Investigating the development of children’s temporal memory across the primary school years

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Abstract

The examination of children's knowledge of, and memory for, temporal information is an under-researched area. In particular, very few studies have directly examined the relationship between different aspects of temporal memory. The current thesis therefore aimed to explore whether there was a relationship between short-term, episodic and semantic temporal memory for sequencing, duration and dating performance across the primary school years. Experiment 1 revealed that children's knowledge about time was independent of their ability to order elements within an experienced event, according to both the sequence in which the elements occurred and the duration of each element. Experiment 2 expanded upon this research; children's short-term temporal memory for sequencing and duration was found to develop independently of their knowledge about time and their episodic memory for sequencing and duration. Finally, Experiment 4 aimed to see whether there was a relationship between children's ability to date novel events, and their knowledge about dating concepts. This study found that these two abilities were not related during development. A further aim of this thesis was to explore whether novel methods could be employed to improve children's temporal performance. Experiment 3 found that a counting strategy could increase the accuracy of children's short-term duration reproductions, whilst a cumulative rehearsal technique aided children's short-term sequencing recall. Other methods to aid temporal performance were also explored in Experiment 5; while a timeline tool was not found to increase children's ability to sequence elements within an event, using a duration timeline was an effective way for children to represent the durations between daily activities. The implications of the current findings are highlighted, whilst further avenues of research are considered.

Table of Contents

Acknowledgments .... **iii**

Abstract .... **iv**

Table of Contents .... **v**

List of Tables .... **xiv**

List of Figures .... **xvi**

Chapter 1: Literature Review **1**

1.1. Temporal Memory Overview **1**

1.2. Application of Research **3**

1.3. Dating **5**

1.3.1. Dating Theories 6

1.3.2. Dating Annual Events 7

1.3.3. Dating Novel Experienced Events 8

1.3.4. Dating Staged Classroom Events 11

1.3.5. Dating in Forensic Settings 13

1.3.6. Dating Summary 14

1.4. Sequencing **14**

1.4.1. Sequencing Theories 15

1.4.2. Episodic Sequencing 16

1.4.3. Short-Term Sequencing 22

1.4.4. Sequencing Summary 24

1.5. Duration **25**

1.5.1. Duration Theories 25

1.5.2. Episodic Duration 27

1.5.3. Short-Term Duration 30

1.5.4. Duration Summary 33

1.6. Semantic Temporal Memory **33**

1.7. Children's Metamemory **35**

1.8. Review Conclusions **37**

1.9. Chapter Overview **39**

Chapter 2: Investigating the Relationship between Semantic Temporal Memory and Episodic Temporal Memory for Novel Events **41**

2.1. Introduction **41**

2.1.1. Episodic Temporal Memory 41

2.1.2. Semantic Temporal Memory 43

2.1.3. Potential Implications 43

2.2. Aims and Hypotheses **44**

2.3. Semantic Memory Pilot Study **45**

2.3.1. Method 45

2.3.1.1. Participants 45

2.3.1.2. Materials 45

2.3.1.3. Procedure 46

2.3.2. Results and Discussion 46

2.4. Method **48**

2.4.1. Participants 48

2.4.2. Materials 48

2.4.2.1. Semantic Temporal Memory Questionnaire 48

2.4.2.2. Episodic Film 49

2.4.3. Procedure 49

2.4.3.1. Semantic Temporal Memory Questionnaire 50

2.4.3.2. Episodic Film 50

2.4.4. Scoring 51

2.4.4.1. Semantic Temporal Memory Questionnaire 51

2.4.4.2. Episodic Sequencing Task 51
2.4.4.3. Episodic Duration Task 52
2.5. Results 52
2.5.1. Semantic Temporal Memory 52
2.5.2. Episodic Free Recall 54
2.5.3. Episodic Sequencing: Ordering Task 54
2.5.4. Episodic Duration: Ordering Task 56
2.5.5. Relationship between Episodic Ordering Tasks 58
2.5.6. Episodic Duration: Verbal Questions 59
2.6. Discussion 62
2.6.1. Exploring Relationships 62
2.6.2. Development of Temporal Abilities 64
2.6.2.1. Semantic Temporal Memory 64
2.6.2.2. Episodic Temporal Memory 65
2.6.3. Temporal Memory Theories 68
2.6.4. Future Research 69
2.6.5. Conclusion 70
Chapter 3: Exploring Short-Term Temporal Abilities and Metamemory Judgments 71
3.1. Introduction 71
3.1.1. Short-Term Sequencing 71
3.1.2. Short-Term Duration 73
3.1.3. Metamemory Judgements 75
3.2. Aims and Hypotheses 77
3.3. Method 78
3.3.1. Participants 78
3.3.2. Materials 78

3.3.2.1. Short-Term Sequencing Task 78

3.3.2.2. Short-Term Duration Task 79

3.3.2.3. Metamemory Measures 81

3.3.3. Procedure 81

3.3.4. Scoring 82

3.3.4.1. Short-Term Sequencing 82

3.3.4.2. Short-Term Duration 82

3.3.4.3. Metamemory Strategy Judgments 83

3.4. Results 83

3.4.1. Short-Term Sequencing 83

3.4.1.1. Movement and Position of Items 83

3.4.1.2. Sequencing Score 86

3.4.2. Short-Term Duration 87

3.4.3. Relationship between Semantic and Episodic Memory 89

3.4.4. Sequencing Metamemory Judgments 90

3.4.4.1. Performance Judgments 90

3.4.4.2. Difficulty Estimates 91

3.4.4.3. Strategy Use 92

3.4.5. Duration Metamemory Judgments 92

3.4.5.1. Performance Judgments 92

3.4.5.2. Difficulty Estimates 93

3.4.5.3. Strategy Use 94

3.5. Discussion 95

3.5.1. Sequencing 95

3.5.2. Duration 98

3.5.3. Relationship between Aspects of Temporal Memory 101

3.5.4. Metamemory Judgments 103

3.5.5. Conclusion ... 105

Chapter 4: The Effects of Strategies and Suppression on Short-Term Temporal Memory ... 107

4.1. Introduction ... 107

4.1.1. Sequencing Strategies ... 108

4.1.2. Duration Strategies ... 110

4.1.3. Articulatory Suppression ... 111

4.2. Aims and Hypotheses ... 112

4.3. Method ... 112

4.3.1. Participants ... 112

4.3.2. Design ... 113

4.3.3. Materials ... 113

4.3.3.1. Short-Term Sequencing Task ... 113

4.3.3.2. Short-Term Duration Task ... 114

4.3.4. Procedure ... 114

4.3.4.1. Time 1 ... 114

4.3.4.2. Time 2: Strategy Condition ... 115

4.3.4.3. Time 2: Suppression Condition ... 116

4.3.5. Scoring ... 116

4.3.5.1. Short-Term Sequencing Task ... 116

4.3.5.2. Short-Term Duration Task ... 116

4.4. Results ... 117

4.4.1. Sequencing Results ... 117

4.4.1.1. Time 1 Sequencing ... 117

4.4.1.2. Time 2 Sequencing ... 120

4.4.2. Duration Results ... 125

4.4.2.1. Time 1 Duration ... 125

4.4.2.2. Time 2 Duration 126

4.5. Discussion 129

4.5.1. Impact of Strategies 129

4.5.1.1. Increases in Performance 129

4.5.1.2. Attenuated Age Effects 130

4.5.2. Impact of Suppression 132

4.5.2.1. Reductions in Performance 132

4.5.2.2. Attenuated Age Effects 134

4.5.3. Application of Research 135

4.5.4. Further Areas of Research 135

4.5.5. Conclusion 136

Chapter 5: Children's Dating of Experienced Events 137

5.1. Introduction 137

5.1.1. Episodic Memory for Dating 138

5.1.2. Impact of a Delay on Dating Ability 139

5.1.3. Semantic Temporal Memory for Dating 139

5.2. Aims and Hypotheses 140

5.3. Semantic Memory Dating Questionnaire Pilot Study 141

5.3.1. Method 141

5.3.1.1. Participants 141

5.3.1.2. Materials 141

5.3.1.3. Procedure 141

5.3.2. Results and Discussion 141

5.4. Method 143

5.4.1. Participants 143

5.4.2. Materials 143

5.4.2.1. Dating Questions 143

5.4.2.2. Semantic Memory Dating Questionnaire 144

5.4.3. Procedure 144

5.4.4. Scoring 145

5.5. Results 146

5.5.1. Relative Recency 147

5.5.2. Dating Accuracy 147

5.5.3. Semantic Memory Dating Questionnaire 150

5.6. Discussion 151

5.6.1. The Effect of Delay 151

5.6.2. Relationship between Aspects of Temporal Memory 152

5.6.3. Age Effects in Dating 153

5.6.4. Application to Forensic Settings 153

5.6.5. Further Areas of Research 154

5.6.6. Conclusion 155

Chapter 6: Exploring the Impact of a Timeline Tool on Temporal Memory 156

6.1. Introduction 156

6.1.1. Sequencing 157

6.1.2. Duration 159

6.2. Aims and Hypotheses 161

6.3. Method 161

6.3.1. Participants 161

6.3.2. Design 162

6.3.3. Materials 162

6.3.3.1. Sequencing Film 162

6.3.3.2. Temporal Timeline 162

6.3.3.3. Working Memory Measure 162

6.3.3.4. Duration Story and Activity Cards 162

6.3.4. Procedure 163

6.3.4.1. Sequencing Task 163

6.3.4.2. Duration Task 164

6.3.5. Scoring 166

6.3.5.1. Sequencing Task 166

6.3.5.2. Duration Task 167

6.3.5.3. Working Memory Measure 167

6.4. Results 168

6.4.1. Sequencing 168

6.4.1.1. Item Recall 168

6.4.1.2. Sequencing Ability 169

6.4.2. Duration 171

6.4.2.1. Placement of Activities 171

6.4.2.2. Duration Intervals 173

6.5. Discussion 175

6.5.1. Sequencing 175

6.5.2. Duration 179

6.5.3. Conclusion 181

Chapter 7: General Discussion 182

7.1. Overview 182

7.2. Original Contributions to Research Area 182

7.3. Summary of Key Findings 184

7.3.1. Experiment 1: Episodic and Semantic Temporal Memory 185

7.3.2. Experiment 2: Short-Term Temporal Memory and Metamemory 186

7.3.3. Experiment 3: Impact of Strategies and Suppression 187

7.3.4. Experiment 4: Children’s Dating Abilities 187

7.3.5. Experiment 5: The Effectiveness of a Timeline Tool 188

7.4. Further Considerations and Future Directions..188

7.4.1. Generalising Findings to Different Settings...189

7.4.2. The Effect of Delay upon Performance..189

7.4.3. Widening the Age Range Examined 190

7.5. Research Implications..191

7.5.1. Legal Settings 192

7.5.2. Educational Settings 193

7.6. Conclusion..194

References 195

Appendix A: Ethics Certificate..210

Appendix B: Initial School Contact Letter 211

Appendix C: Parental Consent (Exp. 1-4) 212

Appendix D: Parental Consent (Exp. 5)...213

Appendix E: Pilot Temporal Memory Questionnaire and Scoring (Exp. 1) 214

Appendix F: Temporal Memory Questionnaire (Exp. 1).......................................217

Appendix G: Script and Items from the Episodic Film (Exp. 1) 219

Appendix H: Task Instructions (Exp. 1)......................... Error! Bookmark not defined.

Appendix I: Task Instructions (Exp. 2) .... Error! Bookmark not defined.

Appendix J: Task Instructions (Exp. 3)...225

Appendix K: Pilot Dating Questionnaire and Scoring (Exp. 4).............................227

Appendix L: Dating Questionnaire (Exp. 4)..228

Appendix M: Task Instructions (Exp. 4) 229

Appendix N: Timeline Instructions for Sequencing Task (Exp. 5) 230

Appendix O: Working Memory Measure – Backwards Span Task and Instructions (Exp. 5) 231

Appendix P: Task Instructions, Distancing Story and Activity Cards (Exp. 5)....233

List of Tables

Table 1.1: National Curriculum teaching of temporal concepts....................................... 4

Table 2.1: Percentage of questions correct on the pilot semantic memory questionnaire 46

Table 2.2: Percentage of questions correct on the semantic memory questionnaire...... 53

Table 2.3: Average number of items recalled from the film in each year group 54

Table 2.4: Sequencing score on the episodic task 56

Table 2.5: Duration ordering score on the episodic task 58

Table 2.6: Difference in seconds away from the correct duration for three items 60

Table 2.7: Average time difference (seconds) for the cumulative score and film length 61

Table 3.1: Strategy use classification system 83

Table 3.2: Sequencing score on the short-term task.. 86

Table 3.3: Duration score on the short-term task 88

Table 3.4: Performance estimates on the short-term sequencing task............................ 90

Table 3.5: Difficulty estimate on the short-term sequencing task.................................. 91

Table 3.6: Strategy use on the short-term sequencing task 92

Table 3.7: Performance estimates on the short-term duration task 93

Table 3.8: Difficulty estimate on the short-term duration task 94

Table 3.9: Strategy use on the short-term duration task 94

Table 4.1: Sequencing score at time 1.. 119

Table 4.2: Strategy use on the sequencing task at time 1 120

Table 4.3: Sequencing score at time 1 and time 2 for strategy and suppression conditions 123

Table 4.4: Duration score at time 1 125

Table 4.5: Strategy use on the duration task at time 1.. 126

Table 4.7: Duration score at time 1 and time 2 for strategy and suppression conditions 127

Table 5.1: Percentage of questions correct on the pilot dating questionnaire 142

Table 5.2: Dating questions asked about the staged event 144

Table 5.3: Accuracy on the relative recency task 147

Table 5.4: Percentage of correct answers to questions about the staged events 148

Table 5.5: Total dating score across all 10 questions about the staged events 150

Table 5.6: Percentage of questions correct on the dating questionnaire 150

Table 6.1: Individual elements within the film 166

Table 6.2: Recall of information from the film 168

Table 6.3: Sequencing ability (total pairs and adjaent pairs 170

Table 6.4: Placement of activity cards along the timeline (in cm) 172

Table 6.5: Duration intervals between activities (in cm) 174

List of Figures

Figure 2.1: Movement of items from the correct position on the episodic sequencing task ... 55

Figure 2.2: Proportion of items in the correct position on the episodic sequencing task ... 55

Figure 2.3: Movement of items from the correct position on the episodic duration task ... 57

Figure 2.4: Proportion of items in the correct position on the episodic duration task ... 57

Figure 2.5: Difference in performance between episodic sequencing and duration tasks ... 59

Figure 3.1: Example screen-shots of the short-term sequencing task ... 79

Figure 3.2: Example screen-shots of the short-term duration task ... 80

Figure 3.3: Movement of items from the correct position on the short-term sequencing task ... 84

Figure 3.4: Position each item was placed (from 1-6) for all six items ... 85

Figure 3.5: Proportion of items in the correct position on the short-term sequencing task ... 86

Figure 3.6: Range of responses at each duration ... 87

Figure 3.7: Relative difference between reproduced durations and true durations ... 88

Figure 3.8: Correlation between sequencing score and duration score ... 89

Figure 4.1: Movement of items from the correct position at time 1 ... 117

Figure 4.2: Position each item was placed (from 1-6) for all six items at time 1 ... 118

Figure 4.3: Proportion of items in the correct position at time 1 ... 119

Figure 4.4: Movement of items from the correct position at time 1 and time 2 ... 121

Figure 4.5: Proportion of items in the correct position at time 1 and time 2 ... 122

Figure 4.6: Condition x time interaction (across age groups) for sequencing score ... 124

Figure 4.7: Condition x time interaction (across age groups) for duration score ... 128

Figure 5.1: Task x age interaction for the short-term and episodic dating scores 149

Figure 6.1: Order of task completion for Experiment 5 163

Figure 6.2: Duration intervals between activity pairs (in hours and minutes) 175

Figure 7.1: Schematic representation: Relationship between aspects of temporal memory 184

Figure 7.2: Schematic representation: Impact of temporal interventions 185

Chapter 1: Literature Review

1.1. Temporal Memory Overview

Temporal memory refers to our memory for time. The ability to remember temporal information is a vital feature of autobiographical memory (Friedman & Lyon, 2005), giving a context to a recollection about one's own life. Without information about when an event occurred, how long it lasted or the order of elements within the event, a complete picture cannot be built, meaning potentially vital information about the event will be lacking. Research into the development of temporal memory in children is limited.

Initial research into temporal memory development was conducted by Piaget (1971). Following a number of experiments (e.g. asking children which of two objects moved for a longer duration), Piaget concluded that children's temporal cognition was different to that of adults. Piaget believed that it was not until children passed through a number of developmental stages that they developed an understanding of time – a process that occurred by around 9 or 10 years of age (Orbach & Lamb, 2007). However, subsequent research suggests that temporal memory develops at a much earlier age. Infant studies have shown the emergence of certain temporal abilities at a pre-verbal stage (Bauer & Mandler, 1992; Columbo & Richman, 2002), whilst children have been found to regularly make reference to the past, present and future in their speech by 3 years (Ames, 1946). The literature review will highlight the available research into the development of temporal memory in children. The current thesis examined temporal memory in children between the ages of six and eleven. This sample was chosen to encapsulate the age span of British primary schools, whilst ensuring that children were old enough to understand the task instructions. Temporal research with children over twelve years of age (i.e. at secondary school) is less common (Chelonis, Flake, Baldwin, Blake, & Paule, 2004; Forman, Mantyla, & Carelli, 2011; Friedman, 1986, 2007). Children were recruited from every other school year from Year 2 upwards (i.e. Year 2, Year 4 and Year 6); this was to ensure that the age groups were not too similar and allowed for age effects to be uncovered.

Temporal memory research can be separated into three distinct categories for investigation: short-term, episodic and semantic memory. Short-term temporal memory is our ability to remember temporal information for a short period of time, e.g. the order of images or the duration of tones. Episodic temporal memory is our ability to remember temporal information about personally experienced events, recalled in the context of a certain time and place (Tulving, 2001). Examples of episodic temporal memory include remembering how long a birthday party lasted for, or the order the animal enclosures were visited on a trip to the zoo. Finally, semantic temporal memory refers to our memory for time patterns, i.e. our knowledge about time, e.g. the number of minutes in an hour or the order of the days of the week. This semantic knowledge is often taught as part of the National Curriculum in primary schools in England and many other countries throughout the world.

It follows that ‘temporal memory’ is a broad umbrella term, encompassing different aspects of memory for time: i.e. frequency/number of occurrences, dating, sequencing and duration. Frequency of occurrence, also referred to as ‘rate of occurrence’, describes how often an event occurred. This could be going to a yoga class once a fortnight or eating three times a day. Similarly, number of occurrences is the number of times something happened, e.g. going to Spain four times, or moving house twice.

The ability to know when an event occurred can be described as ‘dating’. Location-based dating refers to an externally referenced period of time, such as the summer, or a certain date, e.g. the 7th of July. In contrast, distance-based dating refers to the amount of time that has passed since the event occurred (e.g. ‘9 months’). In order for children to be able to date an event, they require episodic memories containing temporal information, semantic memory about time patterns and executive processes to integrate these two forms of memory (Friedman & Lyon, 2005). Dating is the most researched area of temporal memory, with a number of studies being conducted by Friedman (Friedman, 1992a; Friedman, Gardner, & Zubin, 1995; Friedman & Kemp, 1998; Friedman & Lyon, 2005).

Sequencing refers to ordering events from start to finish, i.e. in the correct chronological order. When ordering familiar events, we possess a schematic representation. A common schematic representation is a daily sequence; in a typical day, we would have breakfast, go to school or work, have lunch, return home, have dinner and go to bed. We are also able to sequence elements of a novel event, e.g. going jet-skiing. Sequencing events, whether familiar or novel, is known as episodic sequencing. We can sequence short-term information; this requires individuals to remember a sequence for a few seconds before recall. Examples include remembering a sequence of digits making up a phone number, or recalling a pattern. Infant research suggests that children begin to include temporal order information in their event representations under certain conditions from a very young age (Bauer & Mandler, 1989), but the developmental trajectory of sequencing abilities in older children is an under-researched area of temporal memory.

A final aspect of temporal memory relates to the duration of an event, i.e. how long something lasts, from start to finish. Examples could include a television show lasting 30 minutes or a holiday lasting 2 weeks. Duration is represented by a number of different time units, e.g. seconds, minutes, hours, days or longer. Like sequencing, the duration being judged could be an experienced event such as a car journey from London to Scotland (referred to as ‘episodic duration’) or a duration lasting only a few seconds, such as a bulb being lit or a tone being heard (referred to as ‘short-term duration’). As noted by Block, Hancock and Zakay (2000), many everyday cognitive situations require durations to be estimated; it is therefore important for researchers to develop an understanding of when these abilities emerge during childhood. Although there are several studies investigating short-term memory for duration (Espinosa-Fernandez, de la Torre Vacas, Garcia-Viedma Mdel, Garcia-Gutierrez, & Torres Colmenero, 2004; Mantyla, Carelli, & Forman, 2007), there is a lack of systematic, rigorous research examining children’s memory for the duration of experienced events.

1.2. Application of Research

Understanding children’s temporal memory abilities can have useful applications to real-world settings. An area where temporal memory research could be beneficial is the field of education. Understanding when children can fully grasp how long something lasts for, or the order of events, can help to shape their learning experience; it is of little use trying to get a child to complete a task which requires such skills if they have not yet reached the appropriate level of development. A child may be told that they have 10 minutes to complete the task they are currently working on, or they may be informed that a special assembly will last 30 minutes; this use of time concepts may not benefit younger children if they have not yet grasped these units of time. Similarly, a child may be provided with a sequence of steps they have to remember in order to make something in an arts and crafts lesson; giving children a list of actions to carry out will be unhelpful if they cannot remember the order of the different tasks over a range of minutes or longer. A greater knowledge of children's temporal abilities could potentially lead to a set of guidelines to help teachers deal with both teaching and using time concepts across the primary school years.

Some aspects of temporal memory are taught in line with the National Curriculum, which governs teaching practices employed in primary schools in England (Department for Education, 2013). Table 1.1 outlines the different ages at which children are taught temporal concepts. Children were recruited from primary schools which were closely aligned in their teaching to the National Curriculum. After Year 3, there is no further formal teaching of temporal concepts outlined across the primary school years.

Table 1.1: National Curriculum teaching of temporal concepts

School Year	Temporal Concept Taught
Year 1 (ages 5-6 years)	Sequencing events in chronological order using language such as 'before', 'after', 'next' Recognising and using dating language, e.g. the days of the week, months and years
Year 2 (ages 6-7 years)	The number of minutes in an hour and hours in a day
Year 3 (ages 7-8 years)	Estimating time to the nearest minute Comparing the durations of events

A further area which may benefit from an understanding of when temporal abilities develop is the field of eyewitness testimony. The child is often the only witness in trials relating to alleged sexual abuse (Chae, 2010); this means that the accuracy of a child's testimony is of crucial importance in reaching the correct verdict. As well as asking children about what happened, it is important that both the prosecution and defence gather temporal information about the event. Knowing the order in which events occurred, when the alleged incident happened, and how long it lasted for can all help to build a case. Knowledge of when children become proficient at dealing with sequencing, duration and dating questions can allow a jury to take into consideration the credibility of the temporal information provided by the child. Being able to provide accurate temporal information will maximise the coherence of a child’s testimony and ensure that they are perceived as credible witnesses; this in turn may increase the likelihood of the correct verdict being reached (Klettke, Graesser, & Powell, 2010; Voss, Wiley, & Sandak, 1999).

Unfortunately, legal professionals sometimes fail to consider the level of temporal knowledge that a child possesses during questioning. In the United Kingdom, interviewers dealing with child witnesses are expected to follow guidelines set out in the Home Office (2011) protocol ‘Achieving Best Evidence’. This protocol acknowledges that children have difficulty dealing with dates, times and the length and frequency of events. The document provides age norms for telling the time (7 years) and understanding days of the week and the seasons (at least 8 years), although it is advised that this information is used as a guide only. Nevertheless, Davies and Fuery (2009) noted that precise temporal questions are often asked of child witnesses, with no consideration of their developmental age. Further research has found that interviewers fail to follow established guidelines (Warren, Woodall, Hunt, & Perry, 1996). Waterman and Blades' (unpublished data) examination of video-recorded interviews made by West Yorkshire Police's child protection unit demonstrated the regularity with which temporal questions are asked; at least one form of temporal question was asked in each interview analysed, and many interviews contained large numbers of temporal questions. In a review of forensic interviews conducted with child witnesses in New Zealand, Hanna et al. (2010) found that the number of difficult concepts asked of the child (e.g. when something happened, how often it occurred or how long it lasted) did not differ depending on the child’s age.

1.3. Dating

Of the limited research on children’s temporal memory, most has investigated children’s ability to make dating judgements. Being able to locate an event in time is a crucial skill; memories need to be anchored to a time period in order to shape the narrative of our lives. It is rare for an individual to be able to recall the exact date of when an event occurred. Instead, events can be judged in relation to anchors; this may be a key date such as a birthday or Christmas, and other events can be judged relative to this date, e.g. ‘it was the week before Christmas’. Alternatively, characteristics of the event itself can help to define when exactly an event occurred; cold weather or the wearing of shorts may give some indication of the season in which an event occurred. Similarly, constraints in certain situations may help to narrow down when an event occurred; in the case of children, knowing that an event happened during school time would naturally rule out it occurring on a Saturday or a Sunday (for more detailed information, see Betz & Skowronski, 1997). The competing explanations of dating will be outlined, before the available literature will be reviewed.

1.3.1. Dating Theories

Friedman (1993) hypothesised that there are both location-based processes and distance-based processes involved when dating an event. Location-based processes involve linking an event to a point in time; this could be a conventional time pattern (e.g. a month of the year) or a personal time pattern (e.g. at university). Information about when an event occurred is thought to be stored with the memory at the time of encoding; researchers have suggested that temporal information is ‘tagged’ onto the memory for later retrieval (Glenberg, 1987; Hasher & Zacks, 1979). Further location-based theories propose that contextual information about an event, such as the individual’s internal state, is stored alongside the memory. At retrieval, individuals interpret this additional information, such as how cold they were, to make assumptions about temporal qualities of the event. For example, wearing a scarf whilst living in university accommodation could indicate winter during 2006 to 2009. Friedman (1993) concluded that location information is vital in our ability to recall temporal information about an event. This general knowledge about time patterns allows us to place an event on a number of timescales.

Distance-based processes involve the individual estimating how much time has passed between the event in question and the present, e.g. 3 minutes or 6 months. Judgments are made based upon varying properties of memories. For example, the amount of detail recalled can provide an indication of when an event occurred; Brown, Rips, and Shevell (1985) suggested that an event will seem more recent if we can recall more detail about it. The strength of the memory trace will decline over time due to decay or interference; a lack of clarity about an event might indicate that it happened a long time ago. Distance theories also suggest that events are stored in memory in the order they occur, meaning that newer events are placed at the forefront of our memory, moving previous events further into the past (Murdock, 1974). Research looking at children's ability to make relative recency judgments (i.e. which of two events occurred most recently) suggests that distance-based information can help even pre-school children to judge when an event occurred, despite their lack of understanding about timescales (Friedman et al., 1995; Friedman & Kemp, 1998). These two forms of dating are thought to be independent; distancing abilities have been shown to develop at an earlier age than locating abilities (Friedman, 1991, 1992a). This implies the two processes of dating are distinct from each other.

In addition to the location and distancing theories, researchers have also put forward order theories to explain children's dating abilities. These theories are based on the relative times of occurrence; events are believed to be associated with those preceding or succeeding them in time, e.g. knowing you went to Florida before you bought a house (Lewandowsky & Murdock, 1989). Researchers have suggested that the before-after relation between items is automatically stored (Tzeng & Cotton, 1980). However, order theories are only able to account for how the order of events is stored, rather than when something happened or how long ago it was. Location, distance and order theories are therefore each able to explain different aspects of dating abilities.

1.3.2. Dating Annual Events

Researchers have investigated children's ability to date annual events, i.e. events which children experience on a yearly basis (Friedman, 1992a, 2000, 2002; Friedman et al., 1995; Friedman & Kemp, 1998). Friedman et al. (1995) examined the abilities of children between 4 and 12 years of age to judge which of two annual events (Christmas and their birthday) occurred a 'long' time ago and which occurred a 'short' time ago (known as a 'relative recency' judgment). When children's birthdays occurred in the near future, 10 and 11 year olds were fairly accurate (90% correct), compared to children below 9 years (30% correct). However, when birthdays had occurred in the near past (i.e. the last 2 months), 94% of 4 and 5 year olds were able to make accurate relative recency judgments. In contrast, the closer children's birthdays got to Christmas (i.e. occurring in November or December), the worse their performance was in judging relative recency. This illustrates that although young children were able to make accurate recency judgments when two events did not occur closely in time, errors occurred when the two events happened within a shorter time period.

Friedman (1992a) asked 4, 6 and 8 year olds to make relative recency judgments about four annual events: Christmas, Easter, the 4th of July and their birthday. Children were also asked which month the different events occurred in. The results showed that children at all ages performed at levels below chance when making temporal comparisons between two events in the past; 58% of 4 year olds answered correctly, compared to 55% of 6 year olds and 58% of 8 year olds. When asked to estimate the month the events occurred in, it was evident that the youngest group struggled with this task; the only event which produced a significant proportion of accurate answers was the month of the child's birthday, for which 68% of children were accurate. By 6 and 8 years of age, a significant proportion of children correctly provided the correct month for Christmas (36% and 89% respectively), the 4th of July (32% and 67%) and their birthday (86% and 94%).

1.3.3. Dating Novel Experienced Events

The two studies described above suggest some developmental increases in dating annual events, although children struggled to differentiate between events which occurred closely in time. However, annual events are discussed widely and children learn information about them from an early age, e.g. Christmas occurs in the winter and it sometimes snows. In contrast, asking children about a novel event (i.e. an event that they have very little or no previous experience of) instead relies upon their recall of a specific event and its location in time. This is a more accurate reflection of what children can remember about when an event occurs, rather than the semantic information they have been taught about such events. Several researchers have therefore investigated children's ability to date relatively novel experienced events (Friedman, Cederborg, Hultman, Anghagen, & Magnusson, 2010; Friedman & Kemp, 1998; Friedman, Reese, & Dai, 2010; Pathman, Doydum, & Bauer, 2013; Pathman, Larkina, Burch, & Bauer, 2013).

Friedman and Kemp (1998) examined children's ability to accurately judge the relative recency of two previously experienced events from the school calendar. Children between the ages of 5 and 7 years made relative recency judgements between a variety of experienced events, including class trips (e.g. to a nature reserve) and visitors to the school (e.g. a policeman); for each pair of events, children had to indicate which one was a long time ago and which one was a short time ago. Children's overall accuracy rate was 52%; this indicates that children were unable to reliably discriminate between when two experienced events occurred, suggesting a difficulty in making relative recency judgments for novel events.

In addition to making relative recency judgments about novel events, researchers have also examined children’s ability to date an event using a number of time scales. Friedman, Reese, et al. (2010) looked at the ability of 8 to 12 year olds to date novel, parent-nominated events from up to 4 years in the past. Parents generated a number of events that the child had experienced, both at school and at home. Parents were instructed to think of events that were unique enough not to be confused with previously similar occurrences (e.g. school productions of The Wiz or a family day trip to Wellington Zoo). Children were questioned about when the event occurred on five timescales: time of day, month, season, calendar year and school year. There were no significant age differences on the five timescales, suggesting that 8 year olds were as capable at dating events as 12 year olds. However, dating inaccuracies were present; children produced an average inaccuracy in their judgements of 1.5 to 2 months from when the event occurred. On time of day judgements, children produced an average inaccuracy of less than 2 hours from when the event occurred. As would be expected, retention interval was found to affect performance, with children’s accuracy decreasing over longer periods of time; events which occurred up to 4 years in the past proved more difficult for children to date than those occurring a few months previously.

Further research into dating novel parent-nominated events was conducted by Pathman, Larkina, et al. (2013), who gave parents a calendar and asked them to provide examples of events experienced by their child over the past 4 months. Parents were instructed to select events that were unique to the child and particularly memorable. Examples of events included a trip to a children’s museum and a friend’s birthday party. Four events, at least 4 weeks apart from each other, were presented to children aged 4, 6 and 8 years. A relative recency judgment was made between two of the events, where children indicated which event occurred a long time ago and which event occurred a short time ago. Children also dated the events on four timescales: time of day, day of the week, month of the year and season. Four year olds were unable to accurately judge the relative recency of the two events; they did not perform at levels above chance (52% correct). In contrast, the 6 and 8 year olds were performing at levels above chance (85% correct and 93% correct respectively). An overall dating ability score was computed, based on the time of day, day of the week, month and season timescales. Performance was found to significantly increase with age; 4 year olds obtained a mean score of approximately 1 out of 4, compared to 1.6 for the 6 year olds and 2.7 for the 8 year olds. Examining each time scale individually, there were age increases in performance on all scales except for the time of day. Clear increases were shown for the month of the year, with 11% of 4 year olds answering correctly, compared to 73% of 8 year olds.

