection	0.08	12.77	0.63	1.58
Stress	0.04	22.76	0.38	2.65
Stress x Worry	0.02	57.53	0.56	1.79
Stress x Brooding	0.02	56.39	0.46	2.18
Stress x Reflection	0.03	30.93	0.72	1.38
		Prospective		
Fruit and Vegetables T1	0.94	1.06	0.94	1.06
Age	0.88	1.14	0.88	1.14
Sex[a]	0.93	1.08	0.93	1.08
BMI	0.88	1.14	0.88	1.14
Neuroticism	0.41	2.43	0.41	2.43
Worry	0.08	12.45	0.38	2.61
Brooding	0.05	21.25	0.37	2.69

Reflection	0.07	14.43	0.66	1.51
Average Stress	0.05	21.20	0.37	2.67
Average Stress x Worry	0.02	61.19	0.51	1.95
Average Stress x Brooding	0.02	60.69	0.44	2.29
Average Stress x Reflection	0.03	32.85	0.70	1.43

Note. [a]Sex was not standardized as this variable is dichotomous

Table K. 6 Multicollinearity Statistics for Alcohol

	Non-Standardised		Standardised	
	Tolerance	VIF	Tolerance	VIF
		Cross-Sectional		
Age	0.88	1.14	0.88	1.14
Sex[a]	0.94	1.06	0.94	1.06
BMI	0.88	1.14	0.88	1.14
Neuroticism	0.41	2.41	0.41	2.41
Worry	0.09	11.21	0.40	2.50
Brooding	0.05	19.10	0.36	2.77
Reflection	0.08	12.77	0.63	1.58
Stress	0.04	22.76	0.38	2.65
Stress x Worry	0.02	57.53	0.56	1.79
Stress x Brooding	0.02	56.39	0.46	2.18
Stress x Reflection	0.03	30.93	0.72	1.38
		Prospective		
Alcohol T1	0.96	1.04	0.96	1.04
Age	0.87	1.14	0.87	1.14
Sex[a]	0.94	1.07	0.94	1.07
BMI	0.89	1.13	0.89	1.13
Neuroticism	0.41	2.44	0.41	2.44
Worry	0.08	12.40	0.38	2.61
Brooding	0.05	21.15	0.37	2.68

Reflection	0.07	14.40	0.66	1.52
Average Stress	0.05	21.22	0.37	2.67
Average Stress x Worry	0.02	61.17	0.52	1.94
Average Stress x Brooding	0.02	60.10	0.44	2.27
Average Stress x Reflection	0.03	32.74	0.71	1.42

Note. [a]Sex was not standardized as this variable is dichotomous

Appendix L – Chapter 5 Sleep Items

The following questions refer to last night's sleep.

1. How long did it take you to fall asleep? (e.g. 1 hour and a half = 01:30)

2. About how long did you sleep altogether?

3. How TIRED did you feel this morning? Response options: 1 (not at All), 2, 3, 4, 5 (Very)

Appendix M – Daily Hassles Measure

Please complete the following questions about the daily stressors or hassles you have experienced today. Space has been provided for reporting 6 separate daily hassles, only use as many as you need, you are not expected to fill them all.

Provide a brief description of each hassle/stressor you have experienced today, the time when you experienced it, and rate its **intensity** from *1 (Not at all Intense) to 5 (Very Intense).* Intensity is defined here as: *how severe/extreme your feelings were while you were experiencing the hassle.*

Daily hassles are defined as:
Events, thoughts or situations which, when they occur, produce negative feelings such as annoyance, irritation, worry or frustration, and/or make you subjectively aware that your goals and plans will be more difficult or impossible to achieve as a result.
This could be a hassle such as a physical injury to you or a loved one, missing a bus and being late for an appointment, or having a disagreement with a friend.

How intense was this stressor? Response option: 1 (Not at all Intense), 2, 3, 4, 5 (Very Intense)

Appendix N – Daily/State Worry Measure

The first question asks how often you have **worried** today. You are asked here to state how often you have worried today on a 5 point scale (1 = 'Never' to 5 = 'Very Often'). You are also asked to rate on a 5 point scale, how intense these worries were (1 = 'Not at all Intense' to 5 = 'Very Intense').

Worry is defined as:
Negative, repetitive thoughts about **future** *events which have the potential to be stressful or upsetting. These worrisome thoughts are usually distressing, can be difficult to control and can lead to a spiral of different worries.*
For example, worrying that you will not perform well in an exam tomorrow.

1. Today, **how often** did you **worry** or focus on negative things that may occur or happen to you in the **future**? Response options: 1 (Never), 2, 3, 4, 5 (Very Often)

2. If you worried today, how intense were these worries? Response Options: 1 (Not at all Intense), 2, 3, 4, 5 (Very Intense)

Appendix O – Daily/State Brooding Measure

This question asks how often you have **ruminated** today. You are asked to state how often you have ruminated today on a 5 point scale (1 = 'Never' to 5 = 'Very Often'). You are also asked to rate on a 5 point scale, how intense these ruminations were (1 = 'Not at all Intense' to 5 = 'Very Intense').

Rumination is defined as:
Negative, repetitive thoughts about upsetting emotions or events which have happened in the **past** *(including today). These ruminative thoughts are usually distressing, can be difficult to control and can lead to a spiral of different ruminations.*
For example, you may ruminate upon an exam question you felt you answered badly yesterday.

1. Today, **how often** did you **ruminate** over negative things that have happened to you or upset you in the **past (including today)**? Response options: 1 (Never), 2, 3, 4, 5 (Very Often)

2. If you ruminated today, how intense were these ruminations? Response Options: 1 (Not at all Intense), 2, 3, 4, 5 (Very Intense)

Appendix P – Chapter 5 Between-Meal Snacking Measure

The following questions ask you to detail any **between-meal snacks** you have consumed throughout **today**.

Please list each food or calorie-containing drink that you have consumed between meals today, the amount consumed and the time at which you had them (e.g. fruit, glass of fruit juice, can of cola, chocolate bar, packet of crisps, nuts, cakes).

Response: 8 free type response boxes

Appendix Q – IPAQ-SF

These questions will ask you about the **time you spent being physically active today**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and garden work, to get from place to place, and in your spare time for recreation, exercise or sport.

1. Think about all the **vigorous activities** that you did **today**. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. *Think only about those physical activities that you did for at least 10 minutes at a time.*

   a. Today, did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   b. If yes, how much time did you spend doing **moderate** physical activities on one of those days? (24 hour clock, 1 hour 10 minutes = 01:10)

2. Think about all the **moderate activities** that you did **today**. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. *Think only about those physical activities that you did for at least 10 minutes at a time.*

   a. Today, did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   b. If yes, how much time did you spend doing **moderate** physical activities on one of those days? (24 hour clock, 1 hour 10 minutes = 01:10)

3. Think about the time you spent **walking today**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

   a. Today, did you **walk** for at least 10 minutes at a time?

   b. If yes, how much time did you spend **walking** on one of those days? (24 hour clock, 1 hour 10 minutes = 01:10)

4. The last question is about the time you spent **sitting today**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.
    a. **Today**, how much time did you spend **sitting**? (24 hour clock, 1 hour 10 minutes = 01:10)