Further research examining children's ability to date a novel event on a number of timescales was conducted by Friedman, Cederborg, et al. (2010). Children between the ages of 6 and 12 years were questioned about when they attended a paediatric consultation. Children were asked about the month, day of the week and the time of day of their visit, as well as how long ago the visit was. Analysis was conducted by splitting the children into two age groups (above 9 years and below 9 years). Time of day estimates were found to deviate by 79 minutes on average, whilst younger children were found to be less accurate (mean of 132 minutes) compared to older children (mean of 41 minutes). Judging the month the event occurred, 69% of children were accurate, whilst most of the wrong answers supplied were the months on either side of the correct answer. On the day of the week timescale, 40% of children provided the correct day. There were no age increases for month of the year or day of the week judgments. Children were also asked to judge how long ago they visited the clinic. For children who visited the clinic 1 week previously, the average estimate was 11.5 days (i.e. a 4.5 day error). This figure was 23.0 days (i.e. a 7 day error) for children who visited the clinic a month previously. Although no mean values were provided, the authors reported age effects, with younger children producing less accurate estimates of how long ago the event occurred compared to the older children.

Finally, Pathman, Doydum, et al. (2013) assessed children's ability to date photographs of experienced events. Children aged 8 and 10 years, as well as an adult sample, took photographs of novel events occurring over a 4 week period. Approximately 12 days later, participants were presented with randomly selected pairs of these photographs and asked to make relative recency judgments. The pairs were either from the same week (e.g. both from week 1), adjacent weeks (e.g. weeks 2 and 3) or separated by a week (e.g. weeks 2 and 4). The results showed that all ages made accurate recency judgments at levels above chance. The adults were found to be more accurate, with 78% of participants making a correct recency judgment, compared to 69% of the children. Performance was greatest when the two events were separated by a week, whilst performance was poorest when the events came from the same week; this increased delay between the two events led to greater levels of accuracy.

1.3.4. Dating Staged Classroom Events

The studies outlined above suggest that the ability to date a novel event becomes more refined with age during childhood, although children produce a level of inaccuracy in their estimates of when novel events occur. Although there are advantages to using real-life event settings in terms of ecological validity, there are disadvantages relating to how much a researcher can control extraneous variables. Although the parent-nominated events used by Friedman, Reese, et al. (2010) and Pathman, Larkina, et al. (2013) were activities that did not occur on a regular basis, it is unlikely that the events the parents selected were truly novel; children may have also had previous memories of other school plays or trips to the zoo. Similarly, the children tested by Friedman, Cederborg, et al. (2010) had previous experience of a paediatric clinic, with at least four previous visits made by each child. These events therefore cannot be considered truly novel. Naturally occurring events are also problematic in terms of individual differences between children's experiences. The reasons for children's visits to the paediatric clinic varied from general examinations to genital and rectal examinations; these events would have produced differing levels of distress and embarrassment. Finally, the photographs taken by children and adults in research by Pathman, Doydum, et al. (2013) may differ greatly in terms of the type of activities undertaken, as well as the novelty of these activities.

A method used to overcome such problems is a staged event paradigm (Friedman, 1991; Friedman & Lyon, 2005; Tang, Bartsch, & Nunez, 2007). This involves researchers carrying out a demonstration or activity in the classroom, before children are asked questions about when the event occurred. Staged events allow researchers to ensure all children are exposed to the same event at similar times. This makes comparisons between children, as well as between age groups, easier.

Friedman and Lyon (2005) carried out in-class demonstrations with children between the ages of 4 and 14. Children witnessed two events; the first involved placing a number of items into a box, whilst the second involved an egg being sucked in and out of a bottle. Children were interviewed 3 months after the demonstrations took place; they were first asked to freely recall what they could remember about the events, before being asked several dating questions. Free recall of temporal information was found to be extremely rare when children were describing the events. When assessing the accuracy of children’s temporal judgements, collapsing the results across the two events revealed an increase in age for the time of day judgements; the youngest children were found to be on average 199 minutes off the correct time of day, compared to 18 minutes for the oldest children. Collapsing the results across the two events, the percentage of children correctly estimating the month the events occurred increased from 20% in the youngest children to 56% in the oldest children. Finally, the percentage of children correctly estimating the season increased from 52% to 89%.

Friedman (1991) examined the ability of children aged 4, 6 and 8 years to make dating judgements about two events which had occurred in the classroom; one event occurred 7 weeks before testing, whilst the other occurred 1 week before testing. The first event was a lesson on how videotaping works, whilst the second was a lesson on teeth brushing. As well as a relative recency question, children were also asked about the time of day, day of the week, month and season in which the videotaping event occurred. The results revealed that 70% of the 4 year olds were accurate in their relative recency judgments, whilst all of the 8 year olds answered the recency question correctly (100%). The youngest group were below chance in their accuracy on all four timescales, whilst the two older groups were above chance for time of day, month and season. Only 21% of 4 year olds were able to provide the correct or adjacent month, compared to 64% of 6 year olds and 100% of 8 year olds. Similarly, only 14% of 4 year olds provided the correct season, compared to 50% of 6 year olds and 64% of 8 year olds. All ages performed at levels below chance when estimating the day of the week the event occurred. These results support the idea of young children being able to use distancing information to make dating estimates; although 70% of the 4 year olds made accurate recency judgments, this age group had very little knowledge about timescales, implying that they were not using location information to compare the two events.

Finally, Tang et al. (2007) taught 4, 5 and 6 year olds two novel facts and two novel body movements on two occasions, separated by a week. Immediately after the second session, children were asked questions about when learning occurred. These were either distance questions (i.e. ‘which fact/movement have you known longer?’) or location questions (i.e. ‘did you know [fact/movement] yesterday?’). Asking distance questions produced greater levels of performance (81% of children correct) compared to location questions (44%); such findings support Friedman’s (1991, 1992) suggestion that location questions are particularly difficult for young children. No age differences were found between the three year groups, with children’s performance ranging from 80 to 89% for the distance questions, and 35 to 58% for the location questions.

1.3.5. Dating in Forensic Settings

Researchers have also investigated children’s use of dating references and their dating abilities in forensic settings (Orbach & Lamb, 2007; Wandrey, Lyon, Quas, & Friedman, 2011). Orbach and Lamb (2007) analysed 250 forensic interview transcripts of alleged abuse with children between the ages of 4 and 10 years. Researchers coded references to temporal attributes in five categories: duration, sequencing, dating, number of occurrences and frequency of occurrences. Examining dating abilities, the authors found that children made on average 2.3 spontaneous dating references in their narrative. This was found to significantly increase with age, from 0.9 references made by the 4 year olds, to 4.0 references made by the 10 year olds. There was also an increase in the mean number of dating references when including references made following specific requests for information from the investigator (1.6 references by 4 year olds compared to 6.8 references by 10 year olds). However, this increase was not found to be significant. Children made more references to temporal locations, e.g. ‘it happened on a Tuesday’ (mean of 3.35 references) than they did to temporal distances, e.g. ‘it happened 2 weeks ago’ (mean of 0.49 references). These results go against Friedman’s (1991, 1992) claims that younger children find it easier to make distancing references. Orbach and Lamb expressed surprise at the tendency for children to make more location-based references, and offered a possible suggestion as to why; the children were likely to have experienced abuse within familiar daily activities, providing children with location-based temporal information about when the events took place.

When considering research examining archival data, a major limitation is the lack of verification about the events that occurred; the only information provided to the researchers was the children’s forensic transcripts. Caution should therefore be taken when interpreting findings, as there is a distinct lack of control. Research by Wandrey et al. (2011) had higher levels of control due to verifiable dates. The researchers examined the ability of maltreated children between 6 and 10 years to make temporal location judgements about two personally significant and highly stressful events: visits to court (occurring on average 6 months before testing) and changes in foster placements (occurring on average 18 months before testing). Children were asked to date the events in terms of how old they were at the time, and what month and season the event occurred. The results showed that overall, 54% of children provided their correct age for their first placement (mean of 159 days away from the correct answer), compared to 59% for their first court visit (mean of 87 days away). Accuracy in recalling the correct month was poor, with 8% of children answering correctly for their first placement (M=62 days away) and 11% of children answering correctly when asked about their first court visit (M=71 days away). Recall of the correct season was slightly more accurate: 32% of children provided the correct season for their first placement (M=47 days away), whilst 21% of children provided the correct season for their first court visit (M=51 days away). These results therefore suggest difficulty in dating personally experienced events by children as old as 10 years. This appears to contrast with the abilities shown by other research when examining children of comparable ages; the authors suggest that the differences between their results and previous research may be due to the maltreated status of the children being tested.

1.3.6. Dating Summary

The research outlined above illustrates that although some studies have shown age increases in dating ability, inaccuracies are still present throughout childhood. Children’s judgments on timescales lacked precision, whilst relative recency judgments were particularly difficult when events occurred close in time. Children showed particular difficulty in dating events that occurred further in the past. Whereas parent-nominated events and photographs resulted in variation in the events children experienced, staged classroom events allowed tighter control of what occurred. Previous staged classroom events have been separated by a period of up to 7 weeks; as research has shown that children have difficulty in dating events that occurred further in the past, research examining children’s ability to date events separated by a relatively long period of time would further enhance the field of temporal memory for dating.

1.4. Sequencing

The ability to sequence events in the correct order is crucially important when trying to piece together an account or structure a narrative. Piaget (1971) suggested that children below 7 years of age lack the ability to make causal and logical connections between events, creating difficulty when trying to reconstruct a sequence. However, research indicates that children are able to mentally represent sequences at a much earlier age.

The explanations put forward to explain children's sequencing abilities will first be discussed, before the existing research into sequencing is reviewed.

1.4.1. Sequencing Theories

Friedman (1992b) outlined three models to explain sequencing abilities. Sequential models, such as Anderson's (1983) temporal string model, suggest that there are directional associative links between elements. One element is thought to be linked with the next element that occurred; we get information about the order of events by moving in a forward direction along the string of elements.

A second category of models are semantic code models (e.g. Seymour, 1980), which propose that locative codes are associated with each element in the temporal pattern; this code provides a linguistic description of where in a sequence an event occurs. Seymour (1980) hypothesised that such codes indicate the location of the months in the year e.g. codes such as 'first', 'early', 'central', 'late' and 'last' can be used to represent the position of the months. This model captures absolute, not relative, locations in the sequence.

Friedman (1983) developed an image model to explain children's sequencing ability, which overcomes two problems associated with sequential and semantic code models: the directional nature of sequential models, and the absolute nature of semantic code models. The image model proposes that the time of events in a sequence is believed to be represented in a similar manner to positions in space. An image-generating mechanism is thought to store representations of events; this can either be related to habitual schematisations (e.g. months along a line or in a circle) or novel images of a previously unexperienced event. Unlike the sequential models, image models show where elements occur in the sequence, relative to other elements; this type of model does not have the same directional properties inherent in sequential models. As a result, the model can account for the fact that children as young as 4 years are able to sequence events in a backwards order, from end to start (Friedman, 1990; Friedman & Brudos, 1988). This therefore suggests that children's representations of daily activities are not simply coded as a series of stepwise, forward links, as proposed by sequential models. The image model can also deal with children's ability to sequence events from changing reference points. Whereas semantic code models capture only the absolute nature of a sequence, image models are able to account for the fact that children as young as 4 years are able to sequence daily activities from changing reference points, i.e. starting in the middle of a sequence, rather than beginning with the ‘first’ element (Friedman, 1990). Semantic code models would suggest that children would find such a task difficult if they only possess the absolute positions of elements within a sequence. Finally, image models propose that information is stored about the intervals separating elements in a sequence; 4 year olds are able make estimates about duration intervals between daily events (e.g. bath and bed) which correlate with the true durations (Friedman, 1990). Semantic code models would have difficulty in explaining how children are able to do this, as they suggest that only isolated information is stored about the different elements (Friedman, 1992b). It is therefore evident that although all three models are able to explain how children are able to arrange elements within a sequence in the correct forward order from start to finish, only image models are able to explain the more complex aspects of sequencing ability seen in children.

1.4.2. Episodic Sequencing

1.4.2.1. Early Developmental Studies

Some sequencing abilities have been found to develop from an early age; children start to encode information about the order of events at a pre-verbal stage. Elicited imitation paradigms are used with infants who are unable to verbally express the order of a sequence (Bauer, Hertsgaard, Dropik, & Daly, 1998; Bauer & Lukowski, 2010; Bauer & Mandler, 1989, 1992; Lukowski et al., 2005; O'Connell & Gerard, 1985). Using this method, an experimenter models a sequence of actions using toys, before the infant is encouraged to imitate the behaviour seen to reproduce the sequence. This paradigm allows both familiar and novel events to be demonstrated, requiring infants to encode the temporal order of the sequence before imitating what they saw.

Bauer and Mandler (1989) exposed 16-month and 20-month old infants to novel three-item sequences, which were modelled by the researcher twice. Sequences were either causal (one action had to be completed before the next action) or arbitrary (the sequence would make sense in any order). Following modelling, the older infants produced a greater number of ordered sequences. The greatest number of correctly ordered sequences was in the causal condition; 20-month olds recalled a mean of 1.43 pairs in the correct order (out of 2), whilst 16-month olds recalled 0.98 pairs. When examining the arbitrary condition, this number fell to 0.73 pairs for 20-month olds and 0.70 pairs for 16-month olds. This suggests that the sequences were more easily remembered if they followed a logical order. Similar research showing increased recall of the order of modelled sequences has also been conducted by Bauer and Lukowski (2010); 16-month old infants recalled a mean of 0.76 pairs (out of 2) in the correct order, compared to 1.40 pairs in the 20-month olds.

Examining whether sequencing abilities were present in younger infants, Bauer and Mandler (1992) modelled a two- or three-item sequence to 13-month olds; the researchers demonstrated the sequence twice before encouraging infants to imitate what they had seen. The results showed that the infants were able to sequence both familiar (e.g. putting a bear to bed) and novel (e.g. making a rocking horse) events at levels above chance following exposure to modelling; overall, infants correctly sequenced 66% of the modelled events. This research was extended to 11 month old infants, who also produced two-item ordered sequences at above-chance levels. More recent research by Lukowski et al. (2005) explored the imitation abilities of 9 month olds when exposed to an elicited imitation paradigm. Infants witnessed the experimenter carrying out three sequences, made up of two actions (e.g. pushing a button and sliding a block). When the infants were given the materials to imitate what they had seen, the results showed that 43% of infants produced one or more ordered pairs of actions after only one exposure to the sequence. Infants saw the same sequences over two more sessions (approximately 2 days and 7 days later); by the final imitation session, 63% of infants produced one or more pairs of actions in the correct order.

These results therefore indicate that infants can remember the order of simple actions that have been modelled to them to a certain extent. However, there are obvious limitations in applying this method to explore the sequencing abilities of older children. The events used are basic two or three element sequences, enacted in front of the infant with no distractions; the sole focus of children’s attention is therefore on the modelled events. The events are also often demonstrated several times, so children have repeated exposure to the sequence. In order to examine the ability of older children to sequence elements within a novel event which is only experienced once, a different methodological approach must be taken.

1.4.2.2. Sequencing Daily Activities and Familiar Events

Daily activities or events experienced on a regular basis have been used to examine sequencing abilities in older children (Fivush, 1984; Fivush & Mandler, 1985; Friedman, 1977b, 1990; Friedman & Brudos, 1988; Panagiotakopoulos & Ioannidis, 2002; Xeromeritou & Natsopoulos, 1991). Pictures depicting these activities are typically given to the child and they are asked to arrange these pictures in the order that they occur. Fivush and Mandler (1985) examined 4 and 6 year olds' ability to sequence six picture cards, depicting familiar events (e.g. going to the supermarket, a trip to McDonalds) and novel events (e.g. going parachuting, taking a train ride). The results showed developmental increases in ability, with older children showing greater sequencing accuracy; mean Kendall rank-order correlations increased for the familiar events from approximately 0.60 at 4 years, to approximately 0.80 and 0.90 at 5 and 6 years respectively. Familiar sequences were easier for children to order compared to unfamiliar events; the mean Kendall rank-order correlations decreased to approximately 0.15, 0.55 and 0.75 for the three increasing age groups. This finding suggests that children were using their pre-existing knowledge about the familiar events to aid their sequencing. As the children had well-established event representations about these events, they were more capable of ordering the familiar events correctly, compared to the novel events. It is important to note that the children in these experiments did not experience the activities they were sequencing directly; children were instead relying on their knowledge about these events or the information presented to them in order to complete the sequencing task.

Further research examining children's sequencing of daily events was conducted by Friedman (1990). Children between 3 and 9 years of age were required to sequence four picture cards depicting daily activities: waking, eating lunch, eating dinner and going to bed. The number of children successfully ordering the cards only reached levels above chance at 4 years; by this age, 83% correctly ordered the task. This suggests that when children are familiar with the events that they are sequencing (i.e. they have repeated experience), they are able to complete these card-sorting exercises at a relatively early age. A second experiment examined children's ability to sequence events from differing reference points in the day. A reference point was chosen from one of the four images (e.g. eating lunch) and children were asked which of two picture cards would occur next if they went forward or backward in time. The results revealed that even 4 year olds were able to correctly judge the relative order of daily activities; all age groups were above the 50% chance level. The greatest difficulty was encountered when children had to cross over the night boundary, i.e. from eating dinner to waking. These results suggest that children begin to perform mental operations upon daily activities, and from changing reference points, by 4 years of age.

1.4.2.3. Sequencing Novel Experienced Events

The studies discussed above deal with daily sequences or familiar events; such events will be very familiar to children, having had repeated exposure to the events, e.g. going to the supermarket or having a bath. As a result, children will have developed schemas for these recurring events. Schemas are cognitive frameworks, or mental representations, containing information about an event; regularities in multiple occurrences (e.g. always reading a menu before ordering food) are collated over time to create a generalised, well-organised representation (Fivush, 1997). Sequencing these familiar events may therefore rely less on children's memory for specific experiences, and more on their knowledge about what usually occurs in these type of events. For example, a child will be able to place a picture of getting dressed after a picture of having a bath, because they have had repeated exposure to this sequence of events on a daily basis. Examining children's memory for a novel event, i.e. something a child has very little or no experience of, would allow researchers to examine children's ability to remember the order of events, rather than relying on their schematic representations. Research into children's sequencing of novel events is therefore crucial.

Only two studies have examined sequencing of novel experienced events (Friedman, Reese, et al., 2010; Pathman, Doydum, et al., 2013). Friedman, Reese, et al. (2010) looked at the ability of children between 8 and 12 years of age to order parent-nominated events from up to 4 years in the past. Examples included a visit to Wellington Zoo and a school production of The Wiz; parents were instructed to provide events which were special to the child and would not be confused with other similar events. In addition to the dating element of the study discussed previously (see section 1.3.3.), children were required to sequence the events. One of the four items came from each of the following time periods: 6 months to 1 year ago, 1 to 2 years ago, 2 to 3 years ago and 3 to 4 years ago. Children were presented with the four events and asked to arrange them in the order that they occurred, from first to last. Approximately half of the children ordered the cards correctly; this rate was above chance. Of the children who made ordering errors, it was rare for children to place a recent event (i.e. 6 months to 1 year ago) in one of the more remote locations (i.e. 2 to 3 years ago, or 3 to 4 years ago); less than 10% of the children placed this event in a remote location. As would be expected, children experienced most difficulty when ordering the oldest events; those occurring 2 to 3 years or 3 to 4 years earlier proved to be difficult to sequence, with approximately half of the children confusing the order of these two distant events. These results suggest that children begin to grasp the order of events by 8 years of age, although errors were still present, particularly when dealing with events from several years ago.

A second study looking at children's ability to sequence novel events was conducted by Pathman, Doydum, et al. (2013). Children between the ages of 8 and 10, as well as an adult sample, took photographs of experienced events over a 4 week period. They were instructed to take photographs of events that were unique or special, although no examples of the events are supplied. In addition to the dating aspect of the research (see section 1.3.3.), participants were required to sequence a subset of 12 photographs (three photographs from each week) in the order that they occurred. Four different scoring measures were used: two measures were relatively lenient, whilst two were more precise. The lenient scoring measures included total pairs (i.e. items just had to be in ascending order, e.g. 1-2 or 2-5) and the correct week (i.e. the photographs were in the correct quarter of the sequence, depending on the week they were taken). The two precise measures were adjacent pairs (i.e. items had to be consecutive and adjacent, e.g. 3-4 but not 3-5) and the exact location (i.e. the photograph had to be placed in the correct position, such as the fifth photograph placed in the fifth location). Analysis revealed that the adults were more accurate when using the total pairs scoring system (mean of approximately 70% correct in adults compared to 60% in children). In addition, the adults were more accurate in selecting the correct week the events occurred compared to children (mean of approximately 60% compared to 50% in children). There was no significant difference between the two groups when using the two more precise measures of adjacent pairs and the exact location. Although the age range of the child sample spanned over 3 years, no analysis was conducted to examine the development of episodic sequencing within this age range.

Research into sequencing novel events is therefore very narrow, and the two available studies have several limitations. As discussed in section 1.3.4., the events experienced in both studies may not be truly novel; it is likely that children had previous memories of other school plays or trips to the zoo (Friedman, Reese, et al., 2010), whilst it is also probable that the images captured in the photographs may have occurred before (Pathman, Doydum, et al., 2013); it would be unlikely for participants to have had a large number of novel experiences over the 4-week testing period. There is therefore a need for research examining children’s memory for the order of events that are truly novel to them, and of which they have had no previous experience.

A further issue with the methodology employed by Friedman, Reese, et al. (2010) is the use of parent-nominated events; in general there is a lack of verification, as researchers cannot know for sure whether the information provided is correct. Research has shown that adults’ temporal judgements are often far from accurate (Friedman, Cederborg, et al., 2010), whilst their accuracy has been shown to decline following a delay (Friedman, 2004). It therefore cannot be assumed that the information provided by parents in sequencing studies is accurate. As noted by Wandrey et al. (2011), it is also possible that the events nominated by parents have been the subject of extensive parent-child conversation, which may have included temporal information. This may result in any discrepancies in the temporal information provided by parents being incorporated into children’s testimonies.

Research using photographs is also limited by the fact that participants are given autonomy over which events they capture for use in the study. As mentioned in section 1.3.4., the events captured in the photographs may also differ greatly, both within the child sample and between adults and children. Methods which will allow researchers to have control over the temporal characteristics of the event, as well as ensuring all participants experience the same event, will remove these limitations.

Finally, the events included in the studies spanned a relatively long time period: up to 4 years in the past for Friedman, Reese, et al. (2010) and up to 4 weeks in the past for Pathman, Doydum, et al. (2013). Such a timeframe may prove to be easier for children to sequence, as the events would have been more temporally distinct compared to elements within a single event; there does not appear to be any research examining children’s ability to sequence individual elements within a solitary event.

1.4.2.4. Sequencing in Forensic Settings

As highlighted in section 1.3.5., Orbach and Lamb’s (2007) analysis of forensic transcripts examined the sequencing references made by children between 4 and 10 years of age. Sequencing references were either forward, backward or simultaneous (e.g. ‘he was… while we were…’). The results showed that sequencing information accounted for nearly 65% of all temporal references; children were more likely to make reference to the sequence of events compared to other aspects of temporal memory. Forward sequencing was more frequent than backward sequencing. There was also an increase in the number of sequencing references made with age; older children were more likely to make spontaneous reference to sequencing information, i.e. they volunteered the information without being asked. However, it is important to note that there was no way to verify the accuracy of the information children provided; the increase in sequencing references with age may not have reflected an increase in sequencing *accuracy* with age. The authors noted that it would be valuable for research to examine the accuracy of children’s temporal reports about experienced events for which researchers have objectively recorded temporal information.

1.4.3. Short-Term Sequencing

In addition to episodic sequencing, research has examined how well children can order a short-term sequence. This type of task requires a child to observe a series of shapes or letters, or listen to a series of sounds, before being asked to arrange the stimuli in the order presented. In contrast to working memory, where individuals are required to manipulate information (e.g. reversing a sequence, making a judgment about a sentence), short-term memory merely requires children to remember a sequence for a number of seconds before recall. The phonological loop, proposed by Baddeley and Hitch (1974), plays a vital role in serial recall tasks for verbal stimuli or stimuli that can be verbally recoded (i.e. an image that can be assigned a verbal label, such as ‘triangle’). A sub-system of the phonological loop, known as the phonological store, is a time-limited, temporary storage system which holds speech-based information. In addition, an articulatory rehearsal mechanism allows individuals to rehearse this information, preventing items from decaying. Visual items can be recoded into a phonological format through the articulatory rehearsal mechanism, allowing them to enter the phonological store. Rehearsal is also thought to occur within the visuospatial sketchpad; Logie (1995) proposed a visual cache, which stores information such as the shape and colour of items, as well as an inner scribe, which is responsible for rehearsal and reducing decay.

Research has shown general increases in short-term memory from an early age through to adolescence. A steep increase has been shown up to 8 years of age, before a gradual increase in ability is evident up to approximately 11 years of age (Gathercole, 1999). Short-term memory for order is thought to be independent from memory for information about the items; research has supported the idea of memory for order and memory for item information being separate, reflecting distinct cognitive processes (Henson, Hartley, Burgess, Hitch, & Flude, 2003; Majerus, Van der Linden, Braissand, & Eliez, 2007; Nairne & Kelly, 2004).

Several researchers have examined the relationship between verbal short-term memory for sequences and vocabulary development (Gathercole, Service, Hitch, Adams, & Martin, 1999; Gathercole, Willis, Emslie, & Baddeley, 1992; Leclercq & Majerus, 2010; McCormack, Brown, Vousden, & Henson, 2000). However, less research has focused on the development of children’s visual short-term sequencing memory, i.e. their memory for a pattern of shapes or images. Gathercole, Pickering, Ambridge, and Wearing (2004) found that children’s memory for visual information develops during the first few years at school; children first rely solely on the visuospatial sketchpad, before using visual codes and verbal recoding. Finally, a preference is shown for verbal encoding (Hitch & Halliday, 1983). This implies that with increasing age, children become more proficient in converting a visual image to a verbal code.

Research by Visu-Petra, Cheie, and Benga (2008) examined children’s short-term memory for visual sequences. Children between the ages of 3 and 9 years completed a visual span task in which they were shown sequences containing several visual stimuli (e.g. coloured circles), before reproducing the order seen; the list length increased from two to eight items. The results showed an increase in the number of correct trials from the two preschool groups (mean age of 4 year 2 months and 5 years 11 months) to the two school-age groups (mean age of 7 years 3 months and 8 years). The difference between the two oldest groups was not significant.

There are several limitations to the research by Visu-Petra et al. (2008) that must be considered. The testing session was terminated after children achieved three consecutive wrong trials; the scoring method used was based on this all-or-nothing approach, with children achieving a score dependent on the number of trials sequenced correctly. This scoring system therefore did not take into account the degree to which children's sequences were incorrect. It may be that some children simply reversed the order of two items and were otherwise relatively accurate, whilst other children may not have placed any of the items in the correct sequence; the scoring system employed did not differentiate between these differences in performance.

Secondly, children were required to first recall the items in order to sequence them, i.e. they were not provided with the stimuli that needed to be sequenced. As a result, the sequencing tasks were a measure of both children's item recall and their sequencing ability, thus increasing the working memory load of the task. As noted above, memory for order and memory for item information is separate, reflecting distinct cognitive processes (Henson et al., 2003; Majerus et al., 2007; Nairne & Kelly, 2004). Having to recall the items for sequencing meant that children left items out (errors of omission) or added in items in that were not in the sequence (errors of commission). Children who were unable to recall all of the items in the sequence may have been able to sequence them correctly if all the items were given to them before sequencing. Similarly, a child who showed relatively good sequencing abilities, but who added in an extra item or missed one of the items out, would not have been given any credit for the rest of the sequence, i.e. they would have scored 0 on the trial.

More research is therefore required into children's short-term visual sequencing abilities in order to explore age-related differences in the degree of inaccuracy displayed on incorrect trials, as well as to measure sequencing ability that is independent of children's ability to recall items.

1.4.4. Sequencing Summary

Research into the development of children's sequencing abilities has focused on daily activities or familiar events; children possess schematic representations for both types of sequence. Very little research has examined children's ability to order elements within a novel event. A more comprehensive examination of children's ability to sequence events under tight control through the use of a staged event paradigm would be desirable; this would eliminate the problems encountered with parent-nominated or photographed events, thus increasing the validity of the findings. In addition, research into short-term sequencing ability has mainly examined purely verbal sequences, with limited focus on children's ability to sequence visual information. An examination of children's ability to order both episodic and short-term visual sequences across the primary school years would thus shed more light on this under-researched area of temporal memory.

1.5. Duration

Duration is the ability to know how long something lasts for. The majority of research into memory for duration has focused on short-term estimates of time. However, very little research has examined children's memory for the duration of novel, experienced events. Theories explaining duration estimates will be first examined, before research into both episodic and short-term memory for durations will be reviewed.

1.5.1. Duration Theories

Several theories have been put forward to explain duration abilities. Physiological models emphasise the role of an internal clock; this biological pacemaker is thought to mark the passing of time (Hancock, 1993). However, as noted by Burt and Kemp (1991), it is difficult to see how such models could explain duration estimates of public and experienced events. These models also offer no account of retrospective duration estimates, i.e. when individuals are only aware that they have to make a duration estimate after the stimuli has been presented.

Cognitive-based models have also been proposed to explain duration abilities. The storage-size model (Ornstein, 1969) claims that the amount of non-temporal information about an event gives us an indication of its duration. The more information that is stored during an interval, the longer the duration is perceived to be; events for which individuals have a lot of information should therefore be estimated as longer than events they know less about. Similarly, older events should be estimated as shorter than more recent events, as individuals would remember less about them. Research by Arlin (1986) provided support for the model; children who witnessed six pictures over a 9 second interval judged this duration to be longer than children who witnessed only three pictures over the same time interval. However, research by Burt and Kemp (1991) questioned the model's usefulness. Adults were asked to estimate the durations of several public events (e.g. the Falkland's war, Pope John Paul I's reign), as well as rating how much they remembered about the events. The results showed no correlation between the duration estimates made and the amount of information participants recalled. Similarly, there was no correlation between when the event occurred and participants' duration estimates. The authors noted that Ornstein's model was developed to explain brief time intervals in the range of seconds, rather than experienced events. This research therefore suggested that the amount of stored event information cannot be used alone to estimate duration.

Burt and Kemp (1991) put forward a reconstructive model of duration estimation, which states that individuals base their duration judgments on general event knowledge. When making duration estimations, individuals categorise events to allow them to access additional information about this type of event, e.g. natural disasters or wars. Duration judgments are then made based on this pre-existing knowledge about the duration of events within the same category. Several experiments examining adults' duration estimates of public and personal events lend support for this model (Burt, 1992; Burt & Kemp, 1991). For example, Burt (1992) found a similarity in the estimates made by participants about specific events they had experienced (e.g. a holiday to Australia), and estimates made by a separate sample of participants about general event descriptions (e.g. going on holiday). This led the author to suggest that duration estimates are reconstructed using general event knowledge. Burt, Kemp, and Conway (2001) retested many of the same participants 10 years later and found that their estimates of the specific events were very similar to their original estimates; this provided further support for the reconstructive process. However, the reconstructive model fails to explain how individuals can make reliable duration estimates for relatively novel events for which they have no prior experience of; such events cannot be categorised as there would be no pre-existing duration knowledge.

Finally, hybrid models attempt to combine physiological and cognitive factors within the same model. Attentional models (Hicks, Miller, & Kinsbourne, 1976; Zakay, 1989) postulate that the perceived duration of an event is related to the amount of attention that is paid to the time that has passed. When attention is paid to non-temporal information about the stimuli, the duration is perceived as shorter, as less attention is devoted to temporal information. Zakay and Block (1994) proposed an attentional-gate model. An attentional gate, which is a cognitive mechanism, is controlled by the amount of attention paid to a stimulus. Greater levels of attention leads to the gate being opened more widely; pulses emitted by a pacemaker (similar to physiological models and also influenced by factors such as arousal) then pass through the attentional gate, before a cognitive counter records the number of pulses to determine the duration. The attentional gate therefore controls how much temporal information is transferred to our memory. When the majority of attentional resources are dealing with non-temporal information, the gate remains closed, reducing the perceived duration. Support for this model comes from research showing that tasks completed under deeper processing conditions (i.e. requiring more attentional resources) were estimated as shorter than tasks requiring more shallow processing (Arlin, 1986). However, this model is unable to explain retrospective duration estimates, and similar to physiological models, it is difficult to see how the model could explain duration estimates of public and experienced events.

It is therefore evident that there exist several models which attempt to explain human duration estimation. Despite this, as noted by Vandierendonck (1998), there exists no single theory or model which is able to explain all of the time estimation data available.

1.5.2. Episodic Duration

1.5.2.1. Duration of Daily Activities

Similar to sequencing research, one way to examine children's understanding of duration is to use events for which they have extensive experience; children as young as 3 years of age will have had repeated exposure to daily activities such as getting dressed, having a bath and going to bed. As a result, they will have developed schematic representations about how long these events will last. Despite its relative simplicity, this method of examining duration abilities has rarely been used when testing children's episodic duration memory. Friedman (1990) looked at the ability of children aged 3 to 9 years to indicate the duration of intervals between two pairs of daily activities. A scale was employed to guide the children, with one end representing a short time, and the other end representing a long time. Children had to place a marker along the scale to indicate the duration between pairs of events. Examples included the time between waking and having breakfast, or the time between having a bath and going to bed. Friedman estimated the length of the duration intervals to allow analysis to be conducted; the correlation between children's estimates and Friedman's interpretation of the 'true' estimates increased with age from 0.21 in the youngest group to 0.72 in the oldest group. Older children also showed a greater differentiation between the different intervals. The variability in children's responses also decreased with continued development. Friedman concluded that by around 4 years of age, children possessed some knowledge about the lengths of intervals between daily activities; they began to transfer this mental representation on to a physical scale to allow some differentiation between durations of familiar events.

There are several limitations to this research, however. The task itself was quite abstract, as children were required to place a cube along a line depicting a small sandglass at one end and a large sandglass at the other end. The lack of reference made to any units of time (e.g. minutes) during the task means we must be cautious in interpreting the findings as showing early duration abilities. A further limitation of the study was the classification system used by Friedman for the correct durations; this was based on the author's own 'rough estimates' (Friedman, 1990, p.1408). For example, the duration between waking to breakfast was estimated to be 30 minutes, whilst the duration between bath and bed was estimated to be 1 hour. Caution should therefore be taken when interpreting the results, as these timings may not be representative of the experiences of all children.

1.5.2.2. Duration of Novel Experienced Events

There exists only one study examining children's ability to judge the duration of relatively novel, experienced events. Friedman, Cederborg, et al. (2010) investigated children's memory for the duration of a paediatric consultation. Although this is not something that occurs on a daily basis, therefore making it relatively novel, the children in the present study had visited the clinic on four or more occasions. Children between 6 and 12 years of age received a telephone call either 1 week or 1 month after their visit to the clinic. As well as answering a number of dating questions (see section 1.3.3.), children were asked to estimate how long they had been in the treatment room for. Children were also asked to estimate how long the phone call had lasted at the end of the conversation. Similar assessments were made by the parents or guardians who had accompanied the children to the clinic. For the purpose of age analysis, children were split into two age categories; one above and one below the median age of 9.6 years. Although children's estimates of the duration were not 'wildly inaccurate' (Friedman et al., 2010, p.553), they lacked a level of precision. Children were likely to underestimate longer durations and overestimate shorter durations. Whilst the average length of time in the treatment room was 22.6 minutes (SD=10.1 minutes, range=5-45 minutes), the average deviation in children's estimates from the correct duration was 13.3 minutes

(SD=9.9 minutes, range=0-38 minutes). In comparison, adults produced an average error of 11.7 minutes (SD=8.4 minutes, range=0-32.5 minutes), suggesting similar inaccuracies. No age effects were found, although this may be due to the way that children were split into two age groups, as the age categories were fairly broad (6-9 years and 9-12 years). Examining children's judgements of the length of the phone interview provided an indication of their ability to make estimates relating to duration on shorter timescales. The mean conversation length was 8.0 minutes long (SD=1.4 minutes, range=5.3-12.0 minutes); children’s mean estimate was 9.7 minutes (SD=8.0 minutes, range=1-60 minutes), with an average absolute deviation of 4.2 minutes (SD=6.7 minutes). The researchers found no correlation between children’s accuracy at estimating the duration of the clinic visit and the duration of the phone conversation. Finally, the results also indicated that children of all ages were able to use conventional time patterns; children were able to make judgements on the correct timescales, such as minutes to represent short durations and days to represent long durations.

This method of asking children about an event experienced outside of the laboratory is beneficial in the sense that the event in question is very true to life. The children were not aware that they would later be questioned on their visit to the paediatric clinic; this increases the validity of the research. However, as discussed in section 1.3.4., there is a loss of control when not tightly controlling variables. Children were at the clinic for different medical reasons: some children experienced a general physical examination, whilst others received a genital or rectal examination. These two events differ greatly in the amount of distress, which may have impacted on children’s memory differently. Further differences in children’s experiences, such as the interaction with medical professionals or the amount of parent-child discussion that occurred following the visit, may have affected recall differently. This therefore highlights the difficulties when using real-life events. A more controlled experiment, in which all children experience the same emotionally-neutral event, would allow more generalizable conclusions to be drawn about children’s duration memory for novel events. Finally, it is important to note that children’s visit to the paediatric clinic was not truly novel to the children involved, with each child having visited the clinic at least four times. Research is therefore needed to examine children’s duration memory for an event with which they have no previous experience.

1.5.2.3. Duration in Forensic Settings

As previously outlined, Orbach and Lamb (2007) examined children's references to the duration of events in forensic interview transcripts. Children between 4 and 10 years of age were classified as making a duration reference when they talked about how long an event lasted from start to finish, the length of time a certain element within an event lasted, or the length of time between two separate incidents occurring. The authors found duration to be the second-least referenced form of temporal information out of the five categories examined, making up only 1.79% of all temporal information supplied. As children produced on average only 0.66 references to duration (decreasing to 0.56 when only examining spontaneous references), detailed analysis was not possible. However, there was an increase in the amount of duration information provided by children, increasing from 0.17 references by 4 year olds to 2.18 references by 10 year olds. Nevertheless, it is evident that children found duration to be a difficult temporal concept, meaning that they were not forthcoming with duration information in their testimonies. As noted in section 1.4.2.5. however, the findings of this study give no indication of the accuracy of the information provided by the children.

1.5.3. Short-Term Duration

Several studies have explored children's ability to produce, or reproduce, short-term durations for a number of seconds (Arlin, 1986; Chelonis et al., 2004; Crowder & Hohle, 1970; Espinosa-Fernandez et al., 2004; Espinosa-Fernandez, Miro, Cano, & Buela-Casal, 2003; Rattat & Droit-Volet, 2007; Szelag, Kowalska, Rymarczyk, & Poppel, 2002). Temporal production tasks commonly require children to produce durations for a specified length of time, e.g. pressing a button for 10 seconds. Temporal reproduction tasks remove the need for units of time, and instead involve children being shown a duration, before being asked to reproduce the same period of time.

Estelle Friedman (1977a) examined the ability of children aged between 2 and 5 years to estimate durations in a temporal production task. Children watched a light or listened to a tone, before indicating when 15 seconds had passed. Children were found to display considerable accuracy; less than 10% of responses were brief and impulsive (3 to 5seconds), or extremely overproduced (greater than 30 seconds). Children were split into two age groups (2½ to 4 years and 4 to 5½ years) to allow age differences to be examined. Analysis found no significant differences in performance between the two groups, suggesting no improvement in the ability to reproduce durations during this age range. However, this study utilised a small sample size of just 22 children, and employed only one duration interval. Caution should therefore be taken when interpreting the results.

Examining later development, Espinosa-Fernandez et al. (2004) asked 4 to 11 year olds to press down a key for between 11 and 13 seconds. Performance was found to increase with age; older children showed less variability in their responses, as well as an increased percentage of correct trials. However, only 38% of trials were correct in the oldest group, indicating a degree of inaccuracy. The number of children able to produce three correct responses in a row also increased with age; 14% of children aged between 4 and 5 years reached this criterion, compared to 73% of 10 and 11 year olds. The authors noted that the ages of 7 and 8 constituted a critical transitional period. This led to the suggestion that this age may be a crucial time of development in duration abilities; this hypothesis is in line with other temporal duration research implying a transition between 6 and 8 years (Droit-Volet & Wearden, 2001; Gautier & Droit-Volet, 2002; McCormack, Brown, Maylor, Darby, & Green, 1999). A similar methodology was employed by Chelonis et al. (2004), in which children between 5 and 13 years of age were required to hold down a lever for a period of more than 10 seconds but less than 14 seconds; this duration was not stated explicitly, but was demonstrated by an experimenter. The results showed that the percentage of correct lever-hold durations increased with age; whereas the five year olds produced an average of 19.4% correct lever holds, by 13 years of age this had increased to 65.4%. In addition, older children were found to show greater consistency in their responses.

Further research by Mantyla et al. (2007) examined the ability of 8 to 12 year olds, as well as adults, to mark the passage of 5 minute intervals whilst watching a film. A green button was pressed to show the time, whilst a red button was pressed to indicate the 5 minute interval (i.e. after 5 minutes, 10 minutes, 15 minutes etc.). Accuracy in indicating the passage of time was similar between the children and adults; both the youngest children and the adults provided more than 80% of the interval responses within 10 seconds, suggesting high levels of performance. However, in order for the children to perform at levels similar to that of adults, children had to make more frequent clock checks (mean of 1.67 per minute) than the adults (mean of 0.70 per minute). Both adults and children displayed similar patterns of behaviour, making infrequent clock checks at the beginning of each 5 minute interval before increasing their checking frequency closer to when the response was needed. Whereas the adult sample made an average of approximately 3.6 clock checks every 5 minutes, this increased to around 8.1 checks for the 10-12 year olds and 10.0 checks for the 8-9 year olds. This research therefore suggests similar temporal memory performance in children and adults, although children needed to employ additional strategies to achieve a comparable level of performance. The increased use of monitoring strategies to complete short-term duration tasks may therefore have impacted upon performance.

Forman et al. (2011) revisited the same children 4 years later, now aged between 12 and 16 years, and asked them to carry out an identical time-monitoring task. Their current performance was then compared to their performance from 4 years previously. Whereas the children originally produced levels of accuracy similar to those of adults, albeit with more frequent clock checks, the children now displayed a reduced level of accuracy. Children were found to monitor the time less frequently, from an average of 9.03 checks every 5 minutes in the original study, to 1.80 checks in the current study. Children were also checking the clock less frequently than the adult sample in the original study. This finding was not the result of their repeated exposure to the task (i.e. completing it a second time), as a subsample of 12 to 16 year olds who had not taken part in the original study displayed similar patterns of clock-checking behaviour and accuracy. The authors suggest that the children were beginning to overestimate their capacity to make duration judgements by this age, displaying overconfidence in their abilities. Examining children's perception of how well they believe they have performed (known as metamemory) on short-term duration tasks would shed further light upon whether children's confidence in their abilities is related to their performance.

Removing the need for the use of units of time (i.e. seconds or minutes), Arlin (1986) used a temporal reproduction design to examine the duration abilities of children between the ages of 6 and 12 years; children witnessed durations before being asked to reproduce the same amount of time. Although children exhibited a developmental increase in their ability to estimate a 9 second duration, all ages underestimated the duration of the stimulus interval. Even the 12 year olds reproduced an interval of less than half of the actual time (mean absolute duration of 4.22 seconds, compared to 2.58 seconds for the 6 year olds). This indicates that children still display difficulties in their short-term duration abilities by the end of the primary school years. However, the current research only examined one duration length; further research spanning a wider range of durations, both longer and shorter than 9 seconds, would indicate whether the tendency to underestimate durations during a reproduction task persists.

1.5.4. Duration Summary

Research examining children's ability to produce, or reproduce, short periods of time has mainly focused on only a limited range of durations. In addition, the literature reviewed suggests that a greater insight into short-term duration abilities could be gained from investigating children's confidence levels about their performance, in addition to differences in strategy use when completing tasks. Only one study has been conducted to examine children's ability to estimate the durations of novel, experienced events; further research, tightly controlling a number of variables through the use of a staged event paradigm, would allow the development of episodic duration memory to be explored more thoroughly.

1.6. Semantic Temporal Memory

Semantic memory is our memory for facts and information about the external world. Children's semantic temporal memory for conventional time patterns is an extremely under-investigated area. A non-peer reviewed study by Davies and Fuery (2009) investigated primary school children's semantic temporal memory. Three age groups were examined: 4 to 5 years, 7 to 8 years and 10 to 11 years. Children were asked questions about general time concepts (e.g. seconds, minutes), dating (e.g. events in the school calendar) and duration (e.g. the duration of school events). The youngest children were found to lack an understanding about these time concepts; none of the children aged between 4 and 5 years were able to correctly report the number of minutes in an hour, or the number of seconds in a minute. This age group showed mean percentage scores of 25.9% on the general time questions, 27.4% on the dating questions and 20.2% on the duration questions. By 7 to 8 years of age, children had a grasp of the units used to measure time (mean of 89.4% correct), yet still lacked consistency in the responses they provided to the duration and dating questions (45.2% and 35.6% respectively). By 10 to 11 years of age, children had begun to show proficiency in their ability to answer general time questions; the mean percentage of questions correct in this section was 98.4%. Despite this, accuracy was lower for duration and dating questions (58.8% and 72.6% respectively).

Davies and Fuery (2009) acknowledged that their research provided only a snapshot of children’s ability to answer time questions, and conceded that further research is required to establish more reliable norms for schoolchildren. There are also several limitations to this study. The pilot research to check understanding of the questionnaire consisted of only three children in each age group; this extremely small sample cannot be considered representative of this age range. The questionnaire also used different response formats for the three sections: the general section required a nominated figure, whilst the dating and duration sections used a multiple-choice format. This makes comparisons between the different sections problematic, as this would involve comparing recognition with recall. The administration of the questionnaire also differed depending on the age group; the 4 to 5 year olds were given the questionnaire on an individual basis, whilst the 7 to 8 year olds completed it in groups of four and the 10 to 11 year olds as a whole class. This creates the problem of differing levels of distraction and attention across the three groups. There is also a lack of statistical analysis within the research; Chi-square analysis was conducted on the dating and duration questionnaires only. Finally as already stated, the study was not published in a peer-reviewed journal. It is therefore evident that further research into the development of children’s semantic temporal memory is essential.

The only other research looking into children’s semantic temporal memory was conducted by Friedman, Reese and Dai (2010). Children between 8 and 12 years of age were given eight problems necessitating the ability to reason about the order of the months of the year. In this task, children were given a reference point (e.g. August) and asked to judge the backwards order of the months. An example would be seeing whether March or December came first when moving backwards from August. Children showed a significant increase in accuracy with age: the youngest children answered an average of 67% of the questions correctly, compared to 88% in the oldest age group. The authors also examined the relationship between children’s knowledge of the months and their ability to judge when parent-nominated events occurred in time (see Section 1.3.3). The results revealed a significant relationship between their ability to think flexibly about the months of the year and their accuracy at dating an experienced event.

It is therefore evident that there exists only limited research into the development of children’s semantic temporal memory. As a result, there exists a need for a more comprehensive assessment of when children begin to understand these crucial time concepts, such as telling the time or knowing how long daily events last for. This knowledge can then be used to inform further research into temporal memory; it would not be helpful to ask a 6 year old to provide a verbal estimate of how many minutes an event lasted if they do not yet understand the concept of a minute.

1.7. Children's Metamemory

Although the field of temporal memory has expanded in recent years, little is known about children's *understanding* of their temporal memory abilities, known as metamemory. Metamemory incorporates our knowledge, monitoring and control of our memory (Dunlosky & Bjork, 2013). Collecting metamemory data alongside measures of memory performance provides researchers with an insight into participants' perceptions of their abilities on such tasks.

When estimating how well children believe they perform on memory tasks in general, previous metamemory research has indicated that young children display a tendency to overestimate their performance (Finn & Metcalfe, 2014; Flavell & Wellman, 1977; Lipko, Dunlosky, & Merriman, 2009; Shin, Bjorklund, & Beck, 2007). For example, Lipko et al. (2009) asked 4 and 5 year olds to predict how many pictures they would be able to remember, before they were shown 10 pictures. The results revealed that children's predicted recall was higher than their actual recall (means of 7.89 and 4.27 respectively), indicating a degree of overconfidence.

This overconfidence in performance has been found to decline with age (Schneider, Mechtild, Lockl, & Nelson, 2000; Schneider & Pressley, 1997). For example, Schneider et al. (2000) used a paired-associates learning task to assess children's judgments of their learning. Children were asked how many word pairs they would be able to recall after a 10 minute delay. The results showed that 10 year olds recalled more pairs (60.8%) than 8 year olds (46.3%). Whilst the 8 year olds predicted that they would recall significantly more word pairs than they actually did, the 10 years olds' predictions did not significantly differ from their recall; this indicates a decrease in overconfidence with age.

Another form of metamemory is the ability to realise that strategies can be employed to overcome our memory limitations. Strategy examples include rehearsal (i.e. repeating the information vocally or sub-vocally, e.g. Lehmann & Hasselhorn, 2007, 2012; Ornstein, Naus, & Liberty, 1975) and elaboration (i.e. focusing on the characteristics of the information or linking items together in order to remember them more effectively, e.g. Gallimore, Lam, Speidel, & Tharp, 1977; Hannon, 2012; Pressley, Levin, & Bryant, 1983). Younger children have been shown to be less likely to spontaneously produce such beneficial strategies compared to older children (Espinosa-Fernandez et al., 2004; Kail, 1990; Kreutzer, Leonard, & Flavell, 1975; Visu-Petra et al., 2008). As Grammer, Purtell, Coffman, and Ornstein (2011) point out, children undergo a transition with increasing age, from employing fairly inactive techniques of remembering at a young age, to employing more active strategies, such as rehearsal and elaboration. Espinosa-Fernandez et al. (2004) examined the strategies children employed when completing a temporal production task (see section 1.5.3. for more information). The results found that the number of children using a counting strategy to mark the passage of time increased with age. Younger children were more likely to simply wait before responding, rather than trying to monitor the duration by counting. In contrast, older children (8-11 years) were more likely to employ a counting strategy to measure the passage of time. Visu-Petra et al. (2008) also explored strategy use when completing short-term temporal memory tasks. Approximately 85% of children between 3 and 9 years of age reported using a strategy to aid their performance. However, the lack of analysis across all age groups prevented any developmental differences in strategy use being uncovered. As hypothesised by Lipko et al. (2009), younger children’s overconfidence in their abilities may make them less aware of the fact that they require a strategy, and as a result may make them less likely to employ one. Although young children may be unaware that they need to use a strategy, research exploring the impact of teaching young children strategies would reveal whether temporal memory performance can be increased through teaching across the primary school years.

There are relatively few investigations into metamemory for temporal information in children. Friedman (2007) examined children’s temporal metamemory for episodic events by asking children if they would be able to remember when various events occurred, and how they would remember this information. However, this study asked children about hypothetical events only, rather than asking them to make actual metamemory judgments about an experienced event and then comparing these judgments to their performance. In addition to asking children about their strategy use, Visu-Petra et al. (2008) also asked children between three and 9 years of age to rate the difficulty of a short-term sequencing task. Unfortunately, a detailed examination of children’s responses was reported for only a subsample of 60 children aged 5 to 6 years (N=223). The results showed that children considered the tasks to be easy, although no statistical analysis was provided and no age effects were explored.

Further research is therefore needed to examine children’s metacognitive understanding of their temporal memory abilities, due to the lack of research conducted in this area. No research appears to have explored children’s changing perceptions of their performance on temporal memory tasks, both before and after task completion. In addition, there does not appear to be any systematic examination of the impact of teaching a strategy on both sequencing and duration abilities.

1.8. Review Conclusions

An examination of the available literature on temporal memory revealed that this area of research is relatively limited. The focus of this thesis is therefore to rigorously investigate how children’s temporal memory develops across the primary school years. Only a very small number of studies have examined children’s ability to judge the sequence or duration of novel events. Limitations in the methodologies used in these studies means there is a lack of control in the events experienced by the children. Staged classroom events provide a way to tightly control for a number of variables and ensure that children experience similar conditions, making developmental conclusions easier to draw. The thesis will therefore aim to examine children’s sequencing and duration abilities for novel staged events.

Although dating has received a relatively large amount of attention from temporal memory research compared other areas of temporal memory, studies have tended to focus on dating either annual events (e.g. birthdays) or events which vary considerably amongst children (e.g. parent-nominated events). Studies which have aimed to overcome these issues by employing controlled staged events have utilised relatively short periods of time between the two events. Examining the dating of two staged events, separated by longer periods of time, would extend this area of research further. The thesis therefore aims to explore the effect that a delay of several months has on children’s accuracy at making relative recency judgments and dating these events on a number of timescales.

There is a distinct lack of research into children’s semantic memory for temporal information. Knowing when children begin to understand concepts such as the number of minutes in an hour or the days of the week could have implications in legal settings, as well as practical applications for the education sector. The thesis will thus utilise a novel questionnaire designed to assess semantic temporal memory in order to examine its development across the primary school years.

In additional to episodic temporal memory, the development of children's short-term temporal memory abilities is an area requiring further research. Studies examining children's ability to produce, or reproduce, durations for a number of seconds have tended to use only a limited range of duration lengths. This thesis will systematically explore children's ability to reproduce durations of varying lengths to examine developmental changes in short-term duration reproductions across the primary school years. Short-term sequencing has largely placed its focus on examining the relationship between verbal sequencing and language development. Far less research has explored the development of children's memory for visual sequences, whilst there are limitations to the scoring systems used to analyse children's performance on previous tasks. The thesis will therefore also explore the development of children's memory for visual sequences, using a more precise measure of sequencing ability.

The three categories of temporal memory outlined above (i.e. episodic memory, short-term memory and semantic memory) have been researched independently of each other. Only one study has begun to examine the links between episodic and semantic temporal memory for dating, whilst no research has examined the relationship between children's ability to make short-term temporal judgments and their ability to make temporal judgments about novel episodic events for sequencing and duration. This thesis will therefore explore the relationship between short-term, episodic and semantic temporal memory development for both sequencing and duration memory.

Related to this, it is also evident from the literature that studies tend to focus on only one aspect of temporal memory, such as sequencing, dating or duration. Of the studies which have looked at more than one area, e.g. children's ability to both date events and order the events correctly, or date events and judge their duration, the results tend to be analysed separately. Researchers have not systematically examined the relationships between these different areas of temporal memory to see whether performance on one aspect develops in line with other aspects. This thesis will examine the relationship between two under-researched areas of temporal memory, sequencing and duration, to discover whether these areas are developmentally related or independent.

Finally, in addition to children’s performance on temporal memory tasks, their understanding of how well they complete such tasks and their ability to use strategies to aid their performance is a valuable source of information. However, little is known about children’s metacognitive understanding of their temporal memory abilities. The existing research into metacognitive judgments of temporal memory is incomplete; further research into children’s perceptions of their performance, and whether this can provide a reliable indicator of children’s performance, would advance the field greatly. This thesis therefore aims to examine the development of metacognitive perceptions about short-term temporal performance. Research has also shown that older children are more likely to understand the need to spontaneously implement strategies to aid their recall; previous research has thus shown an increasing use of strategies with age. As younger children may lack an insight into the need to use strategies, this thesis will aim to explore the effect of teaching primary school children a strategy to aid their performance. Conversely, the thesis will also investigate the effect that preventing children from using strategies has upon their short-term temporal performance.

1.9. Chapter Overview

Experiment 1(Chapter 2) examines the relationship between children’s episodic temporal memory and their semantic temporal memory, i.e. their knowledge about time concepts. Children witnessed a novel episodic event, before making sequence and duration judgments. A novel questionnaire also assessed semantic temporal memory. The relationship between these two forms of temporal memory was explored, in addition to the developmental trajectory of children’s abilities.

Experiment 2 (Chapter 3) focuses on children’s short-term temporal abilities for both sequencing and duration. Both children and adults completed two novel computer tasks, designed to test their short-term sequencing and duration performance. The link between sequencing and duration was examined, whilst the relationship between short-term, episodic and semantic temporal memory was explored further. Metamemory judgments were also made at the beginning and end of the tasks to assess perceptions of performance and task difficulty. The strategies children spontaneously employed were also investigated in this experiment.

Experiment 3 (Chapter 4) builds upon the short-term temporal task, which found that younger children were less likely to spontaneously employ strategies. This experiment therefore examined whether teaching children of all ages the same strategy attenuated any age effects. The effect of articulatory suppression, which prevents spontaneous strategy use, was also explored. Children completed a baseline task before being taught either a strategy or suppression technique.

Experiment 4 (Chapter 5) explores children's dating abilities. Although the main focus of the thesis is on sequencing and duration abilities, the design of the first two studies presented an opportunity to assess children's dating abilities for two events; children experienced the episodic memory tasks and the short-term memory tasks, separated by a delay of approximately 3 months. Children made relative recency judgments and dated the events on a number of timescales. A novel dating questionnaire, designed to assess semantic temporal memory for dating, were also administered to explore the relationship between episodic and semantic dating performance.

Experiment 5 (Chapter 6) examines the possibility of developing ways to increase children's sequencing abilities when ordering elements of a novel event. This experiment adapted a timeline tool previously found to aid performance in adults. Children watched a short film before sequencing the event; children in the experimental condition utilised a timeline to structure their account, whilst children in the control condition used a free-recall writing technique. A second experiment examined children's ability to represent the duration of daily activities along a timeline, from the start to the end of the day. Performance was compared to an adult sample to see whether there were differences in duration ability.

Finally, Chapter 7 provides an overview of the research conducted within the thesis. The main findings of the five experiments are outlined, whilst the novel contributions made to knowledge about children's temporal memory are highlighted. The implications for these findings within both forensic and educational contexts are discussed, before further potential avenues of research are highlighted.

Chapter 2: Investigating the Relationship between Semantic Temporal Memory and Episodic Temporal Memory for Novel Events

2.1. Introduction

The literature review highlighted the fact that research into children's temporal memory is very limited. The current experiment will further explore children's episodic temporal memory for novel events and their semantic memory for temporal concepts, and possible links between these two areas.

2.1.1. Episodic Temporal Memory

Although dating has received quite a lot of attention, sequencing and duration abilities are less researched. Episodic memory for duration is extremely lacking, with only one previous study conducted (Friedman, Cederborg, et al., 2010: see section 1.5.2.2.). Similarly, research into sequencing novel experienced events is limited, as focus has been on examining daily activities or familiar events with which children have a lot of experience (e.g. Fivush & Mandler, 1985). Only two studies have examined children's ability to sequence novel events (Friedman, Reese, et al., 2010; Pathman, Doydum, et al., 2013: see section 1.3.3.). However, both of these studies had a lack of control in the events used; the former used parent-nominated events, whilst the latter used photographs. This means that the accuracy of the nominated events cannot be verified, whilst there will have been variability in the photographs used for sequencing (see section 1.4.2.4. for a discussion of the limitations of these methods). There is clearly a need to investigate the development of sequencing and duration abilities for a novel, experienced event in a controlled setting. When increasing the experimental control of a study, researchers must also consider the impact upon ecological validity; it is possible that the more artificial conditions created by tightly controlling elements of an event may reduce the applicability of the findings to more applied settings. Nevertheless, it is necessary to establish age norms and children's capabilities in a controlled setting, before extending this research to more varied situations, such as outside of a classroom.

Researchers have used two main methods to assess duration abilities in children: verbal estimates and scale designs. Verbal estimates allow children to estimate how long an event lasted for, using concepts such as seconds, minutes and hours (e.g. Friedman, Cederborg, et al., 2010). However, this method relies on children's understanding of time units and what they represent. A child may use '2 seconds' to describe durations spanning an hour if they do not fully understand how long a second is. A scale design removes this problem: children can represent how long they think an event lasted in a visual format, removing the need for an understanding of time units. Friedman (1990) employed a scale design to see how accurately children could represent the intervals between events. Examples of events included the amount of time between waking and breakfast, or the amount of time between having a bath and going to bed. Children were required to place a marker along a scale to indicate duration between the two events. Although Friedman (1990) looked at children's ability to represent the intervals between events, no study has looked at children's ability to order the duration of several elements within an event, relative to each other. The current research will therefore see how well children can order the duration of six elements of an event along a scale, from shortest duration to longest duration. In line with previous verbal estimation research, children will also make verbal estimates about the duration of several elements within the event. Comparisons will be made between these two different measures to see whether a relationship is present.

To remove the problem of varied experiences between children when using real-life events, staged classroom events have previously been employed (e.g. Friedman, 1991; Friedman & Lyon, 2005). One way to stage an event is to show children a pre-recorded film (see e.g., Hayes & Kelly, 1984; Houghton, Cordin, Durkin, & Whiting, 2008). This ensures all children experience the same conditions, thus removing problems such as differing levels of memorability, uniqueness, stress or emotion. No previous study has used this method to look at episodic temporal memory. The current research described in this chapter will therefore seek to fill the gap in the literature on children's ability to sequence a series of elements within a pre-recorded film. This format will also be used to examine children's duration abilities; children will judge the comparative duration of the elements within the film, arranging them according to their length of time, as well as making verbal estimates. This will also enable comparisons to be made between children's sequencing and duration performance.

2.1.2. Semantic Temporal Memory

In addition to a lack of research examining temporal memory for novel events, there exists very little research into the development of children's semantic temporal memory, i.e. children's understanding of conventional time patterns (Davies & Fuery, 2009; Friedman, Reese, et al., 2010; see section 1.6. for more information). The current study will build upon the research of Davies and Fuery (2009), administering a novel questionnaire in a systematic manner to all age groups. In addition to the general and duration sections used by Davies and Fuery, a sequencing section will also be added to assess children's knowledge of daily, monthly and annual sequences. Furthermore, researchers have not yet explored the link between children's knowledge about time patterns and their temporal memory for an experienced event. Only one study appears to have examined the link between episodic and semantic temporal memory. Friedman, Reese, et al. (2010) examined children's capacity to think flexibly about the months of the year, and the relationship this knowledge had with their ability to date parent-nominated events. The authors found semantic knowledge to be linked to children's temporal memory for an experienced event (for a more detailed description, see section 1.6.). However, this study focused on dating abilities alone; no research has explored the link between semantic and episodic memory with regards to sequencing or duration.

Pathman, Doydum, et al. (2013) suggested that semantic knowledge is a crucial element in the development of reconstructive processes. The authors thus stressed the importance of examining the links between time knowledge and sequencing performance: 'In future research, it will be important to examine… relations between developments in children's understanding of conventional time and their reconstruction of the order of personal past events' (p. 322). A primary aim of the current research was therefore to try to establish whether there is a link between children's semantic temporal memory and their ability to sequence events and make duration judgments about a novel episodic event.

2.1.3. Potential Implications

Uncovering a relationship between semantic temporal memory and episodic temporal memory could have implications for the area of eyewitness testimony. It is often the case that a child is the only witness to an alleged instance of abuse; it is therefore important that the information children provide is accurate. Temporal information about a crime (e.g. when the event started or how long ago it occurred) can provide very useful information when building a case; as noted by Orbach and Lamb (2007), providing an accurate temporal context to a testimony can enhance its value. Ascertaining when children can fully grasp temporal knowledge is thus crucial. If a relationship is found between children’s knowledge about time patterns and their sequencing and duration ability, then a semantic temporal memory questionnaire may be a useful tool to indicate how accurate the temporal information children provide might be.

Davies and Fuery (2009) suggested using a similar strategy during police interviews with children. The authors reasoned that interviewers could ask the child to tell the time at the start of the interview to see if the basic time metric had been grasped; if children were unable to tell the time, then Davies and Fuery suggested that interviewers should refrain from asking children about the duration of events. A similar technique asking children about the length of their journey to the interview was also suggested as a way of gauging children’s temporal abilities. This research will allow such claims to be examined, uncovering whether there is a relationship between children’s knowledge about time concepts and their ability to make accurate temporal judgments.

2.2. Aims and Hypotheses

The current study aimed to examine the developmental trajectory of both semantic and episodic temporal memory, to see whether there was an increase in ability with age. It was hypothesised that:

1. There will be an increase in performance with age for semantic temporal memory.

2. There will be an increase in performance with age for episodic temporal memory.

The research also aimed to examine whether there was a relationship between performance on sequencing and duration tasks. No hypothesis was made due to the lack of research into this area. Finally, the research aimed to explore whether there was a relationship between knowledge about time concepts and temporal memory for a novel event. The lack of previous research means no definite prediction was made.

2.3. Semantic Memory Pilot Study

A pilot study was conducted with a small sample of children to examine the semantic temporal memory questionnaire; this was done to ensure understanding of the questions, as well as to see whether the questionnaire was able to effectively discriminate between age and ability.

2.3.1. Method

2.3.1.1. Participants

In this experiment and throughout this thesis, children were recruited from primary schools in Barnsley, South Yorkshire. This is a working class town with a fairly low immigration rate; all children taking part in testing were native English speakers. Children were selected at random from the year groups chosen for testing.

Twenty-six children were recruited (M=12, F=14). Thirteen children were selected from a Year 2 class, with a mean age of 7 years 4 months (range = 6 years 11 months to 7 years 10 months, M=6, F=7). Thirteen children were selected from a Year 4 class, with a mean age of 9 years 5 months (range = 9 years 0 months to 9 years 10 months, M=6, F=7).

2.3.1.2. Materials

A semantic temporal memory questionnaire was created to assess children’s knowledge about time (see Appendix E). Questions were based on those used by Davies and Fuery (2009) and on information from the IXL Learning website (uk.ixl.com). This website is a subscription-based learning site, offering a comprehensive mathematics practice programme for children aged between 4 and 18 years; each school year has questions tailored to their academic level. The website is aligned to the National Curriculum in the United Kingdom and contains numerous mathematical resources for teaching and home learning, including a specific section on ‘time’. Questions related to time on the website include reading the time on a clock and elapsed time puzzles, e.g. ‘It started hailing at 10:00am. The hail stopped at 11:00am. How long did it hail?’ Questions 5, 6, 7 and 8 in the pilot questionnaire were based on examples given by the IXL Learning website for Years 2-6. The questionnaire was composed of 26 questions in three sections: eight questions on general time concepts, eight questions on duration and 10 questions on sequencing. A more detailed description of the questionnaire categories is provided in section 2.4.2.1.

2.3.1.3. Procedure

Children were seated in a quiet room and the researcher read each question out loud to the child. The child's responses were recorded on a copy of the questionnaire, in sight of the child. Children were then thanked and given a sticker.

2.3.2. Results and Discussion

Cronbach's alpha analysis (a measure of internal consistency) revealed the 26-item questionnaire to be highly reliable (α=0.88). Tests of normality revealed that the data were not normally distributed; a negative skew was evident for all three questionnaire sections. The data were reflected and transformed using a SQRT transformation to normalise the data (as recommended in Field, 2013). Statistical analysis was conducted on the transformed data.

Children's responses were coded as either correct or incorrect (see Appendix E for scoring information) and percentage accuracy scores were calculated for each of the four categories (Table 2.1).

Table 2.1: Percentage of questions correct on the pilot semantic memory questionnaire

Question Type	Year 2 (N=13)		Year 4 (N=13)	
	M	SD	M	SD
General (%)	67.31	27.74	93.27	9.70
Duration (%)	53.85	27.19	82.69	12.01
Sequencing (%)	65.38	21.06	80.77	13.20

A mixed-design ANOVA was conducted, with a within-subjects factor of question type (general, duration, sequencing) and a between-subjects factor of age (Years 2, 4). There was a main effect of age on performance, $F(1,24)=13.17$, $p<0.01$, $\eta_p^2=0.35$. There was also a main effect of question type, $F(2,48)=7.83$, $p<0.01$, $\eta_p^2=0.25$. Tukey's analysis revealed a significant difference between the general and duration sections ($p<0.01$), as well as between the general and sequencing sections ($p<0.05$). The interaction between age x question type was not significant, $F(2,48)=1.39$, $p>0.05$, $\eta_p^2=0.06$.

A partial correlation was conducted, controlling for age in months, to examine the correlations between the general section of the questionnaire and both the duration and sequencing sections. The correlation between general and duration knowledge was found to be significant, $r(23)=0.49$, $p<0.05$, whilst a significant correlation was also found between general and sequencing knowledge, $r(23)=0.54$, $p<0.01$.

The individual questions within the questionnaire were also examined. In order to investigate which questions successfully distinguished between children's temporal knowledge abilities, children were split into three groups. This was achieved by ranking the children according to the percentage of questions they answered correctly, then dividing the 26 children into three groups: low ability (12-65%, $N=9$), medium ability (68-79%, $N=8$) and high ability (82-91%, $N=9$). The frequency of correct answers was analysed for all questions individually, to see whether there was a general trend for more of the higher ability children to answer correctly. Only one of the 26 questions produced results that did not follow the general trend; when children were asked to number pictures of daily events in the order they typically occur, 89% of children in the low ability group answered correctly, compared to 63% in the medium ability group (all children in the high ability group answered correctly).

With the exception of one child in Year 2, all children attempted to produce answers on the correct timescales, using the correct units where appropriate. The results also suggested that the semantic temporal memory questionnaire was able to distinguish between age and ability. Children in Year 4 performed significantly better on all three sections compared to children in Year 2. Examining the performance of high, medium and low ability children seemed to suggest that the majority of questions were appropriate; it was not the case that children with lower abilities were performing better than the medium and high ability children on specific questions.

Analysis of the questionnaire, as well as the process of classifying answers as correct or incorrect, resulted in the amendment of the questionnaire for the main experiment. Two questions were removed from the general section of the questionnaire; these asked children to guess what time fictional characters ate their breakfast and tea. Due to a lack of information about the children's home life, and the large amount of variability that may occur between children’s routines, classification of answers as correct or incorrect was problematic. For the same reason, two questions were removed from the duration section; these asked children how long they brush their teeth for, and how long it takes for the register to be taken. Two questions related to the seasons of the year were removed from the sequencing section. Although questions were phrased in a way as to eliminate one of the seasons as the correct answer (e.g. ‘what season comes before spring?’), producing a 33% chance rate, a high proportion of incorrect answers was nevertheless supplied. Some children provided a month or an annual event as their answers, whilst two children asked for a definition of a season, indicating some trouble in understanding the questions. The question asking children to order the daily events was also removed from the sequencing section due to its inability to distinguish between children of differing abilities. The revised 19-item questionnaire (α=0.89) was used in the main study.

2.4. Method

2.4.1. Participants

Participants were 69 children from a primary school in Barnsley, South Yorkshire (M=34, F=35). Children were taken from three school years; 24 children from Year 2 (mean age = 6 years 9 months, range = 6 years 4 months to 7 years 2 months, M=11, F=13), 23 children from Year 4 (mean age = 8 years 10 months, range = 8 years 4 months to 9 years 3 months, M=10, F=13) and 22 children from Year 6 (mean age = 10 years 8 months, range = 10 years 3 months to 11 years 2 months, M=13, F=9). Gender differences were not a focus of this experiment, or any of the other experiments, in the thesis.

2.4.2. Materials

2.4.2.1. Semantic Temporal Memory Questionnaire

An amended version of the questionnaire from the pilot study (see section 2.3) was used in the current study (Appendix F). The questionnaire contained three sections: a general, duration and sequencing section. Questions in the general section examined children’s understanding of time scales, such as the number of minutes in an hour or the number of months in a year. The ability to tell the time was also assessed. The duration section placed a large focus on the school day, asking children how long key events last (e.g. morning break, the school day, the summer holidays). The school day provides common activities experienced by children of all ages. Questions were also included which required children to work out how long an event lasted or what time an event stopped, based on the information supplied. The sequencing section asked about natural temporal sequences, e.g. the days of the week and the months of the year.

2.4.2.2. Episodic Film

An episodic film was scripted and produced by the principal researcher. The film showed a female creating six space items out of household objects (e.g. egg boxes and toilet rolls) to make a ‘scene from space’ (see Appendix G for script and images). The film lasted for 9 minutes and 17 seconds and the six items took varying times to make. The items were a planet (32s), an alien (39s), a rocket (49s), a space buggy (1m 12s), a space scene (2m 10s) and a spaceman (3m 21s). An introduction and end sequence (lasting approximately 17 seconds each) were included in the film to explain to the children what was happening and to show them the finished items. The number of steps in making each item was controlled to ensure that certain items were not particularly memorable due to a more complex design. The amount of narrative was also kept similar across all six items. Three versions of the film were created during editing; this changed the order of the items made to ensure certain objects were not remembered more due to primacy and recency effects. Items could be created in any order, with no sequencing information contained in the video; the creation of one item was not dependent on another.

2.4.3. Procedure

Children were tested on two separate occasions. The first session involved the administration of the semantic temporal memory questionnaire, whilst the second session involved the episodic temporal memory tasks. Testing took place during February, six months into the school year. The same researcher conducted all aspects of testing. Testing was completed in the same small music room, away from any noise and with no clocks in sight. Children were given the opportunity to leave the testing sessions at any time, although all children were happy to participate and showed no confusion at any of the instructions given. All children successfully completed all aspects of testing without showing any signs of impatience.

2.4.3.1. Semantic Temporal Memory Questionnaire

Each child was tested individually. The researcher read each question to the child. The child's responses were recorded on a copy of the questionnaire, in sight of the child. Children showed no confusion at any of the information contained in the questionnaire and possessed knowledge of all annual events mentioned (e.g. Valentine's Day, Halloween); this was verified with class teachers in terms of the teaching and activities that occurred in the classroom about these events.

2.4.3.2. Episodic Film

Children were shown the episodic film (one of three counterbalanced versions) in pairs in the morning (see Appendix G for script and Appendix H for task instructions). Children were unaware that they would later have to complete a memory task, but were aware that they would return to see the researcher for another activity in the afternoon. In this experiment and in all subsequent experiments in the thesis, children were not explicitly told to refrain from telling their classmates about what occurred with the researcher; although it was possible that children could have discussed what happened, it was not considered to be too much of a problem if they did.

In the afternoon, children were tested on an individual basis in a quiet room approximately 4 hours after watching the film. This delay was due to the amount of time it took to show all children being tested on the same day the film in the morning teaching session, as well as taking the lunch break into consideration. Children were then tested in the afternoon in the same order that they watched the film.

Children were asked to recall as many of the different items as they could, to check that they could remember the film. Once children had recalled as much of the film as they could remember, the researcher showed the children the six items that were made in a random order (photographs were shuffled for each child) and the researcher labelled each photograph as it was shown to the child. For items that the child did not recall on their own, the researcher checked that they remembered seeing the item being made; all children indicated that they remembered the items they had forgotten to mention during recall.

Half of the children experienced the sequencing task first, and half experienced the duration task first. After completing the two tasks, children were thanked and given a sticker for their participation.

2.4.3.2.1. Episodic Sequencing Task

Children were given six coloured photographs (shuffled after the recall task) of the items created in the film and asked to arrange them in the order that they were made, from first to last, on the table. Markers labelled ‘first’ and ‘last’ were placed on the table as a guide, approximately 100cm apart; this allowed plenty of room for the children to place the items in between the two markers.

2.4.3.2.2. Episodic Duration Task

Children completed two duration tasks. In the duration ordering task, children were given six coloured photographs (shuffled after the last task) of the items created in the film and asked to arrange them in the order of how long they took to make, from shortest to longest, on the table. Markers labelled ‘shortest’ and ‘longest’ were placed on the table as a guide, approximately 100cm apart; this allowed plenty of room for the children to place the items in between the two markers.

After completing the duration ordering task, children completed the verbal estimate task. Children were asked to make verbal duration estimates for three of the items; this reduced the difficulty of the task, rather than asking them to estimate the durations of all six items. These estimates required children to say how long it took to make the shortest item (planet), the longest item (spaceman) and the item nearest to the mean (rocket). Children were also asked to estimate the total length of the film.

2.4.4. Scoring

2.4.4.1. Semantic Temporal Memory Questionnaire

Responses to the questions were coded as either correct or incorrect. Examples include children’s lunch hour being between 1 hour and 1 hour 15 minutes, or the school day lasting between 6 and 7 hours (see Appendix E for detailed information on scoring for all questions). Percentages were then calculated for each of the three sections.

2.4.4.2. Episodic Sequencing Task

Items in the film were assigned a number, according to the order in which they were presented in the film (this differed for the three counterbalanced conditions). A sequencing scoring system was devised, based on scoring methods used in previous research (Burt, Watt, Mitchell, & Conway, 1998; McCormack et al., 2000). Each of the six items was examined in the sequence individually and a score was given for how far away the item was from its correct position. For example, item one placed in position one would receive a score of zero, as it was placed in the correct position. In contrast, item two placed in position five would receive a score of three, as it was three positions away from the correct position. The score for all six items was totalled to give an overall sequencing score, with lower scores indicating better performance. Scores could range from 0 to a maximum possible score of 18; this was due to the fact that once the first item was placed in one of the six positions, this position was no longer available for the remaining five items to be placed, and so forth.

During the analysis of both the sequencing and duration tasks, a number of scoring systems were considered. Examples include ‘total pairs’ and ‘adjacent pairs’ (see section 6.3.5.1. for a description of these scoring systems), as well as employing the chosen scoring system on only the items used in the verbal estimations task. It should be noted that these different scoring systems did not produce significantly different results to the chosen method of scoring, for either the sequencing or duration tasks.

2.4.4.3. Episodic Duration Task

For the duration ordering task, the sequencing scoring system used in the episodic sequencing task was also used, with each item receiving a score based on how far away it was from the correct position (range=0-18). For the verbal estimates, the difference between the child’s response and the actual duration was calculated. For example, a child who estimated the duration of the planet to be 20 seconds would receive an absolute score of 12 seconds, as the planet took 32 seconds to create. A cumulative score, adding the difference scores together for the three individual items (planet, rocket and spaceman), was calculated. The total film length score was also calculated by examining the difference between the response and the actual duration. Low scores indicated better performance.

2.5. Results

2.5.1. Semantic Temporal Memory

Cronbach’s alpha analysis (a measure of internal consistency) revealed the 19-item questionnaire to be highly reliable (α=0.89). Tests of normality highlighted that the data were not normally distributed; a negative skew was evident for all three categories of the questionnaire. The data were reflected and then transformed using a SQRT transformation, which normalised the data (Field, 2013). Statistical analysis was conducted using the transformed data.

The general trend for all three sections was an increase in accuracy with age (Table 2.2.).

Table 2.2: Percentage of questions correct on the semantic memory questionnaire

Question Type	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)	
	M	SD	M	SD	M	SD
General (%)	55.56	32.48	79.71	26.09	96.21	11.42
Duration (%)	29.86	27.79	59.42	30.91	87.12	11.42
Sequencing (%)	62.50	24.86	86.96	14.87	94.80	7.04

A mixed-design ANOVA was conducted, with a within-subjects factor of question type (general, duration, sequencing) and a between-subjects factor of age (Years 2, 4, 6). There was a significant effect of age on performance, $F(2,66)=33.33$, $p<0.01$, $\eta_p^2=0.50$. Tukey's analysis revealed this difference to be significant between all age groups ($p<0.01$). A main effect of question type was also found, $F(2,132)=26.83$, $p<0.01$, $\eta_p^2=0.29$. Tukey's analysis revealed a significant difference between the general and duration sections ($p<0.01$), as well as between the sequencing and duration sections ($p<0.01$); performance was worse on the duration section of the questionnaire. The interaction between question type and school year was not significant, $F(4,132)=0.84$, $p>0.05$, $\eta_p^2=0.03$.

The individual questions were also examined to see whether they were accurately discriminating between children of different abilities. Children were split into three groups by ranking them according to the percentage of questions they answered correctly; these were low ability (11-58%, *N*=21), medium ability (63-84%, *N*=22) and high ability (89-100%, *N*=26). The frequency of children answering correctly in each group was examined to see whether the general trend was for a greater proportion of children to answer each question correctly with increasing ability. All questions followed the expected pattern, with the highest frequency of correct answers in the highest ability group.

2.5.2. Episodic Free Recall

The mean number of items recalled from the film shows that children were able to remember approximately five of the six space items (maximum=6, see Table 2.3). Children tended to recall these items in a random order, rather than trying to recall them sequentially.

Table 2.3: Average number of items recalled from the film in each year group

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)	
	M	SD	M	SD	M	SD
Number of Items Recalled	4.79	0.88	5.17	0.83	5.14	0.71

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6); this revealed no effect of age on free recall, $F(2,66)=1.57$, $p>0.05$, $\eta_p^2=0.05$.

2.5.3. Episodic Sequencing: Ordering Task

Children tended to place the first and last items on the table first, before working out the order of the remaining items. There was no observable difference in the order that children placed the items which they did and did not recall freely.

The movement of items from their correct position (i.e. how many positions away from correct) was first examined, with most errors only one or two positions away (Figure 2.1).

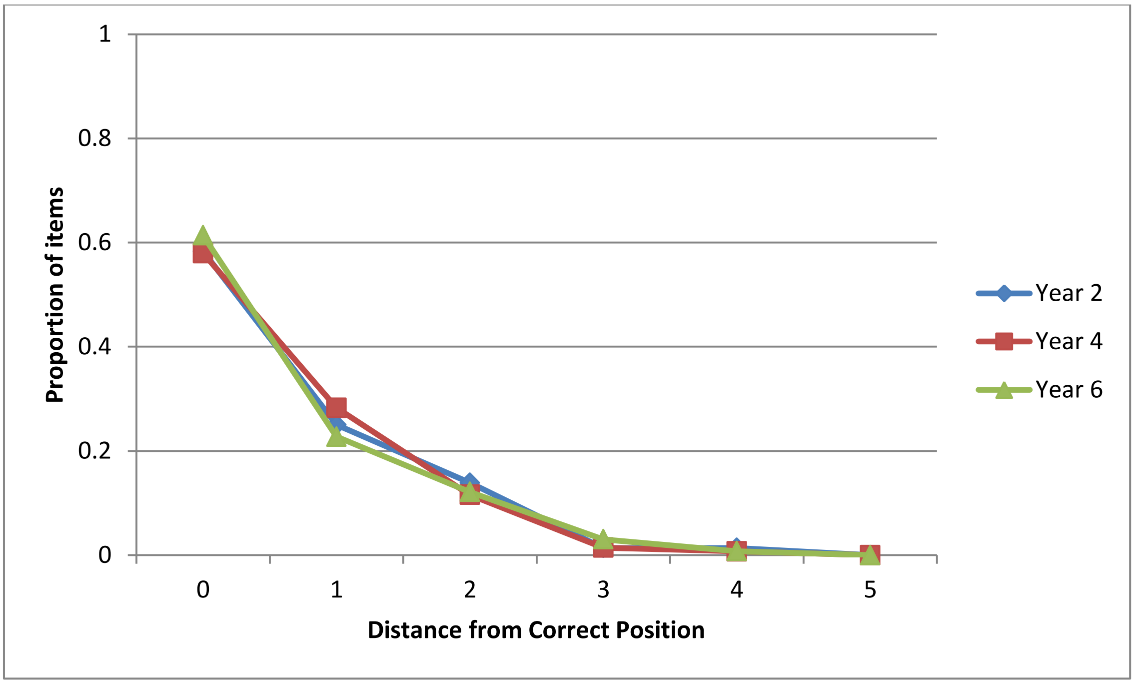


Figure 2.1: Movement of items from the correct position on the episodic sequencing task

The proportion of items placed in the correct position (i.e. item one placed in the first position, item two placed in the second position) was next examined (Figure 2.2).

Figure 2.2: Proportion of items in the correct position on the episodic sequencing task

Using the sequencing scoring system, lower scores represented greater accuracy, with a possible range of 0-18 (Table 2.4).

Table 2.4: Sequencing score on the episodic task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)	
	M	SD	M	SD	M	SD
Sequencing Score	3.75	2.91	3.48	2.97	3.55	2.82

A one-way ANOVA, with a between-subjects factor of age (Years 2, 4, 6) revealed no effect of age on sequencing score, $F(2,66)=0.06$, $p>0.05$, $\eta_p^2<0.01$; there were no age-related increases in the ability to order the sequence of items.

Partial correlations, controlling for age in months, revealed no significant correlation between performance on the episodic sequencing task and children's semantic temporal memory on either the general section, $r(66)=-0.05$, $p>0.05$, or the sequencing section, $r(66)=-0.06$, $p>0.05$, of the questionnaire. There was a significant correlation between episodic sequencing performance and the number of items recalled from the film, $r(66)=-0.43$, $p<0.01$, suggesting that the more that children could remember about the film, the better they were at sequencing the items.

2.5.4. Episodic Duration: Ordering Task

Children tended to place the shortest and longest items on the table first, before working out the durations of the remaining items. There was no observable difference in the order that children placed the items which they did and did not recall freely.

The duration ordering task also examined the positions that children placed the items (1-6), with position 1 representing the shortest duration for an item to be made, and position 6 representing the longest duration for an item to be made. The movement of items from their correct position (i.e. how many positions away from the correct position) was first examined (Figure 2.3).

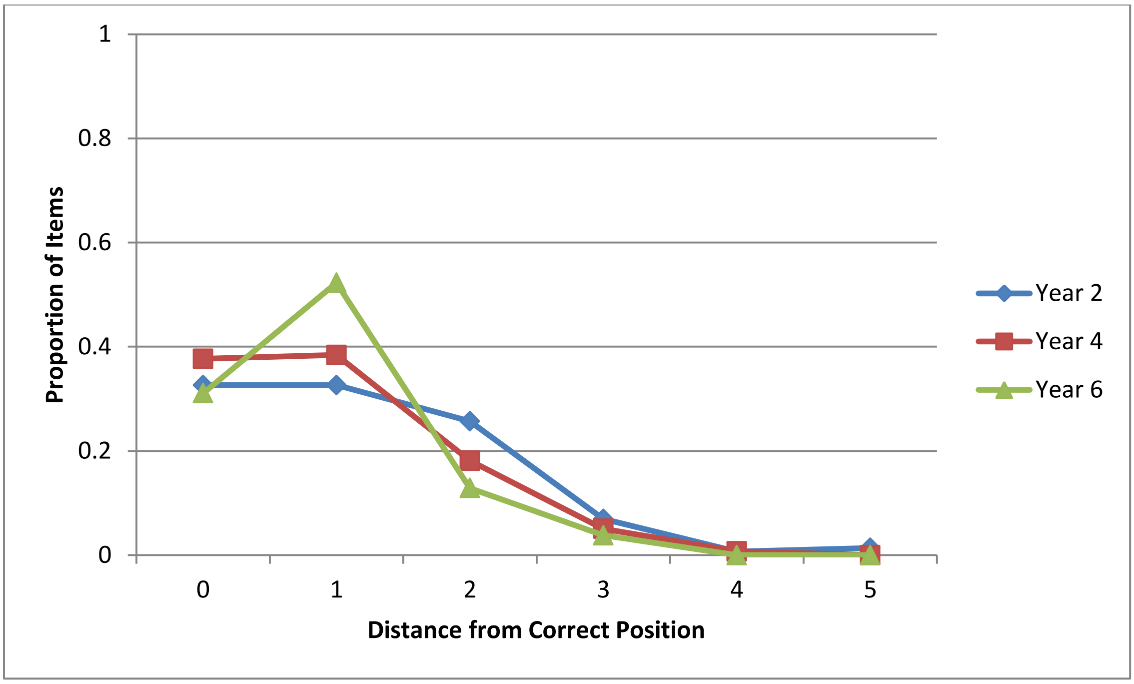


Figure 2.3: Movement of items from the correct position on the episodic duration task

The proportion of items placed in the correct position was also examined (Figure 2.4).

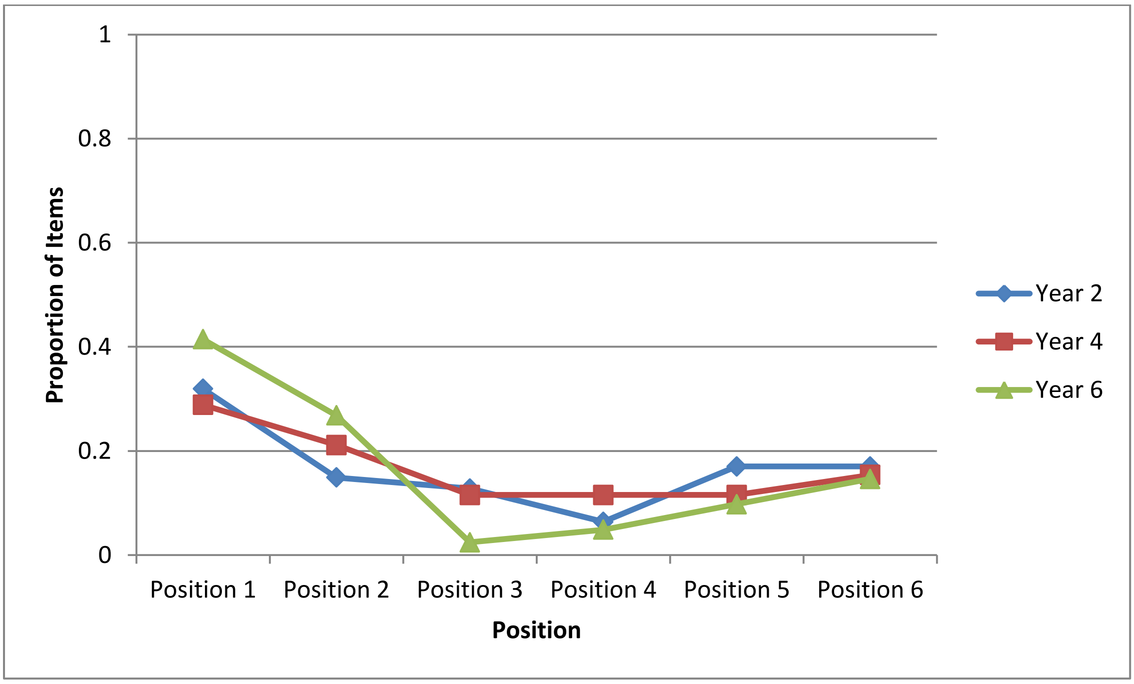


Figure 2.4: Proportion of items in the correct position on the episodic duration task

The mean sequencing score (with lower scores indicating greater accuracy and a possible range of 0-18) was next examined (Table 2.5).

Table 2.5: Duration ordering score on the episodic task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)	
	M	SD	M	SD	M	SD
Episodic Duration Score	6.83	3.91	5.48	2.84	5.45	1.65

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6). There was no effect of age on the duration ordering task, $F(2,66)=1.65$, $p>0.05$, $\eta_p^2=0.05$, indicating similar levels of performance.

Looking at the relationship between semantic temporal memory and episodic duration, partial correlations (controlling for age in months) revealed no significant correlation between the episodic duration ordering task and semantic temporal memory on either the general section, $r(66)=0.16$, $p>0.05$, or the duration section, $r(66)=0.20$, $p>0.05$, of the questionnaire.

The correlation between the episodic duration ordering task and the number of items recalled was significant, $r(66)=-0.31$, $p<0.01$; the more that children recalled about the film, the more accurate they were on the episodic duration task.

2.5.5. Relationship between Episodic Ordering Tasks

As both the sequencing and duration ordering tasks used the same scoring system (i.e. points assigned depending on the number of positions away an item was from its correct position), comparisons were made between children's performance on the two tasks (Figure 2.5).

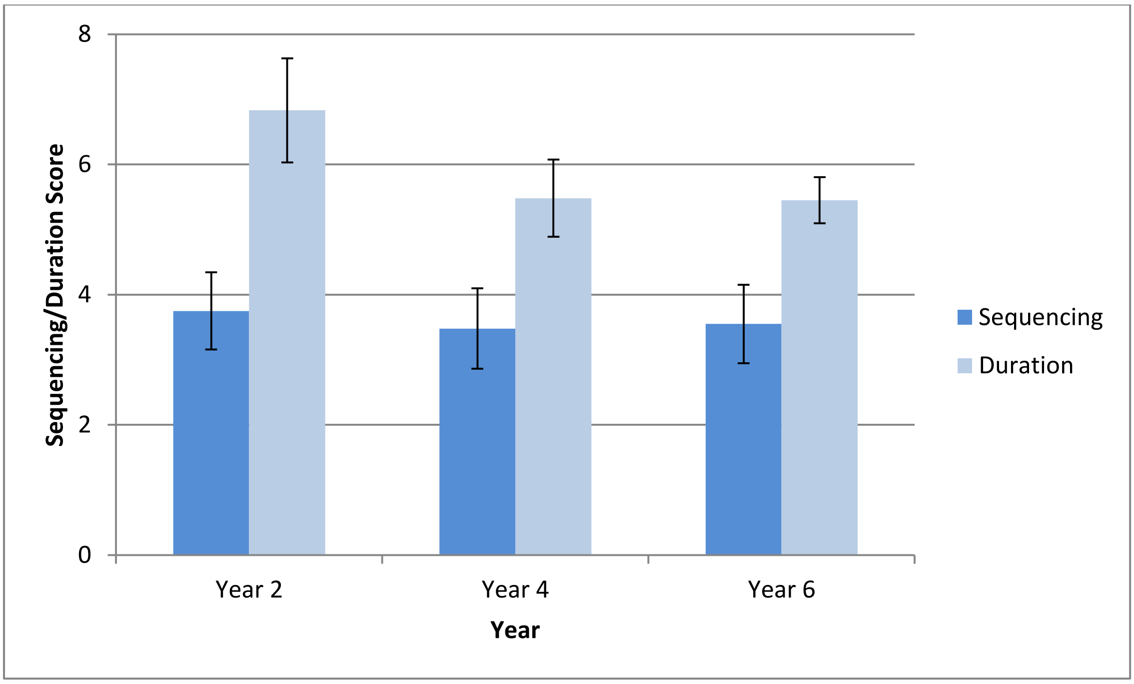


Figure 2.5: Difference in performance between episodic sequencing and duration tasks (maximum score of 18)

A mixed-design ANOVA was conducted to examine the difference in performance on the two ordering tasks, with a within-subjects factor of task type (sequencing, duration) and a between-subjects factor of age (Years 2, 4, 6). There was a main effect of task type, $F(1,66)=33.05$, $p<0.01$, $\eta_p^2=0.33$, with children performing significantly better on the sequencing task. There was no main effect of age, $F(2,66)=0.87$, $p>0.05$, $\eta_p^2=0.03$. The interaction between task type and age was not significant, $F(2,66)=0.88$, $p>0.05$, $\eta_p^2=0.03$. A partial correlation, controlling for age in months, revealed a significant correlation between the duration ordering task and the sequencing ordering task, $r(66)=0.35$, $p<0.01$, implying that the two tasks were tapping into similar skill sets.

2.5.6. Episodic Duration: Verbal Questions

Due to some children’s estimates being so extreme as to alter the mean substantially, outliers greater than three standard deviations were removed. One child was removed from each of the three items, two children were removed from the total film length and three children were removed from the cumulative difference. A log10 transformation was conducted due to a positive data skew (as recommended by Field, 2013).

Children were asked to estimate the duration of three items from the film: the shortest item (planet), the item closest to the mean (rocket) and the longest item (spaceman; see Table 2.6).

Table 2.6: Difference in seconds away from the correct duration for three items

	Year 2		Year 4		Year 6	
	M	SD	M	SD	M	SD
Planet Difference (Duration = 32s)	42.75	34.76	23.73	7.26	21.14	17.35
N	24		22		22	
Rocket Difference (Duration = 1m 12s)	76.61	90.66	47.09	35.22	42.73	27.81
N	23		23		22	
Spaceman Difference (Duration = 3m 21s)	159.42	125.89	123.23	124.65	99.41	55.31
N	24		22		22	

Given that the same age trends applied for all three individual items, analysis was conducted on the cumulative score. The difference away from the correct duration for cumulative score and total film decreased with age (Table 2.7).

Table 2.7: Average time difference (seconds) for the cumulative score and film length

	Year 2		Year 4		Year 6	
	M	SD	M	SD	M	SD
Cumulative Difference	266.39	185.05	177.76	132.95	163.27	84.10
N	23		21		22	
Total Film Difference (Duration = 9m 17s)	477.35	319.85	386.00	389.92	240.00	235.64
N	23		22		22	

A one-way ANOVA was conducted on the cumulative difference score, with a between-subjects factor of age (Years 2, 4, 6). A significant effect of age was found, $F(2,63)=3.29$, $p<0.05$, $\eta_p^2=0.10$. Tukey's analysis revealed the difference between Year 2 and Year 6 to be approaching significance ($p=0.06$), with older children displaying greater accuracy. A one-way ANOVA, with a between-subjects factor of age (Years 2, 4, 6), was also conducted on the total film length difference; this revealed a significant effect of age, $F(2,64)=3.49$, $p<0.05$, $\eta_p^2=0.10$. Tukey's analysis revealed this difference to lie between Year 2 and Year 6 ($p<0.05$), with older children making more accurate estimates.

Partial correlations, controlling for age in months, were conducted between children's verbal duration estimates and their semantic temporal memory. There was no significant relationship between children's cumulative difference score for the verbal questions and either the general section, $r(63)=0.01$, $p>0.05$, or the duration section, $r(63)=0.03$, $p>0.05$, of the semantic temporal memory questionnaire. Similarly, there was no correlation between children's estimates of the total film length and either the general section, $r(64)=-0.09$, $p>0.05$, or the duration section, $r(64)=0.05$, $p>0.05$, of the questionnaire. This suggests that an understanding of time concepts did not impact upon children's verbal duration estimates.

Examining the correlation between the two forms of duration tasks, there was no significant relationship between performance on the duration ordering task and children's cumulative verbal estimate score, $r(63)=0.08$, $p>0.05$. However, there was a significant correlation between performance on the duration ordering task and children's estimates of the total film length, $r(64)=0.26$, $p<0.05$, with children who were more accurate at ordering the items producing more precise verbal estimates about the length of the film.

2.6. Discussion

2.6.1. Exploring Relationships

This is the first study to comprehensively examine the links between semantic and episodic memory for temporal information across the primary school years. The results showed no relationship between children's knowledge about time concepts and their episodic temporal memory for sequencing events or estimating their duration. This finding strongly suggests that children's ability to sequence events from start to finish does not rely upon their understanding of sequential time concepts, such as the order of the months or the days of the week. Similarly, knowing how many minutes there are in an hour or how long school activities last did not affect children's ability to judge the duration of events; children were not translating their knowledge about the number of minutes in an hour, or their understanding of the duration of familiar events, to the novel film in order to make verbal estimates.

These results therefore suggest that time knowledge cannot be utilised to help children make temporal judgments about novel episodic events. Although previous research by Friedman, Reese, et al. (2010) indicated a relationship between episodic and semantic temporal memory, the study used a limited range of questions related only to the months of the year, and examined whether this was related to children's ability to date events (see Experiment 4 for a further exploration of the relationship between semantic memory and dating). The current research is the first study to explore the link between a range of semantic temporal concepts and both sequencing and duration abilities. It therefore appears that although a relationship may exist between semantic and episodic memory for dating, such a finding does not extend to other aspects of temporal memory.

The finding that there is no relationship between children's knowledge about time and their ability to make accurate sequencing and duration judgments on either a relative (ordering task) or absolute (verbal estimate) task means that it would be unwise to use children's grasp of temporal concepts as a way to predict the accuracy of their temporal memory in a forensic setting. Davies and Fuery's (2009) suggestion about using strategies such as telling the time or asking children to estimate the length of their journey would not be an effective way to predict how well a child could cope with questions about the duration of an experienced event. The present study has shown that an understanding of time scales, or judgments about familiar school-based activities, cannot predict the accuracy of children's temporal judgments related to a novel event. This therefore has implications for the legal system when dealing with child witnesses. Using children's level of semantic temporal knowledge as an indicator of how accurate their episodic temporal estimates are may lead to their testimony being wrongly discredited.

This absence of a relationship between semantic and episodic temporal memory also suggests a relative independence in the development of the semantic and episodic memory systems. This interpretation is consistent with research highlighting a double dissociation between semantic and episodic memory (Gadian et al., 2000; Temple & Richardson, 2004; Vargha-Khadem et al., 1997); such research indicates that these two memory systems develop separately, with episodic memory dependent primarily on the hippocampus and semantic memory on the underlying cortices (Vargha-Khadem et al., 1997). These findings are also in line with models of modularity related to memory development (e.g. Tulving, 1972). Due to the different scoring systems involved, it is difficult to make direct comparisons between performance on one type of task and performance on the other. However, the fact that there was an age-related increase in semantic temporal memory, but not episodic temporal memory, indicates a greater development of the former memory store during the primary school years. This lends support to research showing that children can remember information about the world earlier than they can remember information about specific experienced events (see Wheeler, Stuss, & Tulving, 1997).

2.6.2. Development of Temporal Abilities

2.6.2.1. Semantic Temporal Memory

The present research also provided a systematic examination of the development of semantic temporal knowledge from 6 to 11 years of age. The results revealed a developmental increase in semantic temporal memory; older children were more accurate when answering questions about temporal scales, the duration of familiar events and the sequence of the days, months and years (hypothesis 1). This finding supports the developmental trajectory shown in previous semantic temporal memory research (Davies & Fuery, 2009; Friedman, Reese, et al., 2010), whilst extending the findings to a broader variety of temporal memory topics. In addition to these age increases in performance, younger children showed a greater variability in their accuracy on the semantic temporal memory questionnaire compared to older children; this suggests that there are large differences between children of this age in the amount that they know about time concepts. With age, variability decreased and children were performing at similar levels to their peers. This may be as a result of increased exposure to events and formal teaching of temporal information.

Duration was found to be the most difficult section of the questionnaire for children of all ages. This may be due to the teaching practices employed in primary schools in England, which is governed by the National Curriculum (Department for Education, 2013). As discussed in Chapter 1, it is not until Year 3 that children are taught how to estimate and read time to the nearest minutes, and to compare durations of events (i.e. the duration section of the questionnaire). It is therefore not until later in the education system that children are taught the complex tasks of estimating and comparing durations; the temporal concept of duration therefore appears to be less curriculum-based than sequencing and general temporal knowledge. The Year 2 children in the current study had therefore not received any formal teaching about estimating durations or understanding the relative durations of events; in contrast, children in both Year 4 and Year 6 had received formal teaching about comparing the duration of events. Nevertheless, duration teaching does not form a large part of the National Curriculum; the inexperience in estimating and comparing durations may therefore account for the poorer performance seen in this section. Further research thoroughly examining the teaching of such temporal concepts would shed further light on this claim.

2.6.2.2. Episodic Temporal Memory

This research also aimed to examine the development of children’s ability to sequence novel elements within a single event. Children across all ages demonstrated a good recall of the items in the film after several hours. Overall, children were performing quite well on the sequencing task; considering the maximum error score that could be achieved was 18, the highest score obtained on the task was 12, whilst the mean score across all three year groups was below four. This indicates that children were fairly accurate in their ability to order events from start to finish. When ordering a number of elements within an event, 6 year olds were able to remember the sequence of events as well as 11 year olds. A similar level of variability in their performance was also shown. This research also provided a novel insight into children’s ability to order the elements of an event according to their duration, i.e. from shortest to longest. Similar to the sequencing task, there were no age differences across the three year groups, with 6 year olds showing similar levels of performance as 11 year olds. The variability between scores was greater in the youngest children, suggesting larger differences in children’s ability to complete the duration task. This lack of an age difference in performance was not due to ceiling or floor effects; children were not frequently achieving the minimum or maximum score on the two ordering tasks.

Comparing performance on both ordering tasks, all age groups were more accurate on the sequencing task; this is similar to the findings of the semantic temporal memory questionnaire, in which children performed better on the sequencing section of the questionnaire, compared to the duration section. This superior sequencing performance may be due to the fact that children have more experience in ordering events from start to finish. When recalling a story or recounting an experience (e.g. going to the seaside), children as young as 3 years of age have been shown to include order information in their event representations, starting at the beginning and talking about the different elements in the order that they occurred (Mandler, 1984; Nelson, 1986; Nelson & Gruendel, 1986); this indicates that the ability to integrate temporal order in the recalling of an event is available at an early age. In contrast, it may be rare for a child to be asked to think about the duration of an event relative to the duration of other events; there appears to be no research asking children to compare the durations of episodic events. As noted in section 2.6.2.1., there is only limited formal teaching of duration estimates and comparisons in the National Curriculum (The Department for Education, 2013). The results of the present study may therefore reflect children’s lack of experience in making such judgments. Nevertheless, the fact that even Year 2 children achieved a mean score of below seven suggests that children were not completely inaccurate, as the maximum possible score on the task was 18 (indicating very poor performance). Children as young as 6 years of age therefore seem capable of ordering items according to their duration to some extent, although they are more accurate when dealing with the sequence of events.

Although Friedman (1990) found developmental increases in the ability to represent the duration of intervals between events, this does not seem to be the case when children are asked to make relative judgments about the length of the events themselves. This may be due to a difference in task demands. The current study required more complex judgments about several events at once. In contrast, Friedman’s study examined children’s ability to judge the interval between two events, before these events were removed from the timeline and children were presented with another pair of events. Friedman’s task also used daily events, for which the children possessed developed schemas; the current study used a novel event, meaning that children had no prior experience of these elements. The fact that Friedman tested children between 3 and 9 years may also explain why an age effect was found; much of the development of duration abilities may occur during the preschool years. As both the current study and Friedman’s study found a decrease in variability of scores with age, this suggests that children are becoming more reliable in their duration estimates over time.

Children’s verbal estimates showed an increase in accuracy with age. The fact that this increase was found to lie between Year 2 and Year 6 suggests a slow development across the age range examined. This developmental increase in the use of verbal estimates is in contrast to the results of the relative duration ordering task, in which the 6 year olds were performing at similar levels to the 11 year olds. The most likely explanation for this discrepancy is due to the fact that the verbal estimates task required children to make use of temporal concepts such as seconds and minutes; this ability was shown to increase with age on the semantic temporal memory questionnaire. When children were not constrained by the use of such timescales, the youngest children were able to make relative duration judgments to the same degree of accuracy as the oldest children. A correlation between the relative ordering duration task and the verbal estimate of the film length suggests that these two measures of duration ability are intrinsically related; children who had a grasp of the relative lengths of the different items were more accurate when employing timescales to estimate a 10 minute duration. This relationship highlights the benefit of adopting both a verbal estimate measure and a relative duration judgment tool. By using verbal estimates, this provides a rough indication of how well children are able to use timescales in the range of seconds, minutes or hours. Using a relative task alongside this measure removes any problems children may have in using these temporal scales and allows comparisons between different elements of an event to be made.

Although there was no increase in performance on the two ordering tasks with age, there was a correlation between recall of the items in the film and performance on both the sequencing and duration ordering tasks. This implies that the more children could remember about what they had seen, the better equipped they were to sequence the items according to the order they were made or how long they took to make. However, the low variability in the number of items recalled makes it difficult to draw any conclusions about using event recall as a measure of temporal memory performance, due to the fact that the majority of children recalled a similar number of items (out of six). Further investigation of the link between how well children remember multiple aspects of an event (i.e. an event with numerous elements) and how well they perform on sequencing and duration tasks would be useful; if these two measures were found to be correlated, this would provide a simple way to gauge the accuracy of a child’s relative temporal judgments.

Performance on the sequencing and duration ordering tasks was found to correlate; children who were able to order the items according to when they were made were also able to order the items according to their duration. This suggests that children who are able to successfully make relative judgments about one form of temporal memory can perform equally well on relative tasks assessing other forms of temporal memory. This therefore indicates that the relative judgment task may be extended to other areas of temporal memory, such as the number or frequency of occurrence; children who are able to order items according to their sequence or duration may be equally as successful in ordering items according to how many times they occurred or how frequently they occurred over a certain period of time. The use of the relative judgment task would also remove the need for children to provide precise values for the number or frequency of occurrence. Children in legal settings have been shown to display poor performance when estimating numerosity, with a discrepancy found between their estimates and the true number of occurrences of an event (Wandrey et al., 2011). Nevertheless, Wandrey's study found a correlation between children's estimates and the correct response, suggesting some understanding of this temporal concept. The relative judgment task would therefore aid children who struggle to provide such precision, allowing them to represent the relative relations between events. As research has shown that children are regularly asked to estimate how often things occur in interviews and court (Guadagno & Powell, 2009; Lyon & Saywitz, 2006), having a different tool to assess this temporal construct may prove to be beneficial.

2.6.3. Temporal Memory Theories

As noted by Friedman (1990), activities such as card-ordering tasks are unable to shed much light upon the nature of the representations that are underlying these abilities. Children's performance when ordering a sequence of events from start to finish can be explained by sequential models, image models and semantic code models (e.g. Anderson, 1983; Friedman, 1983; Seymour, 1980; see section 1.4.1. for more information on sequencing theories). The tasks undertaken in the current study do not allow any decisions to be made about which model is most capable of explaining sequencing behaviour in children; additional research exploring children's ability to sequence the different elements in a backwards direction, or from a changing reference point (e.g. half way through the film) would shed further light upon this debate. Nevertheless, children of all ages displayed some ability to order the elements of the film according to how long each item took to make; it was rare for items to be placed three or more positions away from its correct position, indicating that children retained a sense of duration for the different items. Friedman's (1983) image model proposes that information is stored about the intervals separating elements in a sequence, whilst semantic code models (e.g. Seymour, 1980) suggest that only isolated information is stored about the different elements. The fact that children were able to make relative judgments about the lengths of the different items may indicate that information about the elements within an event may not be treated in an isolated fashion, and image representations may instead combine information from the different elements within a sequence.

The verbal estimates and relative judgments made about the duration of the items within the film can also be used to examine the numerous duration theories available.

Physiological models of duration, in which a pacemaker is central to duration perception, have difficulty explaining children's ability to make retrospective estimates about the duration of experienced events (Burt & Kemp, 1991); the children in the current study were unaware when watching the film that they would be required to make judgments about the length of the different items. Attentional models (e.g. Hicks et al., 1976; Zakay & Block, 1994) also have difficulty in explaining retrospective duration estimates. Further research examining children's ability to make prospective estimates on the task (i.e. telling the children in advance that they would be making judgments about the time it took to make the items) would be necessary to make further conclusions about these two models.

Burt and Kemp's (1991) reconstructive model of duration estimates is based on the assumption that duration judgments are influenced by general event knowledge of previously similar events. Whilst this is applicable to events such as a murder trial, a war or a royal visit, the event experienced in the current study was relatively novel; as it is highly likely that the children would have had very little prior experience of such an event, the space film could not be categorised in this way due to a lack of pre-existing knowledge.

Finally, the storage-size model (Ornstein, 1969) predicts that the amount of non-temporal information about an event can provide an indication about its duration. The current study ensured that the number of actions included in the creation of the different events was similar, meaning it is difficult to draw any conclusions based on this model. The correlation found between the amount of information recalled and children's accuracy on the duration ordering task indicates some relationship between the amount of non-temporal information children remember and their accuracy when ordering the elements from shortest to longest. However, this relationship did not extend to verbal estimates of the duration of items or the film length. Additional research which varies the number of steps involved in making items of a fairly similar duration (e.g. the planet and the alien) would provide a way to test the storage-size model further.

2.6.4. Future Research

Additional research examining children's semantic temporal memory for events related to their home life could potentially shed more light on children's knowledge about time. Although the school day forms a large part of a child's life, weekends and school holidays may contain more unique activities, i.e. events children have had little experience of. Examples include going to a theme park or visiting a new city. It would not have been possible for the current research to precisely assess children's accuracy about events occurring in their home life without contacting parents to obtain temporal details about these events. Although previous research has relied upon parent-nominated information (e.g. Friedman, Reese & Dai, 2010), this brings with it the possibility that the parental judgments about the duration of the event or the sequencing of the different elements may not be entirely accurate. As previously discussed, examining events outside of the school day also makes comparisons between children difficult due to different experiences. Nevertheless, this remains a possible future area of research.

Furthermore, an additional area for development would be to examine the impact of a delay between experiencing the event (i.e. watching the film) and completing the episodic tasks. Although children were able to recall the majority of elements after a delay of several hours, testing children after a longer period of time (e.g. a week) would allow the relationship between recall and temporal memory to be investigated further. This delay may also find age effects across the primary school years. Experiment 4 (Chapter 5) highlights the effect that a long delay has upon children's memory for when an event occurred (i.e. dating); this could also apply to memory for sequencing and duration.

2.6.5. Conclusion

In conclusion, the results of this study have helped to shed light on a very under-researched area of temporal memory; this novel study is the first to examine in detail the links between semantic and episodic memory for both sequencing and duration. The main finding of the current experiment was the lack of a relationship between semantic and episodic temporal memory; children's knowledge about time concepts was independent of their temporal memory for a novel event. This finding thus strongly disputes claims that children's semantic temporal memory can provide an indication of their episodic temporal memory.

Chapter 3: Exploring Short-Term Temporal Abilities and Metamemory Judgments

3.1. Introduction

Short-term temporal memory refers to an individual’s ability to remember temporal information about basic stimuli (e.g. tones and images) for a short period of time. Two sub-types of temporal memory are sequencing and duration; short-term sequencing requires children to recall the order of a sequence of events from start to finish, whilst short-term duration involves children producing or reproducing durations spanning a number of seconds. The skills needed for these tasks are likely to be similar to the skills required to complete the episodic temporal tasks in Experiment 1 (see Chapter 2). However, researchers have not examined whether there is a link between these two aspects of temporal memory; it remains to be seen whether performance on an episodic temporal task is related to performance on a short-term temporal task. The current study therefore aimed to explore this relationship by devising short-term temporal memory tasks with equivalent characteristics to the episodic tasks, in order to allow comparisons to be made. The same children who took part in Experiment 1 were thus recruited in the current experiment. An adult sample was also employed to produce a clearer picture of children’s temporal memory development; all instructions were kept identical for both adult and child samples to ensure that this could not adversely affect the results of any comparisons.

3.1.1. Short-Term Sequencing

Several researchers have investigated the relationship between children’s short-term sequencing and their vocabulary development (Majerus, Poncelet, Greffe, & van der Linden, 2006; McCormack et al., 2000; Visu-Petra et al., 2008; see section 1.3.3.). Children’s performance on short-term sequencing tasks has been found to be linked with their ability to remember the order of a novel phoneme sequence in order to build up a permanent lexical representation (Majerus et al., 2006). If there is a link between children’s short-term memory for sequences and their ability to retain the order of phoneme activation in the sub-lexical system, it is possible that there is also a link between children’s ability to sequence stimuli after several seconds and their ability to retain the order of several elements within an event after a delay of several hours. Nairne (1992) has argued that equivalent principles might underlie a relationship between temporal coding in short-term and long-term memory. This potential relationship was therefore a focus of the current study.

In order to mirror the conditions of the episodic sequencing task, the current study created a short-term task that used visual stimuli. In contrast to research employing verbal and auditory stimuli, research examining children’s recall of a sequence of visual stimuli is limited (e.g. Visu-Petra et al., 2008). The present study therefore examined children’s ability to recall a sequence of visually presented shapes, in order to closely mirror the task of sequencing pictures of the space items in Experiment 1.

Limitations with the methodology employed in other short-term sequencing research were addressed in the current study. Serial recall designs (McCormack et al., 2000; Visu-Petra et al., 2008) require children to recall the items to be sequenced; this places increasing demands on working memory. Serial reconstruction methods alleviate these demands by providing children with the stimuli to be sequenced, allowing focus to be placed on the sequencing aspect of the task and reducing the working memory demands; the current study therefore employed a serial reconstruction method to reduce the cognitive demands of the task. In addition, this method more closely mirrors the conditions experienced in the episodic sequencing task in Experiment 1, where children were provided with the items to be sequenced. This allows comparisons between children’s performance on the two tasks to be made.

A further limitation to the visual short-term sequencing research conducted by Visu-Petra et al. (2008; see section 1.3.3.) is the scoring method used. A binary classification system was employed, whereby answers were scored as either correct or incorrect; there was no consideration to the degree of inaccuracy in incorrect trials. The current study employed a more sensitive approach to scoring, which differentiated between the degrees of sequencing inaccuracy, e.g. reversing the order of two items, compared to placing all items in the incorrect order. As the scoring system used in the current study was also used in the episodic sequencing task in Experiment 1, this allowed further comparisons to be made between short-term and episodic sequencing abilities.

3.1.2. Short-Term Duration

Research has begun to explore the link between semantic and episodic temporal memory (see Experiment 1 in Chapter 2). However, there exists no research examining the relationship between children's ability to make semantic and episodic duration judgments, and their short-term duration performance.

As discussed in section 1.5.3, research has examined children's ability to produce, or reproduce, short-term durations (Arlin, 1986; Chelonis et al., 2004; Espinosa-Fernandez et al., 2004; Espinosa-Fernandez et al., 2003; Szelag et al., 2002; Ulbrich, Churan, Fink, & Wittmann, 2007). Nevertheless, these studies have focused on short-term memory for duration in isolation. By employing a short-term design that produces results that closely mirror those from the episodic task in Experiment 1 (i.e. the number of seconds children's estimates were away from the correct duration), comparisons in performance to the two types of task become possible.

Several authors believe that a temporal reproduction design is more reliable than production or verbal estimation tasks, as this method does not rely on children's understanding of conventional duration units such as seconds or minutes (Eisler, 1996; Pouthas, 1993; Zakay, 1990). A temporal reproduction design was therefore employed in the current study to examine children's ability to perceive durations and reproduce the same amount of time, without reliance upon semantic temporal memory; as shown in Experiment 1, children's duration knowledge develops at a slower rate compared to other aspects of semantic temporal memory. The reproduction method therefore ensures that younger children are not automatically disadvantaged by their more limited semantic temporal memory. A reproduction design was therefore chosen to allow comparisons to be made with children's performance on the episodic duration task in Experiment 1, in which children verbally estimated the duration of several witnessed elements within a novel event.

Research examining temporal reproduction has tended to examine limited duration lengths, rather than exploring differences in reproduction accuracy over a variety of shorter and longer durations. For example, Arlin (1986) employed a single 9 second duration, whilst Szelag et al. (2002) used durations between 1 and 5 seconds. As a result, the current study employed stimuli ranging from 3 to 26 seconds in length, in order to investigate children's temporal reproductions across a wider range of duration lengths.

The current study therefore aimed to explore the development of temporal reproduction from 6 to 11 years, across a variety of duration lengths. It has been suggested that the period between 7 and 8 years of age is a crucial transition period in the development of short-term duration abilities (Droit-Volet & Wearden, 2001; Espinosa-Fernandez et al., 2004; Gautier & Droit-Volet, 2002; McCormack et al., 1999). The age range employed in the current study allowed this hypothesis to be tested.

The episodic duration task in Experiment 1 used visual stimuli, i.e. children ordered pictures of the six items according to how long they took to make. The short-term duration experiment was therefore designed to use images to represent the durations, as opposed to auditory tones (e.g. McCormack et al., 1999; McCormack, Brown, Smith, & Brock, 2004). Using the same modality allowed comparisons to be made more easily between short-term and episodic duration performance.

In addition to a relationship with episodic temporal memory, it is possible that the ability to reproduce the duration of events is related to children's semantic temporal memory; knowing how many seconds are in a minute, or how many minutes in an hour, may impact upon children's ability to monitor durations spanning several seconds. Similarly, being able to estimate the duration of familiar school events (e.g. the length of lunchtime) may also be related to short-term duration abilities. There exists no research examining the hypothesis that these two abilities are correlated; the current study therefore aimed to explore this further.

Short-term temporal memory for both sequencing and duration require children to maintain information in their short-term memory for a period of time, before recalling this information. In the sequencing task, children had to maintain the sequence of six shapes in their short-term memory, before selecting the shapes in the correct order. The duration task required children to monitor the duration of an image and remember how long it was shown, before reproducing the same duration. The demands of the two tasks were therefore similar, with children having to monitor visual stimuli, remember temporal information and then carry out a task using this information. These similar task demands mean that performance on one form of short-term temporal memory task may therefore be related to performance on the other. However, this prediction has not been explored, with researchers tending to focus on only one aspect of short-term temporal memory at a time. The current experiment thus aimed to examine the performance of primary school children on two computer-based tasks, assessing short-term sequencing and duration temporal memory, and explore whether there was a relationship between their performance on these two tasks.

The current study therefore aimed to see whether short-term temporal memory was related to performance on the semantic and episodic temporal tasks. Similarities in the methodology used in the current study and the episodic task of Experiment 1 (e.g. similar scoring methods, the same number of stimuli) allowed comparisons to be made easily. However, as research has not yet explored the link between these three areas of temporal memory, no firm predictions could be made about the relationship between the three areas.

3.1.3. Metamemory Judgements

The current study also aimed to provide additional insights into children's perceptions of their short-term temporal memory performance, through the use of metamemory judgments and strategy use. As outlined in section 1.7, metamemory refers to our ability to make judgments about our performance on memory tasks, our knowledge about our memory's limitations and our understanding of how strategies can be used to increase performance. Young children display a tendency to overestimate their performance on memory tasks when making predictions about how well they will do (Finn & Metcalfe, 2014; Flavell, Friedrichs, & Hoyt, 1970; Flavell & Wellman, 1977; Yussen & Levy, 1975; see section 1.7 for further information). The majority of these studies investigating children's performance estimates have focused on pre-performance judgments, i.e. how children believe they will perform before task completion. Less focus has been placed on children's perceptions of how well they think they performed after completing a task, i.e. post-performance judgments, and whether this perception changes from pre- to post-performance.

An explanation put forward for why children predominantly display overconfidence in their performance judgments (see section 1.7) is the wishful thinking hypothesis (Stipek, Roberts, & Sanborn, 1984). According to this hypothesis, children's predictions about their performance are based upon how they wish to perform, rather than how they expect to perform. This would therefore suggest that children's estimations about their performance would remain high both before and after completing a task; children would still wish to perform well after continued task experience. Comparing children's estimates of their performance from both before and after task completion provides a way to examine children’s changing perceptions (e.g. DeMarie & Ferron, 2003). The current study therefore examined confidence estimates both before and after completing the short-term tasks.

Finally, another way to measure children’s metamemory is through their difficulty estimates, i.e. how hard they found a task. This is a rarely used method of assessing children’s perceptions of how well they believe they have performed. One study using such a method to assess performance on temporal tasks was conducted by Visu-Petra et al. (2008; see section 1.7.). However, such estimates were treated as a qualitative measure, with children merely commenting on the difficulty, rather than as a way to conduct statistical analysis on their perceptions. The current study therefore assessed participant’s estimates of the task difficulty using a scale design, with judgments ranging from 0 (easy) to 10 (hard).

Assessing children’s spontaneous use of strategies to aid memory performance is another way to examine metamemory, in order to see whether children are aware that they can employ techniques to aid their performance. Children show an increased use of strategies with age; younger children are less likely to employ techniques to help them to complete tasks (Espinosa-Fernandez et al., 2004; Kail, 1990; Kreutzer et al., 1975; Visu-Petra et al., 2008: see section 1.7.). This inability to spontaneously employ strategies is known as a production deficiency (Flavell, Beach, & Chinsky, 1966). The current study aimed to explore whether this production deficit extended to tasks assessing short-term sequencing and duration.

As highlighted in section 1.7, there exists very little research into children’s metamemory for temporal memory concepts, such as sequencing and duration. Although researchers have explored children’s predictions of how many items they will be able to recall (Lipko et al., 2009; Schneider et al., 2000), less emphasis has been placed on children’s metamemory for remembering the order that items were shown. Similarly, very little is known about how confident children are in their ability to reproduce a short-term duration. Furthermore, the lack of rigorous research into children’s changing perceptions of their performance, both before and after exposure to a task, means that this requires additional exploration; this will result in a detailed examination of children’s temporal abilities, as well as their corresponding perception about these abilities. The current study therefore aimed to explore the development of children's temporal metamemory by employing a number of metamemory questions during the testing session. Perceptions about performance were assessed both before and after the task, whilst difficulty estimates were also made. Children's verbal explanations of the spontaneous strategies they used for the sequencing and duration tasks were also recorded.

3.2. Aims and Hypotheses

The aim of the current study was to examine children's short-term temporal memory for sequencing and duration. The research aimed to examine the developmental trajectory across the primary school years, from 6 to 11 years of age, as well as to compare their performance to an adult sample. The experiment also aimed to explore the relationship between children's short-term memory for information and their semantic temporal memory, as well as its relationship with episodic temporal memory. Finally, this experiment also aimed to examine children's metamemory for the short-term temporal tasks. It was hypothesised that:

1. There would be an increase in performance on both the sequencing and duration tasks with age, with 7 and 8 years of age representing an important developmental shift for duration ability.

2. There would be an increased likelihood of participants spontaneously using strategies with age, with younger children showing a production deficit.

3. Younger children would display a greater confidence in their performance compared to older children and adults, in line with the wishful thinking hypothesis.

4. Children's perceptions of their performance would remain similar, both before (pre-performance) and after (post-performance) completing the tasks, in line with the wishful thinking hypothesis.

Due to a lack of previous research, no firm predictions were made about whether there would be a relationship between children's performance on the short-term tasks and their episodic memory for sequencing and duration. Similarly, no predictions were made about whether there would be a relationship between short-term duration performance and semantic memory for temporal concepts. Due to the similar demands of the two short-term temporal memory tasks, this may suggest that performance on the sequencing and duration tasks may be related. However, a firm hypothesis was not made due to a lack of previous literature.

3.3. Method

3.3.1. Participants

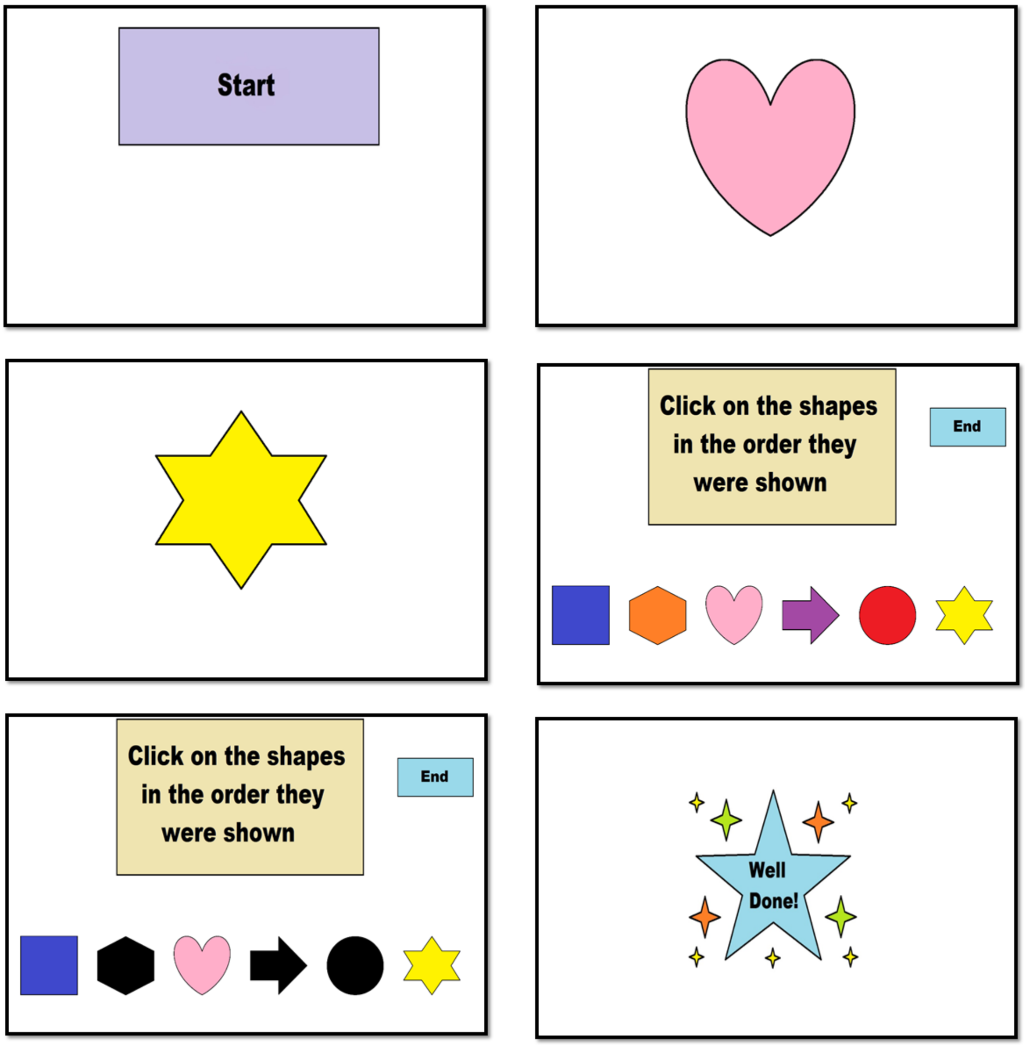
Ninety-two participants took part in the experiment. Sixty-nine children were recruited from a primary school in Barnsley, South Yorkshire (M=34, F=35); these were the same children from Experiment 1. Children were taken from three school years: 24 children from Year 2 (mean age = 6 years 9 months, range = 6 years 4 months to 7 years 2 months, M=11, F=13), 23 children from Year 4 (mean age = 8 years 10 months, range = 8 years 4 months to 9 years 3 months, M=10, F=13) and 22 children from Year 6 (mean age = 10 years 8 months, range = 10 years 3 months to 11 years 2 months, M=13, F=9).

An adult sample of 23 students (M=3, F=20) were also recruited from the University of Leeds participant pool scheme, in exchange for course credits. Participants had a mean age of 21 years 1 month (range = 18 years 9 months to 21 years 11 months).

3.3.2. Materials

3.3.2.1. Short-Term Sequencing Task

The sequencing task was designed using Kinelab software and administered on a touch-screen Fujitsu laptop (see Figure 3.1 for a screenshot of the task). Eight shapes, measuring 10cm x 10cm, were created: a red circle, a blue square, a green triangle, a brown diamond, a yellow star, an orange hexagon, a pink heart and a purple arrow. Before each trial, a start bar appeared at the top of the screen for the child to click on when they were ready for the trial to commence. In the demonstration and practice trials, three shapes appeared in the centre of the screen in succession. Each shape was presented for 2 seconds, with a 1 second gap between presentations. All three shapes then appeared in a horizontal line along the bottom of the screen, with written instructions above the shapes. The touch-screen technology meant that responses were recorded by touching the shapes in the order that they were shown. Shapes turned black after being clicked, to indicate that the response had been recorded. After selecting all the shapes, participants then clicked on the end button in the top right corner to indicate that they had finished the trial. The amount of time taken to complete the trial was recorded by the computer software. The 12 test trials adopted the same format, but this time the number of shapes presented was six; participants were informed of this increase once the practice trial was completed. Three different versions were created to counterbalance any potential order effects.

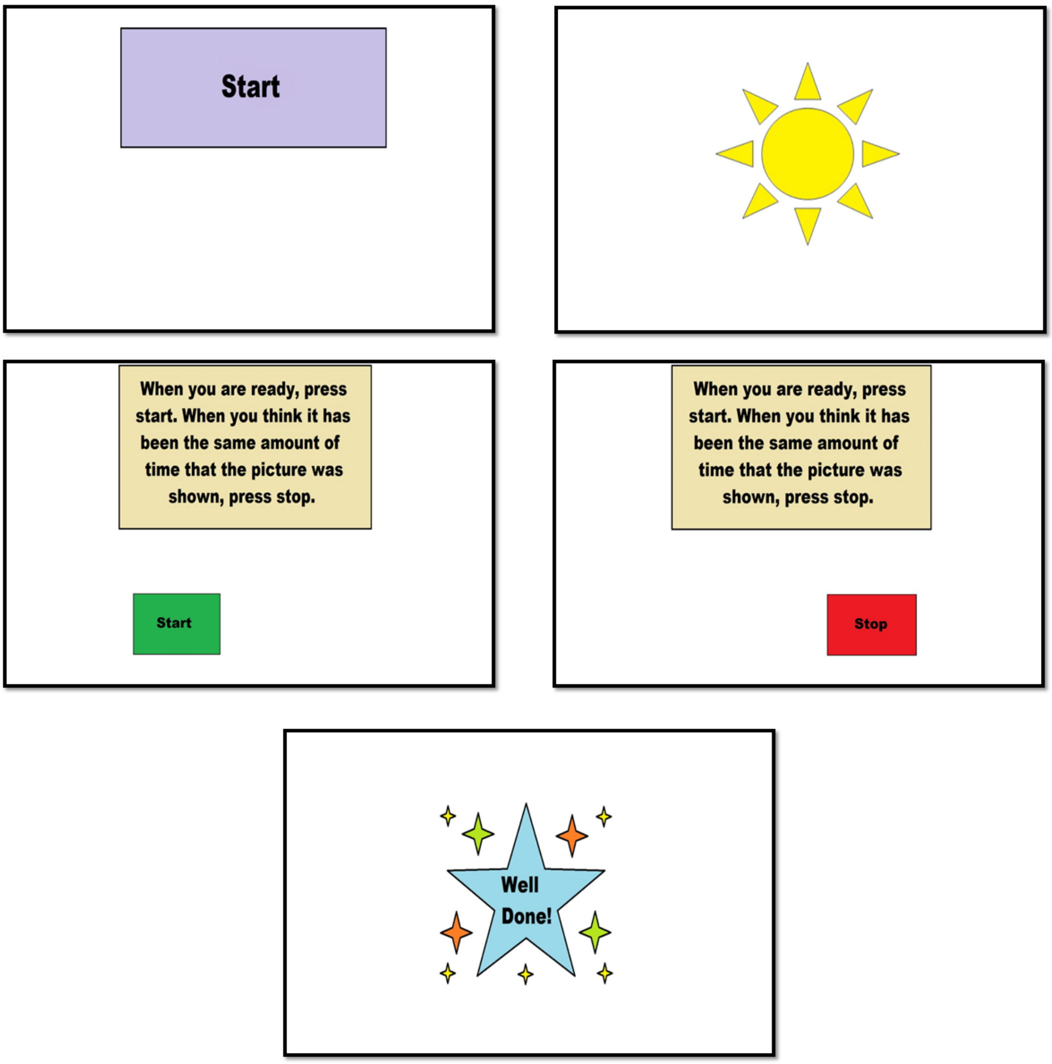

Click on the shapes in the order they were shown

Click on the shapes in the order they were shown

Figure 3.1: Example screen-shots of the short-term sequencing task

3.3.2.2. Short-Term Duration Task

The duration task was also designed using Kinelab software and administered on a touch-screen Fujitsu laptop (see Figure 3.2 for a screenshot of the task). Four stimuli were created: a grey cloud, a yellow sun, a beige moon and a yellow lightning bolt. As with the sequencing task, a start bar had to be pressed before each trial. Shapes were randomly assigned to one of six durations: 3, 6, 13, 16, 23 or 26 seconds. Shapes appeared on-screen for one of these durations before disappearing. Participants were then presented with written instructions at the top of the screen, along with a green start rectangle at the bottom of the screen. After the green rectangle had been pressed, it disappeared and a red stop rectangle appeared. After the participant waited for what they thought was the same duration as the shape was originally presented for, they pressed the red button. The trial then ended and the start bar for the next trial appeared. A practice trial of 8 seconds was completed, before 12 test trials commenced, varying from 3 to 26 seconds in length. Three versions of the task were created to counterbalance any order effects.



When you are ready, press start. When you think it has been the same amount of time that the picture was shown, press stop.

When you are ready, press start. When you think it has been the same amount of time that the picture was shown, press stop.

Figure 3.2: Example screen-shots of the short-term duration task

3.3.2.3. Metamemory Measures

A scale was created, measuring 25cm in length; the numbers 0-10 were clearly marked along the scale at equal intervals. Verbal descriptions were located at 0 (bad/easy) and 10 (good/hard).

Four scripted questions were asked during the tasks:

1. Pre-performance judgment after the practice trial: ‘On a scale from 0-10, with 0 being very bad and 10 being very good, how well do you think you will do on the task?’

2. Post-performance judgment after task completion: ‘On a scale from 0-10, with 0 being very bad and 10 being very good, how well do you think you did on the task?’

3. Difficulty judgement after task completion: ‘On a scale from 0 to 10, with 0 being very easy and 10 being very hard, how hard was the task?’

4. Strategy description after task completion: ‘How did you remember the order the shapes were shown?’ or ‘How did you know how long to wait for?’

3.3.3. Procedure

Testing of the children took place between November and December, three or four months into the school year. The same researcher conducted all aspects of the tasks. Testing was completed in the same small music room, away from any noise and with no clocks in sight. Children were given the opportunity to leave the testing sessions at any time, although all children were happy to participate and showed no confusion at any of the instructions given. All children successfully completed all aspects of testing. See Appendix I for full task instructions.

The child was tested individually, and seated in front of a laptop. The procedure was similar for both the sequencing and duration short-term tasks. The researcher first provided the child with a brief description of what the tasks were about. The researcher then demonstrated the task, providing a verbal description in addition to the on-screen written instructions. The child completed a practice trial to familiarise themselves with the task demands. The participant was then asked how well they believed they would perform on the test trials, using the metamemory scale. During the testing phase, the child completed 12 trials. Following the last trial, a ‘well done’ image was presented on the screen. The child was then asked how well they thought they had performed on the task, using the metamemory scale, before being asked to make a difficulty rating about how hard they found the task. They were then asked for information about the strategies they had used to complete the task; children were asked '*How did you remember the order that the shapes were shown?'* or '*How did you know how long to wait for?*' depending on the task. All children understood these strategy questions and provided a response without further prompting. The child was thanked and given a sticker. The child completed both short-term tasks in one session, with the order of the tasks and the versions of the tasks completed being counterbalanced.

The adult sample followed the same procedure as the children. As noted previously, both adults and children received identical instructions for all aspects of the task. The adult sample was tested in a quiet testing cubicle within the School of Psychology at the University of Leeds.

3.3.4. Scoring

3.3.4.1. Short-Term Sequencing

The sequencing scoring system used on the episodic sequencing task in Experiment 1 was also used for the short-term sequencing task (see section 2.3.4.2. for a detailed description). In summary, each item was given a score, based on how far away it was from its correct position. An average score across the 12 trials was calculated, to provide an overall position score. Scores could range from 0-18, with lower scores indicating better performance.

3.3.4.2. Short-Term Duration

As with the verbal estimates task in Experiment 1, the difference between the participants' recorded response (i.e. the number of seconds they waited) and the correct duration was calculated to give an absolute duration score. For example, a participant who reproduced a 20 second duration after witnessing a shape on-screen for 16 seconds would be given an absolute score of 4 seconds. Lower scores were therefore more desirable. An average absolute duration score was calculated across the 12 trials. An average relative score, taking into account signed differences (i.e. + or -), was also calculated across the 12 trials to see whether participants displayed a tendency to over- or under-estimate the six duration lengths.

3.3.4.3. Metamemory Strategy Judgments

Participants' responses were categorised as either 'strategy use' or 'no strategy'. Descriptions are provided in Table 3.1.

Table 3.1: Strategy use classification system

Response	Task	Description
Strategy Use	Sequencing	Indicated clear description of a technique to remember the order of the shapes e.g. saying them in their head or remembering them in threes
	Duration	Indicated clear description of a technique to remember the length of time, e.g. counting out loud or in their head, tapping
No Strategy	Sequencing	No reference was made as to how they remembered the order of the shapes, e.g. guessing or not knowing how they remembered them, or making vague statements such as they didn't take their eyes off them or really tried
	Duration	No reference was made as to how they remembered the duration, e.g. admitting to guessing or not knowing how they knew how long to wait, or making vague statements such as they were thinking or waiting

3.4. Results

3.4.1. Short-Term Sequencing

3.4.1.1. Movement and Position of Items

The movement of items from their correct position (i.e. whether items were placed in the correct position, one position away, two positions away etc.) was first examined (Figure 3.3).

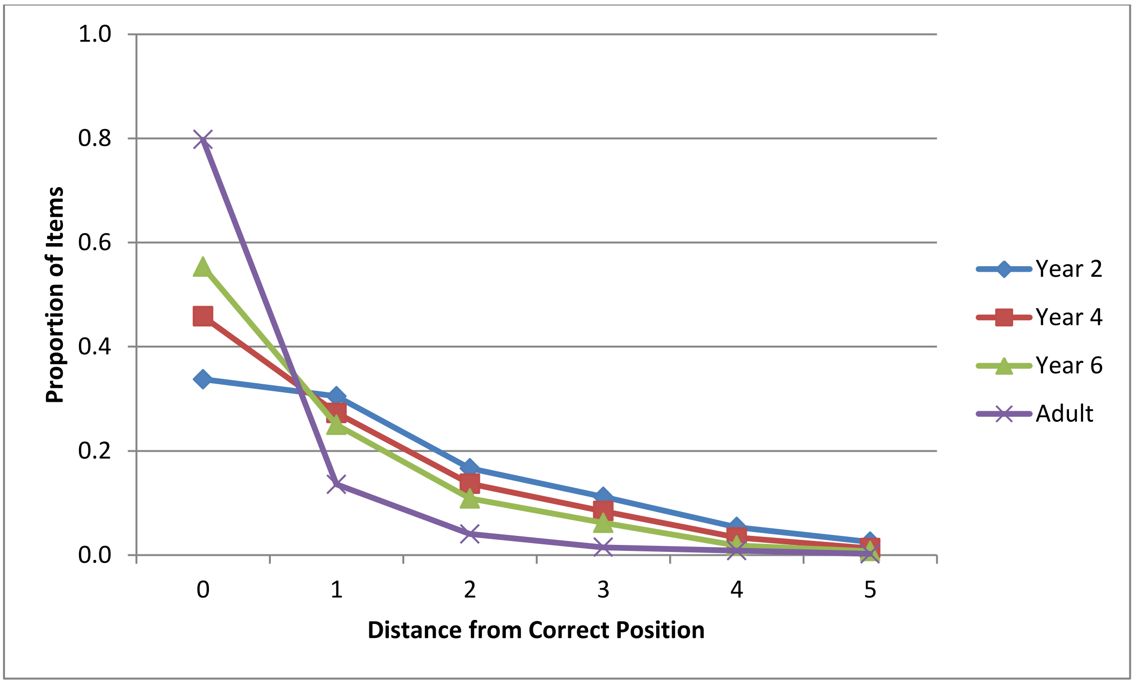


Figure 3.3: Movement of items from the correct position on the short-term sequencing task

Items 1-6 were then examined individually to investigate the positions participants placed each item in (Figure 3.4).

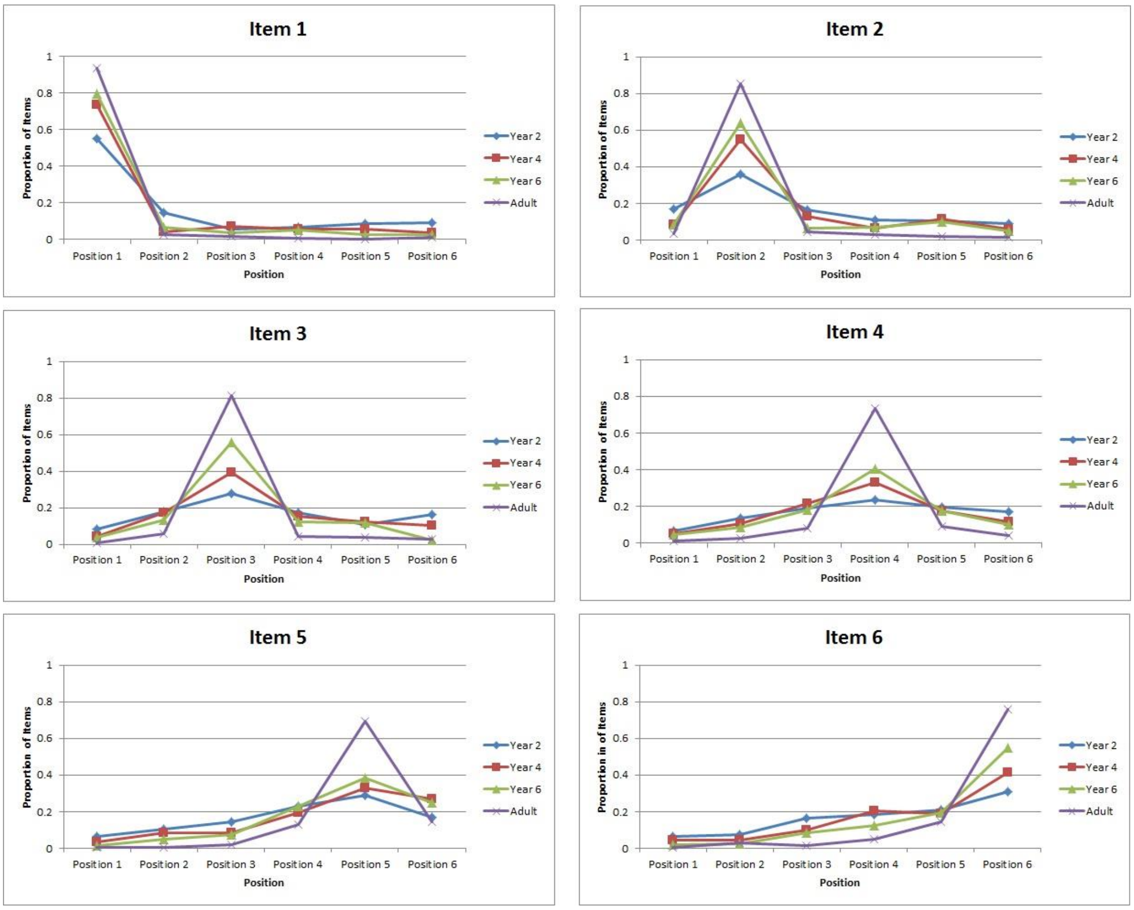


Figure 3.4: Position each item was placed (from 1-6) for all six items

The proportion of items in the correct position (e.g. item one in position one) for each of the six positions was next examined (Figure 3.5).

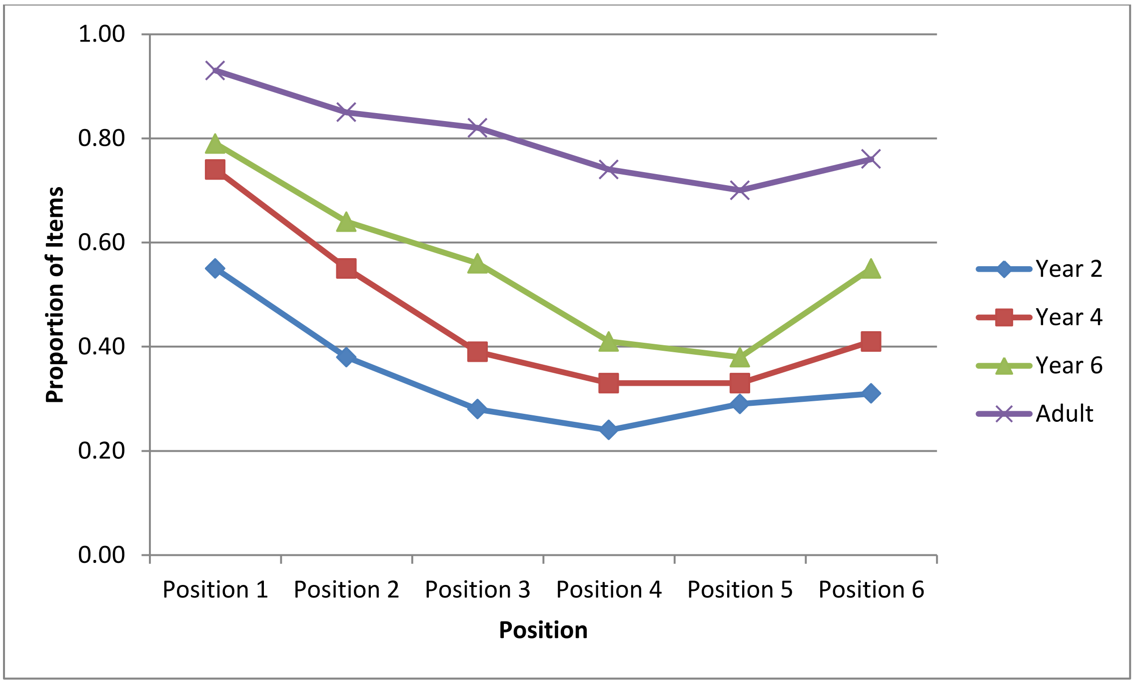


Figure 3.5: Proportion of items in the correct position on the short-term sequencing task

Analysis was collapsed across age groups due to the similar patterns shown. To examine the proportion of items placed in the correct position, a repeated measures ANOVA was conducted, with a within-subjects factor of position (position 1, 2, 3, 4, 5 and 6). Mauchly’s Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(14)=40.35$, p<0.01. Degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon=0.83$). There was a significant effect of position, $F(4.16,378.66)=91.45$, $p<0.01$, $\eta_p^2=0.50$. The difference between position 1 and position 2 was significant ($p<0.01$), indicating a primacy effect. Similarly, there was a significant difference between position 5 and position 6 ($p<0.01$), indicating a recency effect.

3.4.1.2. Sequencing Score

The average short-term sequencing position score was calculated (Table 3.2).

Table 3.2: Sequencing score on the short-term task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)		Adult (N=23)	
	M	SD	M	SD	M	SD	M	SD
Sequencing Score	7.87	1.80	6.08	1.70	4.55	1.71	1.83	1.25

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6 and adult). There was a significant effect of age on sequencing score, $F(3,88)=57.54$, $p<0.01$, $\eta_p^2=0.66$; sequencing accuracy increased with age . Tukey's analysis revealed a significant difference between Year 2 and Year 4 ($p<0.01$), Year 2 and Year 6 ($p<0.01$) and Year 4 and Year 6 ($p<0.05$). There was also a significant difference between the adult group and all three school years ($p<0.01$).

3.4.2. Short-Term Duration

Tests of normality revealed that the average absolute duration score was not normally distributed; there was a positive skew in the data. A Log10 transformation was conducted, which successfully normalised the data (as recommended by Field, 2013). All statistical analysis was conducted using the transformed data. The range of responses at each duration was examined to see whether participants displayed a tendency to reproduce durations close to their correct length (Figure 3.6).

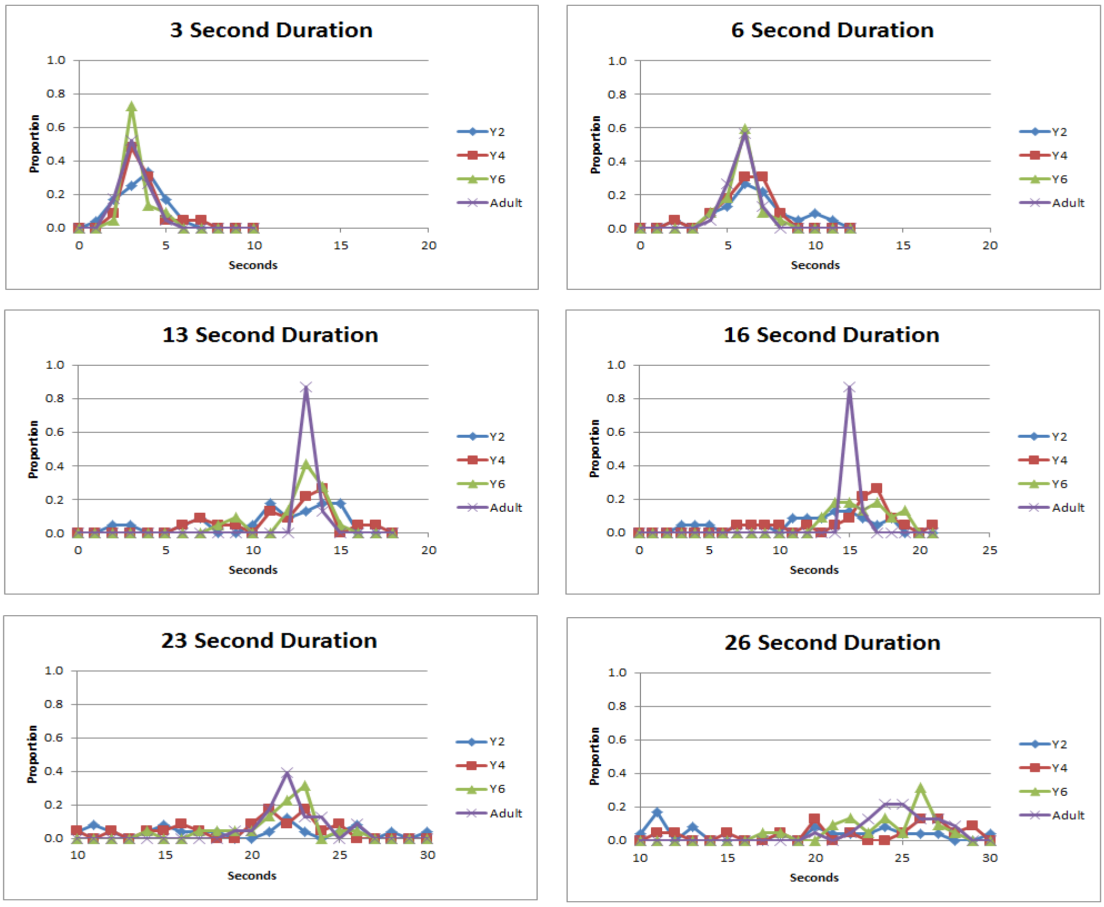


Figure 3.6: Range of responses at each duration

The relative difference between participants' reproductions and the true durations were next examined for each duration length, i.e. whether they under- or over-estimated the durations (Figure 3.7).

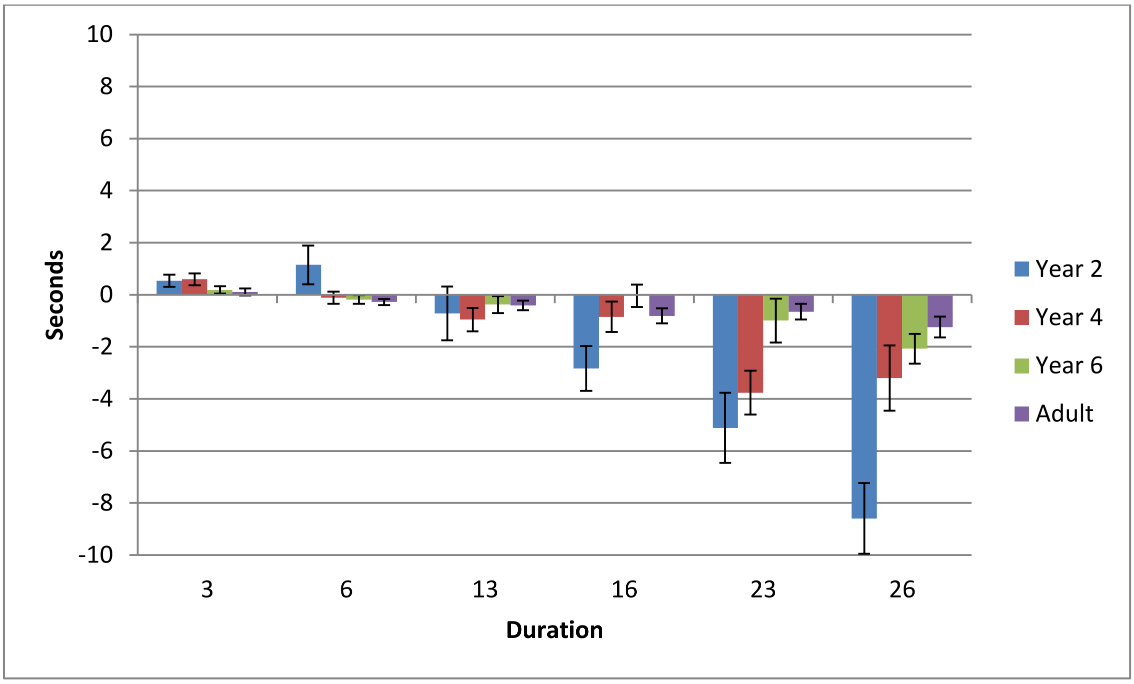


Figure 3.7: Relative difference between reproduced durations and true durations

The average absolute score was calculated across the 12 trials (Table 3.3).

Table 3.3: Duration score on the short-term task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)		Adult (N=23)	
	M	SD	M	SD	M	SD	M	SD
Absolute Duration Score	7.91	4.67	4.70	3.12	2.86	1.62	1.30	0.54

A one-way ANOVA was conducted on the absolute duration scores, with a between-subjects factor of age (Years 2, 4, 6 and adult). There was a significant age effect for the absolute duration score, $F(3,88)=32.98$, $p<0.01$, $\eta_p^2=0.53$. Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.05$) and Year 2 and Year 6 ($p<0.01$); older children showed greater accuracy. The difference between Year 4 and Year 6 was approaching significance ($p=0.06$). A significant difference was also found between the adult group and all three school years (*p*<0.01); adults were more accurate in their duration judgments.

A partial correlation, controlling for age in months, was conducted between the two types of short-term tasks. A significant correlation was found between absolute scores on the short-term duration task and sequencing scores on the short-term sequencing task, *r*(89)= 0.49, *p*<0.01 (see Figure 3.8); as participants' accuracy increased on the sequencing task (i.e. the position score decreased), accuracy also increased on the duration task (i.e. the number of seconds from the correct duration decreased).

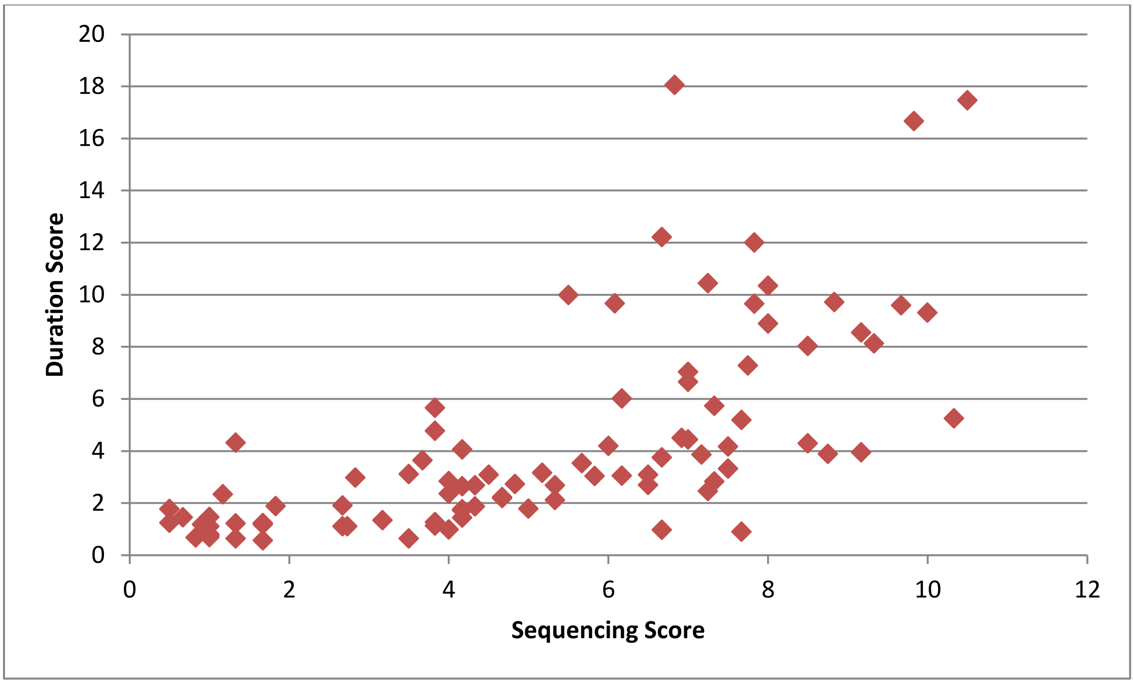


Figure 3.8: Correlation between sequencing score and duration score

3.4.3. Relationship between Semantic and Episodic Memory

Partial correlations, controlling for age in months, were conducted to examine the relationship between children's performance on the short-term temporal tasks and their performance on the semantic temporal memory questionnaire and the episodic memory tasks (from Experiment 1; see Chapter 2).

There was a significant correlation between performance on the short-term duration task and the general section of the semantic questionnaire, *r*(66)=0.39, *p*<0.01, whilst the correlation between short-term duration performance and the duration section of the semantic questionnaire was approaching significance, *r*(66)=0.22, *p*=0.08.

There was no significant correlation between children's performance on the short-term sequencing task and their performance on the episodic sequencing task in Experiment 1, $r(66)=0.14$, $p>0.05$. Similarly, there was no correlation between performance on the short-term duration task and either the episodic duration task, $r(66)=0.11$, $p>0.05$, or the cumulative verbal duration estimates from Experiment 1, $r(63)=-0.10$, $p>0.05$.

3.4.4. Sequencing Metamemory Judgments

3.4.4.1. Performance Judgments

Performance estimates were made by participants both before (pre-performance) and after (post-performance) completing the sequencing task (Table 3.4). The relative difference between these two estimates was also calculated. Scores ranged from 0 (bad) to 10 (good).

Table 3.4: Performance estimates on the short-term sequencing task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)		Adult (N=23)	
	M	SD	M	SD	M	SD	M	SD
Pre-Performance Estimate (0-10)	7.29	2.39	6.57	2.08	7.59	1.84	6.13	1.52
Post-Performance Estimate (0-10)	6.29	2.58	6.09	2.68	5.41	1.65	5.70	2.12
Relative Change in Estimate	-1.00	0.64	-0.48	0.57	-2.18	0.35	-0.43	0.35

A mixed-design ANOVA was conducted, with a within-subjects factor of time of estimate (pre- and post-performance) and a between-subjects factor of age (Years 2, 4, 6 and adult). There was a main effect of time of estimate, $F(1,88)=16.60$, $p<0.01$, $\eta_p^2=0.16$, with post-performance estimates being lower than pre-performance estimates. There was no main effect of age for performance estimates, $F(3,88)=0.99$, $p>0.05$,

η_p^2=0.03, suggesting similar judgments across the four groups. The interaction between time of judgement and age was approaching significance, $F(3,88)=2.55$, $p=0.06$, η_p^2=0.08. This interaction was explored further through repeated-measures ANOVAs for each age group, with a within-subjects factor of time of judgment (pre- or post-performance). There was a significant effect of time of judgment in Year 6, $F(1,21)=38.40$, $p<0.01$, η_p^2=0.65; confidence estimates decreased significantly after completing the task. There was no significant effect of time of judgment for Year 2, $F(1,23)=2.42$, $p>0.05$, η_p^2=0.10, Year 4, $F(1,22)=0.72$, $p>0.05$, η_p^2=0.03, or the adult sample, $F(1,22)=1.50$, $p>0.05$, η_p^2=0.06.

Partial correlations, controlling for age in months, revealed no relationship between participants' short-term sequencing score and their pre-performance estimates, $r(89)=0.04$, $p>0.05$. Similarly, there was no correlation between participants' short-term sequencing score and their post-performance estimates, $r(89)=-0.10$, $p>0.05$.

3.4.4.2. Difficulty Estimates

Difficulty estimates were next examined (Table 3.5). Scores ranged from 0 (easy) to 10 (hard).

Table 3.5: Difficulty estimate on the short-term sequencing task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)		Adult (N=23)	
	M	SD	M	SD	M	SD	M	SD
Difficulty Estimate (0-10)	4.35	3.12	4.35	2.74	5.59	2.36	6.04	1.74

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6 and adult). There was a significant effect of age for difficulty ratings, $F(3,88)=2.85$, $p<0.05$, η_p^2=0.09. Although Tukey's post-hoc analysis revealed no significant differences between the year groups ($p>0.05$), the means suggest an increase in difficulty ratings with age.

There was no correlation between difficulty estimates and performance on the short-term sequencing task, $r(89)=-0.04$, $p>0.05$.

3.4.4.3. Strategy Use

The percentage of participants reporting the use of a strategy was explored (Table 3.6). The most popular strategy used was verbally rehearsing the shapes, whilst other strategies reported included drawing the shapes on the table with their fingers or making a story out of the shapes. One child in Year 4, two children in Year 6 and two adults made reference to a cumulative rehearsal strategy. This involves adding the most recent shape to the shapes seen previously, e.g. ‘circle, circle-square, circle-square-triangle’. An example of a cumulative rehearsal strategy description provided by a child in Year 6 was: ‘I whispered them in my head, and then when another came up I said the sequence I'd already seen’.

Table 3.6: Strategy use on the short-term sequencing task

	Strategy Use (%)	No Strategy (%)
Year 2 (N=24)	62.5	37.5
Year 4 (N=23)	87	13
Year 6 (N=22)	90.9	9.1
Adult (N=23)	95.7	4.3

Independent-samples t-tests, with a between-subjects factor of strategy use (strategy, no strategy) revealed a significant difference between the two groups, $t(90)=2.70$, $p<0.01$; participants employing a strategy were more accurate at sequencing, compared to those not employing strategies.

3.4.5. Duration Metamemory Judgments

3.4.5.1. Performance Judgments

Performance estimates were made by participants both before (pre-performance) and after (post-performance) completing the duration task (Table 3.7). The relative difference between these two estimates was also calculated. Scores ranged from 0 (bad) to 10 (good).

Table 3.7: Performance estimates on the short-term duration task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)		Adult (N=23)	
	M	SD	M	SD	M	SD	M	SD
Pre-Performance Estimate (0-10)	7.17	2.79	6.65	2.69	7.45	1.63	6.39	1.31
Post-Performance Estimate (0-10)	7.79	2.64	7.65	1.61	7.14	1.42	6.52	1.16
Relative Change in Estimate	0.63	0.53	1.00	0.60	-0.32	0.28	0.13	0.25

A mixed-design ANOVA was conducted to examine participant performance estimates, with a within-subjects factor of time of estimate (pre- and post-performance) and a between-subjects factor of age (Years 2, 4, 6 and adult). There was no main effect of time of judgment, $F(1,88)=2.60$, $p>0.05$, $\eta_p^2=0.03$. There was also no main effect of age for performance estimates, $F(3,88)=1.56$, $p>0.05$, $\eta_p^2=0.05$. The interaction between time of judgement x age was not significant, $F(3,88)=1.64$, $p>0.05$, $\eta_p^2=0.05$.

Partial correlations, controlling for age in months, revealed a significant relationship between short-term duration ability and both pre-performance estimates, $r(89)=-0.26$, $p<0.05$, and post-performance estimates, $r(89)=-0.21$, $p<0.05$. This suggests that participants who were more confident in their performance, both before and after completing the task, were more accurate on the short-term duration task.

3.4.5.2. Difficulty Estimates

Difficulty estimates were next explored (Table 3.8). Scores ranged from 0 (easy) to 10 (hard).

Table 3.8: Difficulty estimate on the short-term duration task

	Year 2 (N=24)		Year 4 (N=23)		Year 6 (N=22)		Adult (N=23)	
	M	SD	M	SD	M	SD	M	SD
Difficulty Estimate (0-10)	3.96	3.32	3.61	2.55	3.59	2.63	5.30	2.05

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6 and adult). There was no significant effect of age for difficulty ratings, $F(3,88)=2.08$, $p>0.05$, $\eta_p^2=0.07$, $\eta_p^2=0.09$. A partial correlation, controlling for age in months, revealed no correlation between difficulty estimates and performance on the short-term duration task, $r(89)=0.13$, $p>0.05$.

3.4.5.3. Strategy Use

Strategy descriptions for the short-term duration task were explored (Table 3.9). The most frequent strategy used was counting out loud or in their head, whilst references were also made to tapping or making noises. One child in Year 4 and two children in Year 6 made reference to using a marker to provide a rhythm to their counting (e.g. ‘Mississippi’ or ‘elephant’).

Table 3.9: Strategy use on the short-term duration task

	Strategy (%)	No Strategy (%)
Year 2 (N=24)	66.7	33.3
Year 4 (N=23)	87	13
Year 6 (N=22)	100	0
Adult (N=23)	100	0

Independent-samples t-tests, with a between-subjects factor of strategy use (strategy, no strategy) revealed a significant difference between the two groups, $t(90)=2.66$, $p<0.01$; participants employing a strategy were more accurate at duration reproductions than those not utilising a strategy.

3.5. Discussion

3.5.1. Sequencing

The aim of this experiment was to examine children’s short-term temporal abilities. The results revealed an increase in short-term sequencing ability with age, supporting hypothesis 1. The current research extended this finding from serial recall designs (McCormack et al., 2000; Visu-Petra et al., 2008) to a reconstruction design, whereby participants were provided with the items to be sequenced. Even when the additional task demand of recalling the stimuli before sequencing was removed, performance still showed age improvements. The current study also employed a more sensitive form of measurement to assess sequencing ability, taking into consideration the *degree* to which participants incorrectly sequenced stimuli, and still discovered a developmental increase in sequencing ability.

Across all ages, when errors were made in sequencing items, participants were likely to place the shapes only one or two positions away from its correct position; it was rare for items to be placed more than three positions away. This positional gradient suggests that even the youngest children were able to retain some memory for the temporal order of the items within the sequence. This supports previous literature showing temporal clustering (Bhatarah, Ward, & Tan, 2006; Klein, Addis, & Kahana, 2005); items placed erroneously are more likely to be placed in neighbouring positions than more distant positions. A serial position curve was also evident, with participants more likely to sequence items at the beginning and end correctly compared to items in the middle (i.e. primacy and recency effect). Items at the beginning or end of the sequence could move in only one direction if an incorrect response was made; for example, items at position one could only move forwards to position two or more. In contrast, items in the middle were more prone to interference, as they could move in either direction; for example, items in position three could move backwards to position two or less, or forwards to position four or above. This would increase the likelihood of participants making sequencing errors for the middle items. These findings therefore further extend the literature on serial position curves (Brown, Preece, & Hulme, 2000; Estes, 1972, 1997; Murdock, 1983; Nairne, Neath, Serra, & Byun, 1997; Page & Norris, 1998; Rouder & Gomez, 2001; Shiffrin & Cook, 1978).

Of the strategies utilised across the four groups, the majority of participants employed a verbal recoding strategy for the short-term sequencing task, repeating the names of the different shapes or colours out loud. Younger children displayed a tendency to rehearse items singularly, i.e. just saying the name of the shape displayed on-screen (see also Lehmann & Hasselhorn, 2007; McGilly & Siegler, 1989). Several children also varied the strategies they used within the task, e.g. starting to rehearse only the first letter of the shape or colour, before finding this too confusing and adopting a different strategy for the remaining trials. This use of multiple strategies is in line with research by Coyle and Bjorklund (1997), who found the average number of strategies used in a recall task to be greater than one; this led the authors to claim that when children are employing strategies, variability is the rule, rather than the exception.

Age increases were evident in the percentage of children employing a strategy to aid sequencing, indicating a production deficit in the younger children. This finding is in line with previous literature showing increased strategy use with age (Espinosa-Fernandez et al., 2004; Kail, 1990; Kreutzer et al., 1975) and supports hypothesis 2. Although a similar percentage of older children and adults reported using a strategy, performance on the actual task increased with age. This is also suggestive of a utilisation deficiency (Miller, 1990; Miller & Seier, 1994); children who attempted to employ a rehearsal strategy appeared to gain less benefit from their effort, compared to adults employing the same strategy (see Bjorklund, Miller, Coyle, & Slawinski, 1997 for a review of studies showing a utilisation deficiency).

A possible reason for this difference in the effectiveness of strategy use may be the way that children encoded the task stimuli. Research has shown that children’s ability to recode visual material into a phonological form develops during childhood (Gathercole, Pickering, Ambridge, et al., 2004). Below approximately 7 years of age, children are reliant on the visuospatial sketchpad (outlined in the working memory model of Baddeley & Hitch, 1974) to recall visual information. In contrast, older children are able to recode this visual information into a phonological form through verbal rehearsal, utilising the phonological loop (Hitch & Halliday, 1983; Hitch, Halliday, Schaafstal, & Schraagen, 1988; Miles, Morgan, Milne, & Morris, 1996). This may explain why the younger children were less likely to utilise a verbal rehearsal strategy, as they were more reliant upon the visual features of the stimuli, rather than focusing on phonologically recoding the shapes.

As noted by Pickering (2001), this reduced reliance on the visuospatial sketchpad with increasing age is replaced by more focus on the verbal labels of the stimuli; this allows the verbal information to be maintained in the phonological loop, through the process of rehearsal. During the transition from visual to verbal processing, children are thought to use an intermediate strategy of dual coding, whereby they have both verbal and visual representations of the items to be remembered (Palmer, 2000). Further development results in automatic phonological coding, whereby children can switch their attention from an automatic response that is based on the mode of presentation (i.e. visual), to a controlled response based on the task demands (i.e. a verbal response to allow the sequence to be rehearsed). The transition from visual processing, to dual coding, and finally automatic phonological coding, may thus help to explain the developmental increases seen across the primary school years. Children reliant on visual processing may have been unable to rehearse the names of the shapes, whilst children who used the intermediate strategy of dual coding may have been able to rehearse the shapes to some extent. Finally, children who automatically phonologically recoded the shapes may have been able to rehearse the shapes more easily and therefore showed greater sequencing accuracy.

Changes in attentional capacity may also provide an explanation for the observed increase in sequencing ability. Attention is believed to be reliant upon the frontal lobes. Research has shown that this brain region does not reach maturity until adolescence (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999; Yakovelev & Lecours, 1967) which suggests that younger children in the current experiment would have been unable to pay full attention to the sequencing task, and their performance will have suffered, relative to the adults. The role of attention in temporal performance is discussed further in section 3.5.2.

Increases in processing speed with age may also explain the performance increases in sequencing ability seen across the primary school years and into adulthood. This increased processing speed has been linked to brain development (Kail & Salthouse, 1994). Faster processing is thought to prevent items from decaying (Portrat, Camos, & Barrouillet, 2009), as well as reducing interference (Cowan, 1997); participants are able to articulate stimuli at greater speeds, thus leading to faster rehearsal (Cowan et al., 1998). Pickering (2001) highlights the fact that participants who respond faster on visuospatial tasks are more likely to perform better, whilst Smyth and Scholey (1996) found articulation rate to be related to visuospatial task performance. Older children and adults may therefore have been able to articulate the names of the shapes at a faster pace than younger children, meaning that the sequence was more easily maintained in the phonological loop during rehearsal. In contrast, younger children's slower articulation may have resulted in decay and interference from the next shapes in the sequence, before the children had a chance to rehearse the current shape.

3.5.2. Duration

Short-term duration abilities were also found to increase with age, supporting hypothesis 1. Although there were significant increases in ability between all age groups, the mean difference in scores was greatest between Year 2 and Year 4 (i.e. 6 to 7 years and 8 to 9 years). The current research therefore extends previous research highlighting that this age range is a crucial period of duration development, to include a wider range of durations than previously studied (Droit-Volet & Wearden, 2001; Espinosa-Fernandez et al., 2004; Gautier & Droit-Volet, 2002; McCormack et al., 1999).

There was a tendency for all age groups to underestimate the durations seen, pressing the stop button before the true duration had been reached; this was more pronounced in the youngest children, mirroring previous duration research and extending the findings to a wider range of durations (Arlin, 1986; Block, Zakay, & Hancock, 1999; Espinosa-Fernandez et al., 2003; Ulbrich et al., 2007). This underproduction may be explained by children's poorer attentional resources. Research has shown that when attention is not focused on a task, duration is perceived as shorter (Zakay, 1992). As noted by Droit-Volet (2003), children are easily distracted by their external environment, which may disrupt their temporal perception. Younger children with reduced attentional capacities are thus likely to perceive durations as shorter than they actually are. Research into the temporal perception of children with attentional deficit/hyperactivity disorder (ADHD) has found that these children perform less accurately than healthy controls when reproducing durations (Barkley, Koplowitz, Anderson, & McMurray, 1997). Neuroimaging research has also shown that the prefrontal and frontal cortex structures that are involved in sustained attention (Duncan, 1995; Webster & Ungerleider, 1998) are likely to be involved in estimating time (Mimura, Kinsbourne, & O'Connor, 2000; Rubia et al., 1998), whilst behavioural studies have also found a link between attention and time perception (Columbo & Richman, 2002). These findings provide support for the attentional gate model of duration, proposed by Zakay and Block (1994); younger children paid less attention to the stimuli during the presentation phase, and as a result fewer pulses passed through the attentional gate, resulting in a shortened perception of time.

Attention is therefore likely to influence children’s ability to make temporal reproductions. The central executive is thought to monitor such attentional resources (Baddeley, 1996). However, this relies upon the development of the frontal cortex, which only matures by adolescence (Sowell et al., 1999; Yakovelev & Lecours, 1967). As a result, children are thought to have limited attentional capacities (Demster & Brainerd, 1995; Shepp, Barrett, & Kolbet, 1987). It is therefore possible that the older children and adults in the current study focused on the task to a greater extent, paying more attention to the stimuli and the length of time it was present on-screen, thus leading to more accurate reproductions compared to the younger children. In order to test this hypothesis, further research would have to be conducted; attentional measures would have to be taken and individual differences in attention and performance would have to be measured before any firm conclusions could be drawn.

An alternative explanation for children’s underestimations relates to their waiting abilities. In a review of temporal duration research, Block et al. (1999) suggested that young children may show impatience on reproduction tasks, and as a result may terminate the reproduction session sooner than older children. Further research has shown that children display impatience when completing temporal reproduction tasks and have difficulty when waiting for the correct length of time (Fraisse, 1982). It therefore is possible that the poorer performance shown by the youngest children may not be due to cognitive differences in their ability to perceive durations, and may instead be due to impatience when completing such tasks.

The reproduced durations tended to cluster around the true duration, particularly in the oldest age groups, indicating that participants were relatively consistent at reproducing different duration lengths. The 6 and 7 year olds’ responses to the two shortest durations (3 and 6 seconds) also showed a clustering around the true duration, suggesting that they were not just guessing and were instead accurately perceiving the duration. However, for the longer durations, their responses were more evenly distributed across a wider duration range, indicating less consistency within this age group, and more variability in their responses. Research has suggested that children have noisier encoding of durations, resulting in greater variability in their responses (Droit-Volet & Rattat, 2007). This in turn is again thought to be linked to their difficulty in focusing attention on processing temporal information (Meaux & Chelonis, 2005; Smith, Taylor, Warner-Rogers, Newman, & Rubia, 2002; Szelag et al., 2002).

The most common strategy used on the duration task to monitor the passage of time was through counting, in line with previous research (Levin, Wilkening, & Dembo, 1984; Wilkening, Levin, & Druyan, 1987). The majority of children using a counting strategy counted out loud, whilst adult participants were more likely to count sub-vocally, only revealing the strategy they used when asked. As found with the sequencing task, the percentage of children reporting the use of a strategy increased with age, supporting hypothesis 2 and previous strategy literature (Espinosa-Fernandez et al., 2004; Kail, 1990). This reduced percentage of younger children employing a strategy supports the production deficit hypothesis.

Children’s counting was found to be less rhythmic than adults’ counting, a quality that is important in order to mark the passage of time successfully (Levin & Wilkening, 1989). Although a similar percentage of the older children and the adults employed a counting strategy, the more variable nature of the children’s counting, and their reduced accuracy on the task, suggests children gained less benefit from a counting strategy compared to adults (Miller, 1990; Miller & Seier, 1994). Whereas adults were more able to pace their counting to maintain a constant rhythm, it was more common for children to display variability in the speed at which they counted. For example, some children would count quickly to begin with, before displaying some confusion when entering double figures and therefore slowing their counting down (e.g. “…6, 7, 8, 9…10…11, 12… 13”). Alternatively, some children increased their counting speed during the reproduction phase, compared to the presentation phase, in order to reach the target duration sooner. This was especially the case for longer durations and may be due to their impatience, as discussed above (Block et al., 1999; Fraisse, 1982); further research would be required in order to test this theory, however. This difficulty in counting to larger numbers, as well as an impatience to wait for long periods of time, may explain why children showed more variability for longer durations (23/26 seconds) compared to shorter durations (3/6 seconds).

Memory span has been found to correlate with memory for short-term rhythms; Saito (2001) found that participants who scored more highly on a digit span task were more accurate when reproducing short-term rhythms through a series of key presses. Related research by Saito and Ishio (1998) into the relationship between memory and rhythm led the authors to conclude that an articulatory component of the phonological loop may play a key role in our memory for rhythm. Researchers have also postulated an additional component within the phonological loop, which is thought to be involved in timing control in immediate memory tasks (Hitch, Burgess, Towse, & Culpin, 1996; Saito, 2001). It is possible that this mechanism, which would help participants to maintain a more constant counting rhythm to monitor durations, is less developed in younger children; this would explain the more variable nature of children's counting.

3.5.3. Relationship between Aspects of Temporal Memory

Performance on the sequencing and duration short-term tasks was found to be related. This correlation in performance indicates that the two tasks may be underpinned by a similar construct. Attentional processes may be crucial for remembering both the order of the shapes and accurately reproducing durations. Children displaying high levels of attention are able to focus on relevant information, whilst ignoring irrelevant information and controlling any impulsive responding (Dowsett & Livesey, 2000; Ruff & Rothbart, 1996). In a large-scale experiment of 700 6 year olds, research by the NICHD Early Child Care Research Network (2005) discovered variability in children's attentional capacity; there may also have been large differences in the attentional capacity of children in the current experiment. Children with greater attentional control may have been more likely to display sustained attention, focusing on the sequence presented to them and paying more attention to the length of time the image remained on the screen for. In contrast, children who were easily distracted and found it hard to concentrate for relatively long periods of time may have been more susceptible to interference; they may have turned their attention away from the screen or lost interest in the tasks. Further research assessing the impact of concentration and attention span on performance across a variety of temporal tasks is needed before firm conclusions can be drawn.

Performance on the short-term duration task was found to correlate with the general section of the semantic temporal memory questionnaire, and this correlation was also approaching significance with the duration section of the questionnaire. This suggests that the more that children knew about general time concepts (e.g. the number of minutes in an hour) and the more accurate they were at estimating longer durations (e.g. their lunch break), the more accurate they were in their ability to reproduce a short-term duration. This may be due to the fact that all three forms of duration memory require children to understand units of time, e.g. how long a second or minute lasts for. The children who understood what a second or minute represented, and were able to estimate the duration of daily events, would have been more capable of applying this knowledge to their time reproductions. This is particularly likely to be the case for children who employed a counting strategy, which required some understanding of seconds. Support for this reasoning comes from research into the role of knowledge and its impact upon working memory (Avons & Phillips, 1986; Chi, 1978; Gathercole, Frankish, Pickering, & Peaker, 1999; Wilson, Scott, & Power, 1987). For example, Chi (1978) demonstrated that children who were experienced chess players were more able to recall the location of chess pieces in legitimate configurations. It is therefore conceivable that children with a greater knowledge about seconds and minutes would have been more able to reproduce durations, utilising this knowledge to help them to count along during the presentation phase.

There was no relationship found between short-term and episodic temporal memory for either sequencing or duration. This suggests that temporal memory for short-term durations and sequences is not related to the ability to make temporal estimates about novel, experienced events. This is in contrast to the relationship between short-term duration memory and semantic duration memory. These contrasting results may be due to the fact that the episodic task was novel, whilst the semantic memory judgments (e.g. the duration of lunchtime) were repeated events. Children will therefore have had greater exposure to the duration of these repeated events, compared to seeing the duration of the items in the episodic film only once. Alternatively, the lack of a relationship may be due to the involvement of different brain regions for the two types of temporal tasks; research has shown different areas of brain activation for short-term and long-term memory (Braver et al., 2001; Cabeza, Dolcos, Graham, & Nyberg, 2002; Izquierdo, Medina, Vianna, Izquierdo, & Barros, 1999; Talmi, Grady, Goshen-Gottstein, & Moscovitch, 2005). These different brain regions may develop at different rates during childhood, accounting for the lack of a relationship between children’s performance on the short-term and episodic temporal tasks. Alternatively, methodological differences in the two tasks may explain why there was no relationship between these two forms of temporal memory. The episodic tasks may have been less strategic, relying on children's sense of how long the different items took to make, or the order in which items were made. In contrast, the short-term temporal tasks could be perceived as more strategy-led; children were able to use techniques to aid their performance, which was not possible for the episodic tasks.

3.5.4. Metamemory Judgments

The current study also aimed to examine metamemory judgments about performance on short-term temporal tasks. There was no significant difference between the four age groups in their performance estimates; 6 year olds were as confident in their ability to remember sequences and reproduce durations as the adults were. However, the fact that there was an increase in performance with age, whilst performance ratings were similar across the four groups, suggests that the younger children may have been overconfident in their performance (hypothesis 3). This extends previous research showing overconfidence in young children to temporal memory tasks (Finn & Metcalfe, 2014; Flavell, Friedrichs, & Hoyt, 1970; Flavell & Wellman, 1977; Yussen & Levy, 1975). The lower difficulty ratings by the youngest children for the sequencing task may also reflect a degree of overconfidence; these children may have believed that they performed well on the task, and therefore reasoned that it must have been relatively easy. A possible explanation for young children's overconfidence in their performance is that they equated the amount of effort they put into the tasks as an indication of how well they did (Wellman, 1985). Because the tasks required children to concentrate and retain information in their short-term memory, they may therefore have viewed this effortful process as equating to high levels of performance.

Bjorklund and Green (1992) suggested that this tendency for young children to overestimate their performance may be adaptive, encouraging children to attempt tasks they cannot do well; if children are aware of their poor performance, they may not continue to attempt new tasks. By protecting their self-esteem, children will be more likely to persist, leading to increased practice and possible increases in performance (Shin et al., 2007). Nevertheless, an inability to effectively monitor one's performance may prove to be disruptive to their learning. By not understanding the limitations of their memory, children may not devote as much time to independent learning activities, such as spelling or homework, as they may feel overconfident in their abilities; research has shown that children who are overconfident choose to study fewer items and as a result show poorer performance (Dunlosky & Rawson, 2012; Metcalfe & Finn, 2008). Self-regulated learning may thus prove to be less effective for children who are unable to accurately reflect on their performance (Finn & Metcalfe, 2014). Equipping teachers with an awareness of younger children's tendency to be overconfident in their performance may result in less reliance on self-regulated activities, and more focus on guided teaching to ensure children are effectively learning.

Overall, participants' estimates of their performance on the two short-term tasks remained stable from pre- to post-performance; this finding suggests that increased task exposure did not alter perceptions of their abilities (hypothesis 4). The fact that children did not alter their performance estimates after completing the tasks lends support to the wishful thinking hypothesis (Stipek et al., 1984). Children's inability to significantly alter their post-performance estimates following completion of the tasks may suggest that their estimates are a reflection of how they wish to perform, rather than a reflection of their perceived performance. However, the adult sample did not significantly alter their estimates following task completion either; this suggests that either the wishful thinking hypothesis extended to 16 and 17 year olds, or more likely participants of all ages were fairly confident in their pre-performance estimates and did not feel the need to alter their judgments. Taken as a whole, these results therefore imply that performance judgments remain stable throughout the completion of short-term temporal tasks.

Participants' estimates of their performance on the duration task, both before and after completing 12 trials, was found to correlate with their accuracy in reproducing the durations; higher performance estimates were correlated with smaller discrepancies between the reproduced and true durations. In contrast, there was no relationship between performance estimates on the sequencing task and their sequencing ability. Participants' greater awareness of their ability to reproduce durations may be due to a greater familiarity with the concept of marking the passage of time, rather than sequencing stimuli. As noted by Espinosa-Fernandez et al. (2003), estimates are made about durations on a regular basis, such as crossing a busy street, waiting for something to occur or deciding whether to continue solving a problem, based on how much time has been spent on the task already. In contrast, participants may have less experience with sequencing a series of items, as this is not a task that is encountered on a daily basis. Familiarity with task stimuli has been shown to impact upon metacognitive judgments (e.g. Besner & Son, 2007; Korenman & Peynircioglu, 2004; Reder & Ritter, 1992). Metamemory research has also placed a large focus on participants' perceptions of how familiar items are, as measured through feeling-of-knowing paradigms (Hart, 1965; Koriat, 2000; Metcalfe, Schwartz, & Joaquim, 1993); this indicated that familiarity plays an important role in our metamemory judgments. It may therefore be hypothesised that the increased familiarity in dealing with durations, compared to sequences, led to a more accurate perception of temporal memory capacity and therefore a correlation between performance estimates and performance on the reproduction task. The effect of task familiarity on the accuracy of children's metamemory judgments remains to be examined comprehensively.

Caution has to be taken when interpreting the metamemory estimates made in the current study. Due to the scoring systems employed in both the sequencing and duration tasks, direct comparisons could not be made between children's performance estimates and their performance on the tasks. This is in contrast to studies where participants are asked to predict how many items they will recall, before comparisons are made to the actual number of items that they recalled (e.g. DeMarie & Ferron, 2003). Due to the scoring methods employed in the current study, it would not have been possible for children to estimate their score due to the complex scoring system used. Participants could have been asked how many of the sequencing trials they thought they would sequence correctly before comparisons were made with their number of correct sequences, but such a measure of performance accuracy would have lost the sensitivity of the current scoring system. The metamemory scales used in the current study were therefore more of an intuitive guide as to how well participants believed they would perform, and any conclusions drawn are tentative.

3.5.5. Conclusion

The current research aimed to establish whether there exists a relationship between short-term and episodic temporal memory. The results showed that these two forms of temporal memory are developmentally independent of each other; sequencing and duration abilities on the short-term task were not related to episodic performance. Conversely, there was a relationship between children's knowledge about semantic temporal concepts such as the duration of familiar events and the number of minutes in an hour, and the ability to reproduce durations; this suggests that this time knowledge impacts upon short-term memory for durations.

Age increases were found in both sequencing and duration performance on the short-term temporal tasks. Performance perceptions tended to remain stable from the start to the end of the task, whilst younger children appeared to display overconfidence in their estimates of how well they performed. Increases in spontaneous strategy use were seen with age, with a third of the youngest children not employing a strategy; this is suggestive of a production deficiency. There was also evidence of a utilisation deficiency, with younger children who did employ a strategy gaining less benefit than older children and adults. Strategy use therefore played a key role in the age-related increases seen. If children of all ages were taught how to use a strategy effectively to complete the short-term sequencing and duration tasks, performance in the younger children may thus increase in line with that of older children, attenuating the age effects seen. This was the aim of Experiment 3.

Chapter 4: The Effects of Strategies and Suppression on Short-Term Temporal Memory

4.1. Introduction

Strategies can be defined as ‘the potentially conscious, deliberate and controllable cognitive plans adopted to enhance performance in a memory task’ (Schneider & Sodian, 1997, p. 433). As discussed in section 1.7. in the literature review, research has shown an increasing use of strategies with age across childhood (Espinosa-Fernandez et al., 2004; Kail, 1990). Nevertheless, Bjorklund, Dukes, and Brown (2009) stress that strategy use remains an important area of research. Children have been found to spontaneously employ strategies to aid duration estimations by approximately 10 years (Levin & Wilkening, 1989), although further research has found that children as young as 7 and 8 years employ a counting strategy to mark the passage of time (Espinosa-Fernandez et al., 2004). When examining memory for recalling a list of items, children between the ages of 8 and 10 years begin to rehearse items together (i.e. cumulative rehearsal), rather than merely labelling the items individually (Lehmann & Hasselhorn, 2007).

The findings of the short-term memory research conducted in Experiment 2 revealed that a greater proportion of older children employed a strategy to aid their performance. It has been suggested that younger children do not spontaneously rehearse because they have fewer situations in which they need to remember information (Hagen, Hargrave, & Ross, 1973). For example, older children have more experience with learning spellings or remembering information for a test and will therefore have had more practice with using a rehearsal technique (Leal, Crays, & Moely, 1985). Alternatively, Flavell et al. (1966) proposed a production deficiency hypothesis to account for the fact that young children do not tend to spontaneously produce strategies to aid their performance. According to the authors, children have the ability to use these strategies, but do not tend to do so.

Nevertheless, children can be taught to use strategies through training, in order to increase their task performance (Cox, Ornstein, Naus, Maxfield, & Zimler, 1989; Guttentag, 1984; Johnston, Johnson, & Gray, 1987; Schwenck, Bjorklund, & Schneider, 2009). Experiment 2 also found that although similar percentages of children in Year 4 and Year 6 spontaneously implemented a strategy to aid their performance, performance increases with age were still evident. Younger children who employed a strategy spontaneously may not have achieved the same benefits as older children who employed a similar strategy; this is known as a utilisation deficiency (Bjorklund et al., 1997; Miller, 1990; Miller & Seier, 1994; Schwenck, Bjorklund, & Schneider, 2007). Teaching children across the primary school years some straightforward strategies to aid their sequencing and duration performance would remove the production deficiency and may attenuate the utilisation deficiency, reducing the age effects seen between the oldest and youngest children when completing temporal tasks.

4.1.1. Sequencing Strategies

Experiment 2 found age increases in temporal performance between 6 and 11 years, in line with previous research (Arlin, 1986; Espinosa-Fernandez et al., 2004; McCormack et al., 2000; Szelag et al., 2002; Visu-Petra et al., 2008). Although a variety of factors could account for this performance increase (e.g. attention, processing speed; see section 3.5.), it is possible that strategy use could be an important determining factor of how well children performed on temporal tasks; children who were able to successfully implement a strategy to aid their performance may have achieved greater accuracy on temporal tasks, compared to children who were not aware of the benefit such strategies could have.

The most common strategy spontaneously used to remember the sequence of the six shapes in Experiment 2 was a verbal rehearsal strategy, i.e. saying the names of the shapes or the colours. Research has shown that children’s rehearsal strategies undergo a developmental change, from a singular rehearsal strategy to a cumulative rehearsal strategy (Lehmann & Hasselhorn, 2007; McGilly & Siegler, 1989). A singular rehearsal strategy involves simply saying the names of the shapes or colours in turn. By the end of the sequence, children tend to forget the first items seen, as the sequence was not maintained in their short-term memory. In contrast, older children are more likely to employ a cumulative rehearsal strategy, where the name of the item shown is added to the previous items seen. An example would be ‘circle, circle-square, circle-square-triangle…' Such a strategy ensures that the items remain in the phonological loop, thereby increasing the likelihood of remembering all six items by the end of the sequence.

Teaching children a rehearsal strategy has been shown to be an effective way to increase memory performance (Bebko, 1979; Cox et al., 1989; Gruenenfelder & Borkowski, 1975; Guttentag, 1984; Johnston et al., 1987; Schwenck et al., 2009). Bebko (1979) examined the impact of strategy use on remembering a series of coloured slides. In a baseline testing session, the performance of children who did not spontaneously implement a strategy (non-producers) was poorer than children who found a way to rehearse (producers). Teaching non-producers a cumulative rehearsal strategy was found to increase their performance, in line with the producers' performance. Bebko hypothesised that previous research which has consistently shown age effects in sequencing ability may therefore be due to the fact that the proportion of children using a strategy increases with age. This suggests that teaching children of all ages a strategy to aid performance on both a sequencing and duration task may attenuate any age effects seen.

Research into young children's phonological recoding of visual stimuli has indicated that unless children's attention is drawn to the verbal label, they will not utilise this information in memory tasks (Palmer, 2000); this suggests that young children are bound to the perceptual characteristics of the stimuli, unless they are made aware of the verbal labels. Teaching children a cumulative rehearsal technique to complete a short-term sequencing task may therefore be beneficial for younger children, alerting to them the fact that visual information can be phonologically recoded into a verbal label (see section 3.5.1. for more information about visuospatial versus phonological encoding). As the youngest children in Experiment 2 either did not employ a strategy or used a singular rehearsal strategy, teaching these children a cumulative rehearsal strategy may therefore be more beneficial, compared to teaching older children the same strategy. However, it is unlikely that children of all ages will perform at similar levels as a result of being taught the same strategy; it is likely that younger children will still display a utilisation deficiency, whilst other factors such as attention and processing speed may also play a role in producing developmental increases in performance (Demster & Brainerd, 1995; Kail & Salthouse, 1994; Shepp et al., 1987). The current study therefore aimed to examine whether age increases in short-term sequencing performance could be attenuated through the implementation of a cumulative rehearsal technique.

4.1.2. Duration Strategies

The most common duration strategy spontaneously produced in Experiment 2 was to count along with the shape whilst it was displayed on-screen (presentation phase), before counting to this number again when required to reproduce the duration (reproduction phase); this also supports previous duration literature (Levin et al., 1984; Wilkening et al., 1987). Although this technique proved to be effective for older children and adults, a proportion of younger children who spontaneously used a counting strategy were not found to be consistent in their counting during the two phases; this is indicative of a utilisation deficiency. As discussed in section 3.5.2, several children counted at a relatively steady pace during the presentation phase, before increasing their counting speed during the reproduction phase. As a result, there was little consistency between the two phases. As noted by Levin and Wilkening (1989), a constant rhythm must be kept in order to measure time by counting. Commenting on the findings of research showing children’s difficulty to accurately reproduce durations even after employing a counting strategy, the authors suggest that this may be due to children not understanding that rhythm is important when measuring time. Wilkening et al. (1987) found that counting occurred more frequently to measure durations when there was a rhythmic beat presented alongside the stimuli; presenting children with such information provided an implicit hint about the effectiveness of counting along with the beat. Research by Aagten-Murphy, Cappagli, and Burr (2014) also highlighted the importance of rhythm when monitoring durations; trained musicians, who have increased rhythmic training and experience, were more accurate when reproducing a duration compared to non-musicians.

A common technique to keep a rhythm when counting is to mark the passing of a second by using a word as a marker. This word is inserted after each number increment, e.g. ‘one elephant, two elephant, three elephant…’ This ensures that each number is counted more accurately, representing 1 second in length. This strategy increases the likelihood of the presentation and reproduction phases being more equal in length, thus increasing task accuracy. There exists anecdotal evidence for the use of such words, such as the following quote from the educational book, Train your Brain to Be a Maths Genius:

> ‘To count seconds without a watch, use a long-ish word to help keep an accurate rhythm. For example, “One Mississippi, two Mississippi…” and so on. Other good words are chimpanzee or elephant’ (Dorling, Goldsmith, Surla, & Burnnett, 2012, p.45).

However, there appears to be no research to date which examines the benefit gained from inserting markers to increase rhythmic counting. Teaching children of all ages a counting technique which uses a marker may therefore increase children’s accuracy. This may prove particularly beneficial for the youngest children, who either did not employ a strategy or displayed inconsistencies in their counting. As noted above, it is unlikely that the counting strategy will completely remove developmental increases in duration ability; younger children may still display a utilisation deficiency and may continue to show impatience (Block et al., 1999; Fraisse, 1982) or reduced attentional capacity (Droit-Volet, 2003). The current study therefore aimed to examine whether developmental increases in short-term duration performance were attenuated through the teaching of a counting strategy.

4.1.3. Articulatory Suppression

Another way to test whether age effects can be attenuated through strategy use is to prevent children of all ages from employing a strategy. This is commonly done through an articulatory suppression technique, e.g. repeating a syllable whilst completing a task, such as ‘la-la-la’ (Ang & Lee, 2008; Baudouin, Vanneste, Isingrini, & Pouthas, 2006; Clement & Droit-Volet, 2006; Delgado & Droit-Volet, 2007; Droit-Volet & Rattat, 2007; Rattat & Droit-Volet, 2012). Articulatory suppression tasks prevent individuals from verbally rehearsing the contents of the phonological store. When dealing with visual inputs (e.g. colours or shapes), the suppression task prevents phonological recoding, meaning that individuals are unable to repeat the names of the shapes to be remembered. Similarly, articulatory suppression prevents individuals from counting in order to monitor the passage of time, whilst the simple nature of the suppression task does not consume working memory resources (Rattat & Droit-Volet, 2012). Suppression techniques have been shown to reduce performance on memory tasks (Ang & Lee, 2008; Hutton & Towse, 2001; Miles et al., 1996; Saito & Ishio, 1998). For example, Saito and Ishio (1998) found that the reproduction of rhythms was dramatically disrupted through articulatory suppression, whilst Hutton and Towse (2001) discovered that articulatory suppression reduced children’s ability to recall a sequence of digits.

As research has shown that a greater proportion of younger children do not employ strategies spontaneously (Espinosa-Fernandez, de la Torre Vacas, Garcia-Viedma Mdel, Garcia-Gutierrez, & Torres Colmenero, 2004; Kail, 1990), an articulatory suppression task may be less likely to impact upon their performance compared to older children. In contrast, older children are more reliant upon strategies, and so an articulatory suppression task may be more likely to disrupt verbal strategies (i.e. rehearsal and counting); articulatory suppression may therefore be more disruptive to older children. If this leads to a reduction in performance of the older children, then the articulatory suppression technique may attenuate the age effects seen on short-term temporal tasks.

4.2. Aims and Hypotheses

The aim of the current study was to examine the effect of employing strategies, or suppressing strategy use, on children’s short-term sequencing and duration performance.

It was hypothesised that:

1. Employing a strategy technique at time 2 would increase children’s performance on the short-term tasks, compared to their performance at time 1.

2. Employing a suppression technique at time 2 would decrease children’s performance on the short-term tasks, compared to their performance at time 1.

3. Any age effects seen at time 1 would be attenuated in the strategy and suppression conditions at time 2.

4.3. Method

4.3.1. Participants

Participants were 107 children (M=55, F=52) from a primary school in Barnsley, South Yorkshire. Children were from three school years: 35 children from Year 2 (mean age = 6 years 9 months, range = 6 years 1 month to 7 years 2 months, M=18, F=17), 36 children from Year 4 (mean age = 8 years 11 months, range = 8 years 0 months to 9 years 5 months, M=21, F=15) and 36 children from Year 6 (mean age = 10 years 8 months, range = 10 years 3 months to 11 years 1 month, M=16, F=20).

4.3.2. Design

All children experienced the time 1 testing session. At time 2, 4 weeks later, children were assigned to one of two groups: 53 children were assigned to a strategy condition, whilst 54 children were assigned to a suppression condition. This was achieved through matching children based upon their overall academic scores (an average of mathematics, reading and writing assessment SAT scores) and their performance on the short-term tasks at time 1. There was a fairly even split between the two conditions based upon the strategies that children employed at time 1; both conditions contained children who did and did not spontaneously employ a strategy to aid their temporal performance at time 1.

4.3.3. Materials

4.3.3.1. Short-Term Sequencing Task

The sequencing task was designed with Kinelab software, using the same basic design used in Experiment 2. However, some modifications were made to the task. Instead of using different shapes like in the previous experiment, the current experiment used the same shape (a circle) in different colours; this ensured that children could only use one source of information (i.e. the colour) to rehearse, removing the possibility of some children attempting to remember the shape and some children attempting to remember the colour. Six coloured circles, measuring 10cm x 10cm, were created: a pink, red, blue, green, brown and black circle. These one-syllable colours were chosen to make the difficulty of rehearsal equal for all stimuli. A start rectangle appeared for children to click on when they were ready for the trial to commence. Circles appeared in succession; each circle remained on-screen for 2 seconds, with a 1 second gap between presentations. All six circles then appeared in a horizontal line along the bottom of the screen, with written instructions above. Children touched the circles in the order that they had seen them presented. Circles disappeared after being selected to indicate that the response had been recorded. Children clicked on the end rectangle after sequencing all six circles. A demonstration and practice session were employed before the task started to ensure complete understanding. Unlike Experiment 2, where children experienced a practice trial of only three of the six stimuli, the current practice trials contained all six stimuli to allow children in the strategy condition to practice rehearsing six items. Ten test trials were then completed; this number was reduced from 12 in Experiment 2 to account for the fact that children appeared to get restless after too many trials. Three different versions of the task were created to ensure there were no order effects.

4.3.3.2. Short-Term Duration Task

The duration task used was identical to that in Experiment 2, with the exception of the two 16 second trials being removed. This decreased the number of trials down to 10, to account for the fact that children appeared to get restless in Experiment 2 after too many trials. Children witnessed one of four weather-related shapes appear on-screen for either a short (3s or 6s), medium (13s) or long (23s or 26s) duration. Participants were required to press a green start rectangle, wait for the same amount of time as the shape was originally presented for, then press a red end rectangle. Children witnessed a demonstration trial before experiencing a practice trial (both 8 seconds in duration). Ten test trials were then completed. Three versions of the task were created to remove any order effects.

4.3.4. Procedure

Testing took place during March, seven months into the school year. The same researcher conducted all aspects of the tasks. Testing was completed in the same break-away classroom, away from any noise and with no clocks in sight. Children were given the opportunity to leave the testing sessions at any time, although all children were happy to participate and showed no confusion at any of the instructions given (see Appendix J for full task instructions). Two children in Year 2 needed an additional practice trial for the cumulative rehearsal strategy to fully understand the procedure; following this additional practice, these children showed a good understanding of the task. All children successfully completed all aspects of testing. Children were asked to label six coloured squares to ensure that they were not colour blind and knew the names of all colours.

4.3.4.1. Time 1

Children were tested individually. They were informed that they would be completing two tasks on the computer. Half of the children completed the sequencing task first and half completed the duration task first. Children were shown a demonstration trial by the experimenter to explain what the task required, before they completed a practice trial to ensure understanding. Children then completed 10 test trials, before receiving praise on-screen. Children were then asked '*How did you remember the order that the circles were shown?'* or '*How did you know how long to wait for?*' depending on the task. All children understood these strategy questions and provided a response without further prompting. The second computer task was then completed. Children were thanked and given a sticker.

4.3.4.2. Time 2: Strategy Condition

Children were told that they would be doing the same memory task as the last time they saw the experimenter, but this time they were going to be given some instructions. Half of the children completed the sequencing task first and half completed the duration task first. For the sequencing task, the experimenter explained that the child would see a circle appear on the screen and they would have to repeat the name of the colour they had seen, e.g. 'blue'. They were then told that for the next circle they saw, they should add this colour to the last one, e.g. 'blue, red'. They were told to do this for all six circles, until they were repeating six colours at the end of the trial. Children were then told to select the circles in the order that they had been rehearsing the colours. The experimenter completed a demonstration trial to illustrate the cumulative rehearsal strategy, before children attempted a practice trial to ensure understanding. If children forgot to rehearse the colours, they were prompted by the researcher with the statement 'say your colours'; this need for prompting was rare. The 10 test trials were then completed before praise was given on-screen.

For the duration task, children were told that they would be counting in elephants; they were to count as normal, but say the word 'elephant' after every number, i.e. one elephant, two elephant, three elephant. They were told to start counting as soon as the shape appeared and to stop when it disappeared. After the green start button was pressed, children were required to use the elephant counting system until they reached the same number, before pressing the red stop button. The experimenter completed a demonstration trial to illustrate the strategy, before children attempted a practice trial to ensure they had grasped the technique. Children then completed all 10 test trials using this new strategy, before receiving praise on-screen. If children forgot to count using the elephant technique, they were prompted by the researcher with the statement 'count in elephants'; this need for prompting was rare At the end of both computer tasks, the child was thanked and given a sticker.

4.3.4.3. Time 2: Suppression Condition

Children were told that they would be doing the same computer tasks as the previous session, but this time they would be saying something at the same time. Children were told that they would have to repeat the syllable 'la' over and over again while completing the presentation phase of the tasks, i.e. 'la-la-la'. The two tasks were counterbalanced, with half of the children completing the sequencing task first and half completing the duration task first. The experimenter showed the children a demonstration trial to illustrate what they had to do. For the sequencing task, the experimenter pressed the start bar and began repeating the syllable whilst the six circles appeared in succession. They stopped repeating the syllable when the response screen appeared, and selected the circles in the correct sequence. For the duration task, the experimenter pressed the start bar and began repeating the syllable for the length of time that the shape was shown on-screen. When the duration response screen appeared, the experimenter stopped repeating the syllable and reproduced the duration. Children then attempted a practice trial to ensure understanding. Children completed 10 test trials before receiving praise on-screen. If children forgot to complete the suppression task, they were prompted with the statement 'say la-la-la'; the need for prompting was rare. After completing both tasks, children were thanked and given a sticker.

4.3.5. Scoring

4.3.5.1. Short-Term Sequencing Task

The scoring system used in Experiment 1 and Experiment 2 was employed in the current study (see section 2.3.4.2. for a detailed description). Items out of place received points, depending on how far away they were from their correct position; a lower score indicated a better performance. These scores were then averaged over the 10 trials to produce an average sequencing score (ranging from 0 to 18).

4.3.5.2. Short-Term Duration Task

The same duration scoring system from Experiment 2 was used. The distance away from the correct duration was calculated to generate an absolute difference score. These scores were then averaged over the 10 trials to produce an average duration score.

4.4. Results

4.4.1. Sequencing Results

No differences were shown in either time 1 or time 2 performance in the three counterbalanced versions of the sequencing task, so the results were collapsed across the three versions.

4.4.1.1. Time 1 Sequencing

The distance items were placed away from their correct position decreased with increasing distance for all three school years (Figure 4.1).

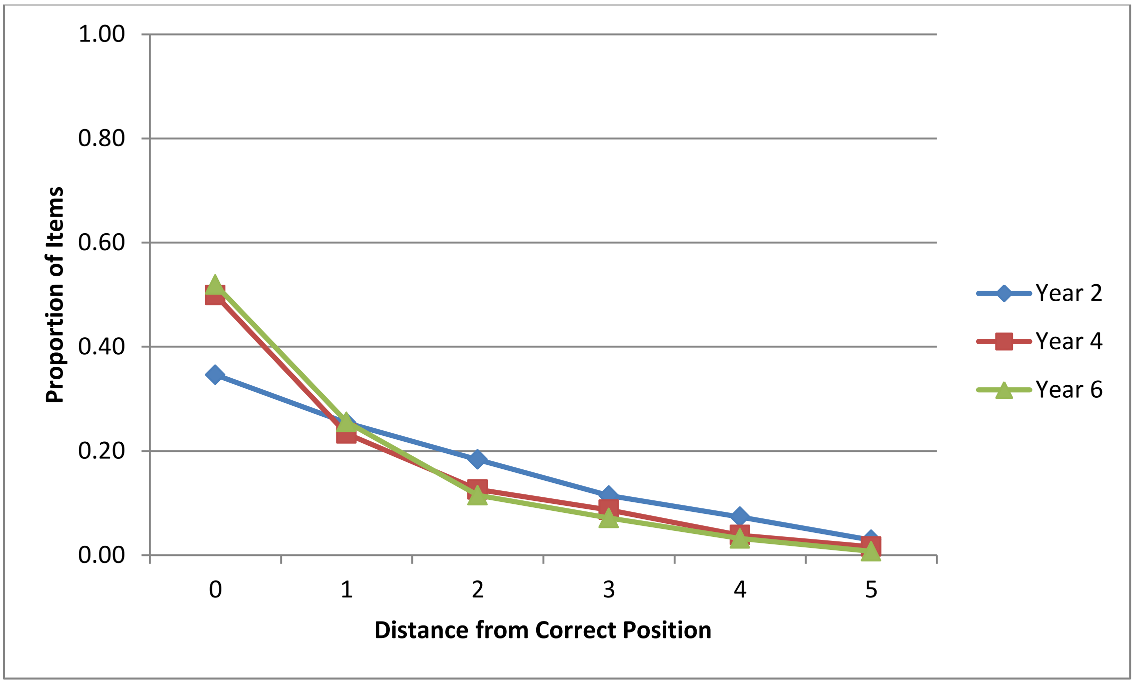


Figure 4.1: Movement of items from the correct position at time 1

Each item was examined in turn to explore their placement across the six positions (Figure 4.2).

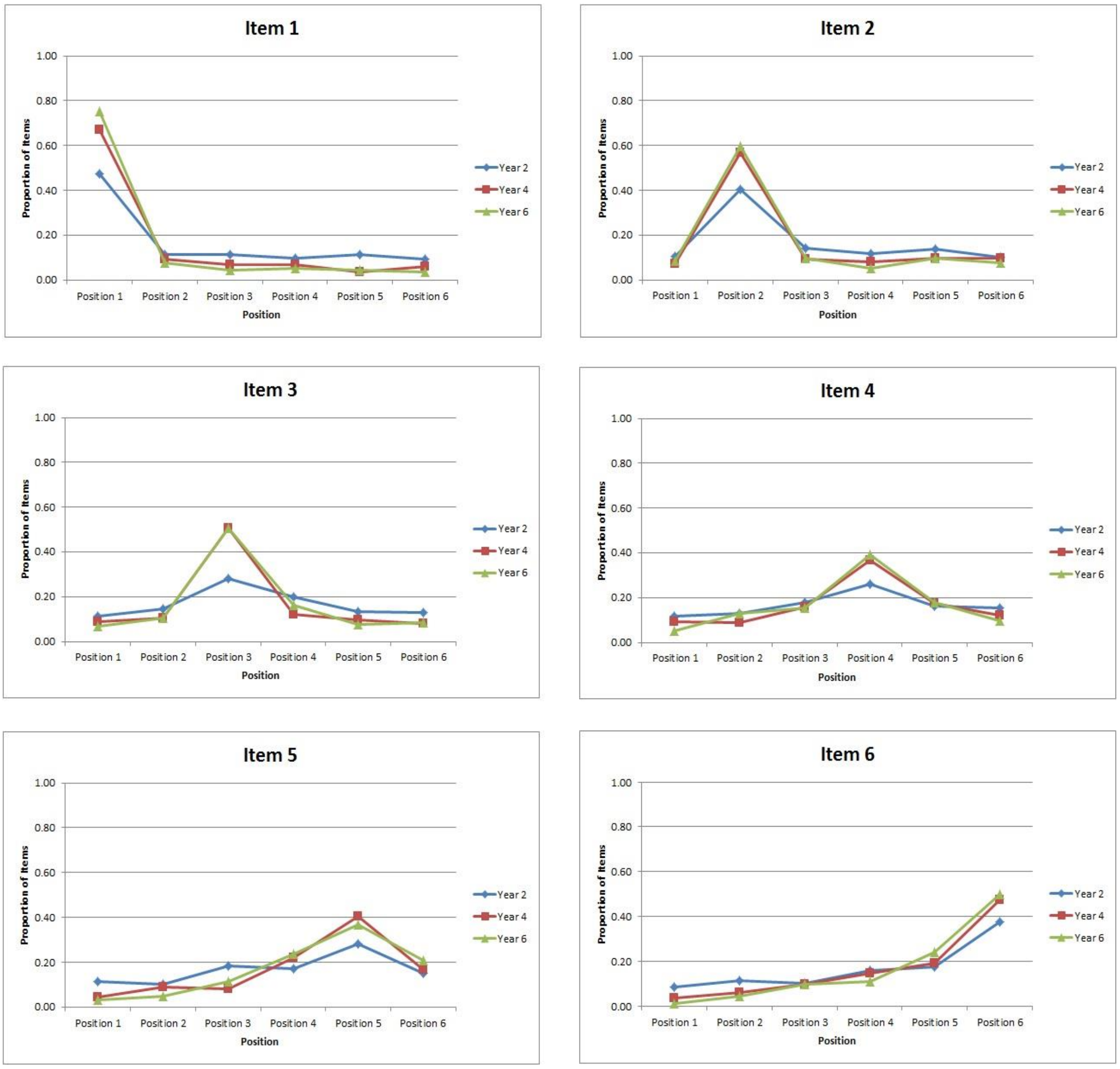


Figure 4.2: Position each item was placed (from 1-6) for all six items

The overall proportion of items in the correct position (from 1 to 6) was examined to see whether primacy and recency effects were evident (Figure 4.3).

Figure 4.3: Proportion of items in the correct position at time 1

Analysis was collapsed across age groups due to the similar patterns shown. A repeated measures ANOVA was conducted, with a within-subjects factor of position (1,2,3,4,5,6). Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(14)=48.59$, $p<0.01$. Degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon=0.82$). There was a main effect of position, $F(4.12, 436.31)=59.34$, $p<0.01$, $\eta_p^2=0.36$. Tukey's analysis revealed a significant difference between position 1 and 2 ($p<0.01$), indicating a primacy effect. There was also a significant difference between position 5 and 6 ($p<0.01$), indicating a recency effect.

Children's sequencing score was next examined, using the sequencing scoring system (Table 4.1).

Table 4.1: Sequencing score at time 1

	Year 2 (N=35)		Year 4 (N=36)		Year 6 (N=36)	
	M	SD	M	SD	M	SD
Sequencing Score	8.38	2.73	5.88	2.74	5.17	2.54

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6). There was a significant effect of age on sequencing score, $F(2,104)=14.13$, $p<0.01$, $\eta_p^2=0.21$. Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.01$), as well as between Year 2 and Year 6 ($p<0.01$).There was no significant difference between Year 4 and Year 6 ($p>0.05$).

The percentage of children reporting the use of a strategy increased with age (Table 4.2). The most common technique reported was rehearsing the names of the colours seen. Out of the children who reported using a strategy, the percentage of specific references to a cumulative rehearsal strategy increased from 11% in Year 2, to 23% in Year 4 and 26% in Year 6. A sub-sample of strategy responses was checked by an additional researcher to ensure inter-rater reliability.

Table 4.2: Strategy use on the sequencing task at time 1

	Strategy Use (%)	No Strategy/Unclear (%)
Year 2 (N=35)	51.4	48.6
Year 4 (N=36)	83.3	16.7
Year 6 (N=36)	91.7	8.3

Independent-samples t-tests, with a between-subjects factor of strategy use (strategy, no strategy) revealed a significant difference between the two groups, $t(105)=2.29$, $p<0.05$; children employing a strategy were more accurate at sequencing.

4.4.1.2. Time 2 Sequencing

To ensure there were no differences in academic or sequencing ability between the two intervention conditions, three independent-samples t-tests were conducted on the three age groups, with a between-subjects factor of condition (strategy, suppression). There was no significant difference between strategy and suppression groups for average academic ability in Year 2, $t(33)=1.04$, $p>0.05$, Year 4, $t(33)=1.67$, $p>0.05$, or Year 6, $t(33)=-0.30$, $p>0.05$. There was also no significant difference between strategy and suppression groups for sequencing scores at time 1 in Year 2, $t(33)=-0.58$, $p>0.05$, Year 4, $t(34)=0.46$, $p>0.05$, or Year 6, $t(33)=0.36$, $p>0.05$.

The movement of items from their correct position was first examined (Figure 4.4). Performance was similar across all three age groups, so the results were collapsed across age.

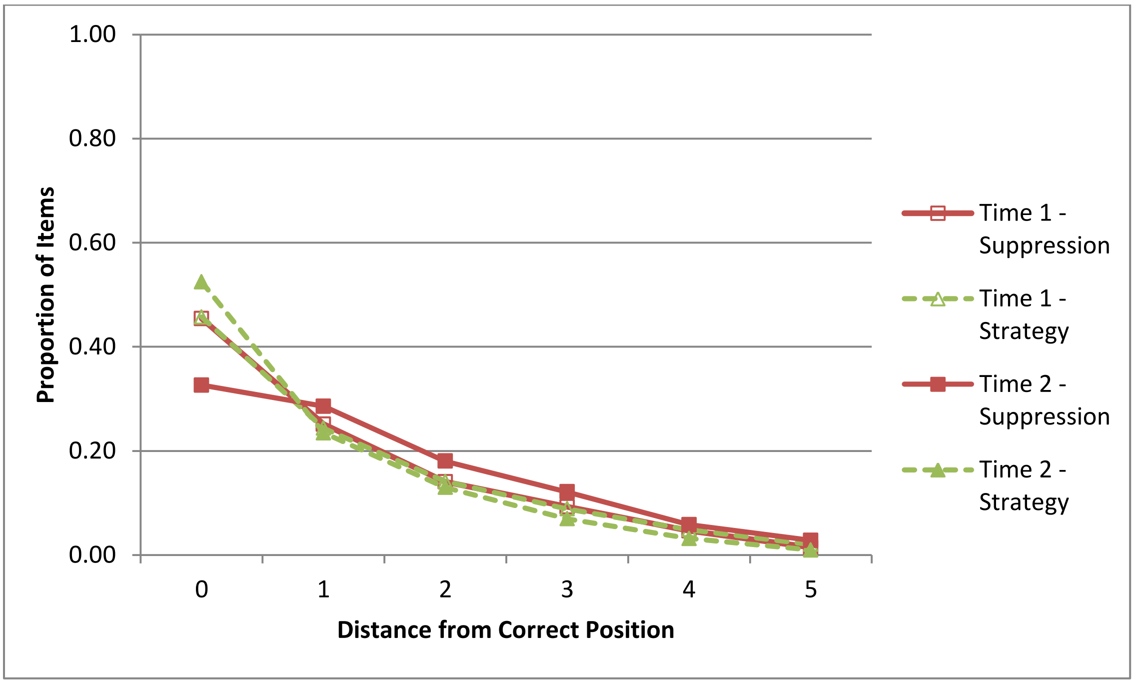


Figure 4.4: Movement of items from the correct position at time 1 and time 2

When analysing the six items individually at time 2, the strategy condition showed a similar pattern to time 1 (see Figure 4.2). In contrast, the curves for the suppression condition were much flatter, indicating reduced accuracy in placing items in their correct position.

The overall proportion of items in the correct position (1 to 6) at time 1 and time 2 was next examined (Figure 4.5). Due to similar patterns displayed by all three age groups, the results were collapsed across age.

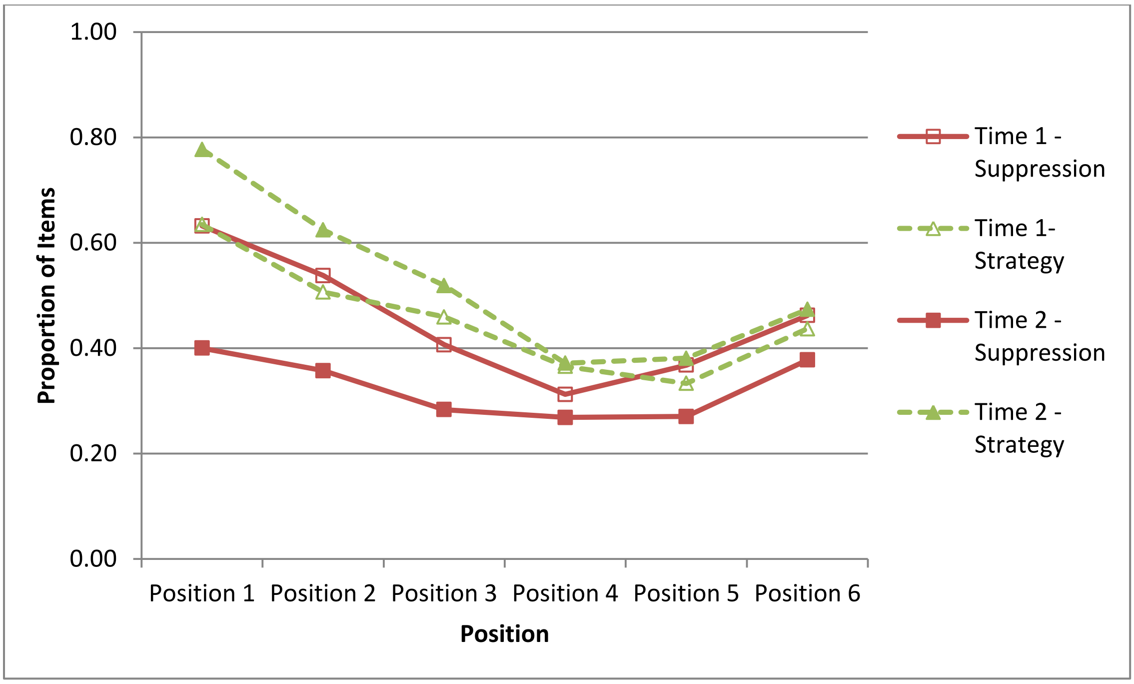


Figure 4.5: Proportion of items in the correct position at time 1 and time 2

To examine the proportion of items in the correct position at time 2, two repeated-measures ANOVAs were conducted for the strategy and suppression conditions separately, with a within-subjects factor of position (1,2,3,4,5,6). For the strategy condition, Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(14)=50.97$, $p<0.01$. Degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon=0.70$). There was a main effect of position, $F(3.48, 180.93)=64.93$, $p<0.01$, $\eta_p{}^2=0.56$. Tukey's analysis revealed a significant difference between position 1 and 2 ($p<0.01$), indicating a primacy effect. There was also a significant difference between position 5 and 6 ($p<0.01$), indicating a recency effect.

For the suppression condition, Mauchly's Test of Sphericity also indicated that the assumption of sphericity had been violated, $\chi^2(14)=28.17$, $p<0.05$. Degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon=0.82$). There was a main effect of position, $F(4.10, 217.28)=10.45$, $p<0.01$, $\eta_p{}^2=0.17$. Tukey's analysis revealed no significant difference between position 1 and 2 ($p>0.05$), indicating no primacy effect. However, there was a significant difference between position 5 and 6 ($p<0.01$), indicating a recency effect.

Children's short-term sequencing ability was next examined at both time 1 and time 2 (Table 4.3).

Table 4.3: Sequencing score at time 1 and time 2 for strategy and suppression conditions

	Strategy				Suppression			
	Time 1		Time 2		Time 1		Time 2	
	M	SD	M	SD	M	SD	M	SD
Year 2 (N=35)	8.66	2.81	6.56	2.48	8.12	2.71	9.26	1.89
Year 4 (N=36)	5.67	2.83	5.09	2.92	6.09	2.72	8.29	1.84
Year 6 (N=36)	5.32	2.43	3.98	2.06	5.01	2.70	7.34	2.99

A mixed-design ANOVA was conducted, with a within-subjects factor of time tested (time 1, time 2) and between-subjects factors of age (Years 2, 4, 6) and condition (strategy, suppression). There was no main effect of time tested on sequencing score, $F(1,101)=1.48$, $p>0.05$, $\eta_p^2=0.01$. A main effect of condition was evident, $F(2,101)=11.17$, $p<0.01$, $\eta_p^2=0.10$, with children in the strategy condition performing better than children in the suppression condition. A main effect of age was also found, $F(1,101)=13.33$, $p<0.01$, $\eta_p^2=0.21$; Tukey's analysis uncovered significant differences between Years 2 and 4 ($p<0.01$), and Years 2 and 6 ($p<0.01$), with older children displaying greater accuracy. The interaction between condition x age was not significant, $F(2,101)=0.23$, $p>0.05$, $\eta_p^2=0.01$. The interaction between condition x time tested was significant, $F(1,101)=50.89$, $p<0.01$, $\eta_p^2=0.34$ (see Figure 4.6), whilst the interaction between condition x time tested x age was approaching significance, $F(2,101)=2.68$, $p=0.074$, $\eta_p^2=0.05$.

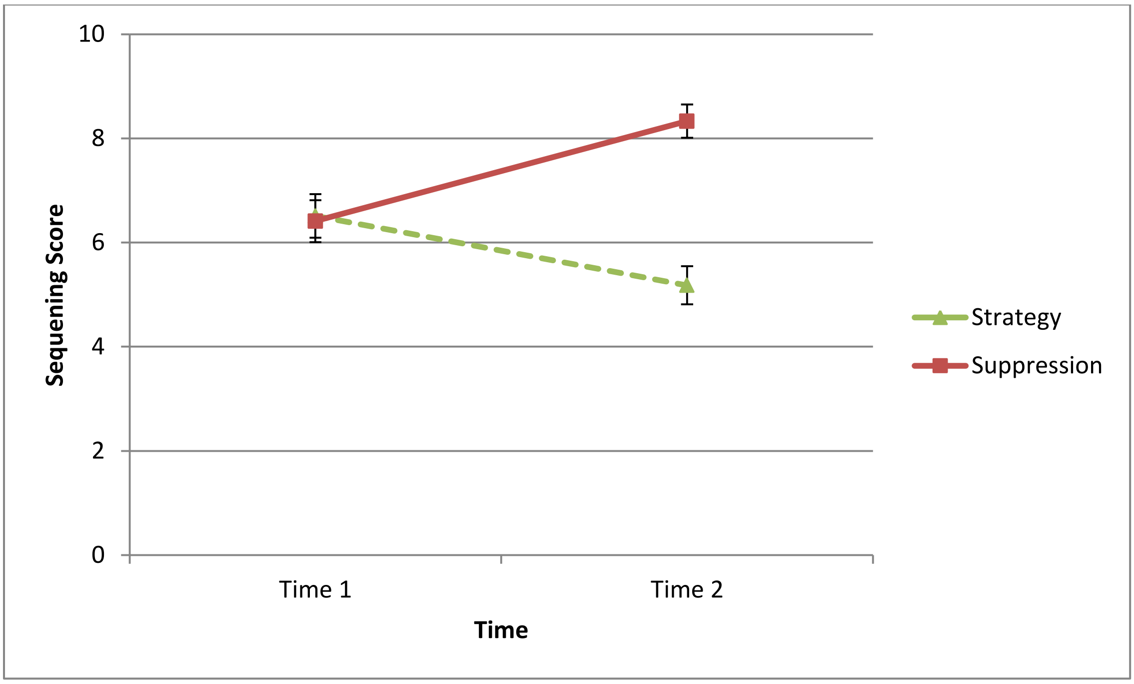


Figure 4.6: Condition x time interaction (across age groups) for sequencing score

To examine these interactions further, two-way ANOVAs were conducted on the strategy and suppression conditions separately, with a between-subjects factor of time tested (time 1, time 2) and a within-subjects factor of age (Years 2, 4, 6). In the strategy condition, analysis showed that there was a significant effect of time tested, $F(1,50)=16.55$, $p<0.01$, $\eta_p^2=0.25$; children's accuracy was greater at time 2, compared to time 1. There was also a main effect of age, $F(2,50)=7.72$, $p<0.01$, $\eta_p^2=0.24$. Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.05$), as well as between Year 2 and Year 6 ($p<0.01$); older children showed greater accuracy compared to younger children. Although the interaction between time tested x age was not significant, $F(2,50)=1.75$, $p>0.05$, $\eta_p^2=0.07$, the mean difference in accuracy between the oldest and youngest children was greater at time 1 (3.34) compared to time 2 (2.58), suggesting a reduction in age effects. This was explored further through two separate one-way ANOVAs for time 1 and time 2, with a between-subjects factor of age (Years 2, 4, 6). At time 1, there was a main effect of age, $F(2,50)=8.03$, $p<0.01$, $\eta_p^2=0.24$; Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.01$), as well as between Year 2 and Year 6 ($p<0.01$). At time 2, there was still a main effect of age, although the effect size was reduced, $F(2,50)=4.66$, $p<0.05$, $\eta_p^2=0.16$; Tukey's analysis revealed this difference to lie between Year 2 and Year 6 only ($p<0.05$).

In the suppression condition, there was a significant effect of time tested, $F(1,51)=36.93$, $p<0.01$, $\eta_p^2=0.42$; children's performance was less accurate at time 2, compared to time 1. There was also a main effect of age, $F(2,51)=5.72$, $p<0.01$, $\eta_p^2=0.18$, with older children showing increased accuracy. Tukey's analysis revealed this difference to lie between Year 2 and Year 6 ($p<0.01$). Similar to the strategy condition, although the interaction between time tested x age was not significant, $F(2,51)=1.49$, $p>0.05$, $\eta_p^2=0.06$, examination of the means suggested that the difference between the youngest and oldest children was greater at time 1 (3.11), compared to time 2 (1.92). Two separate one-way ANOVAs were conducted at time 1 and time 2, with a between-subjects factor of age (Years 2, 4, 6). At time 1, there was a main effect of age, $F(2,51)=6.12$, $p<0.01$, $\eta_p^2=0.19$; Tukey's analysis revealed the difference between Year 2 and Year 4 to be approaching significance ($p=0.07$), whilst the difference between Year 2 and Year 6 was significant ($p<0.01$). At time 2, the effect of age was only approaching significance, $F(2,51)=3.10$, $p=0.054$, $\eta_p^2=0.11$; Tukey's analysis revealed this difference to lie between Year 2 and Year 6 ($p<0.05$).

4.4.2. Duration Results

No differences were shown at either time 1 or time 2 in the three counterbalanced versions of the duration task, so the results were collapsed across all three versions.

4.4.2.1. Time 1 Duration

Children's duration scores at time 1 were first examined (Table 4.4); as the scores represented the number of seconds away from the correct duration, higher scores indicated poorer performance.

Table 4.4: Duration score at time 1

	Year 2 (N=35)		Year 4 (N=36)		Year 6 (N=36)	
	M	SD	M	SD	M	SD
Time 1 Duration Score	4.67	2.35	2.22	1.16	2.20	1.13

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6). The results revealed a significant effect of age, $F(2,104)=26.77$, $p<0.01$, $\eta_p^2=0.34$, with children's duration accuracy increasing with age. This difference was found to be significant between Year 2 and Year 4 (*p*<0.01) as well as between Year 2 and Year 6 (*p*<0.01). The difference between Year 4 and Year 6 was not significant (*p*>0.05).

The percentage of children reporting the use of a strategy increased with age (Table 4.5). The most common technique used was a counting strategy, whereby children reported counting whilst the image was on-screen and counting to the same number during the reproduction phase. Only one child in Year 4 and one child in Year 6 made reference to using a word as a marker to provide a rhythm to their counting; both children reported using the word 'elephant'. A sub-sample of strategy responses was checked by an additional researcher to ensure inter-rater reliability.

Table 4.5: Strategy use on the duration task at time 1

	Strategy Use (%)	No Strategy/Unclear (%)
Year 2 (N=35)	68.6	31.4
Year 4 (N=36)	97.2	2.8
Year 6 (N=36)	91.7	8.3

Independent-samples t-tests, with a between-subjects factor of strategy use (strategy, no strategy), revealed a significant difference between the two groups, *t*(15.84)=4.97, *p*<0.01; children employing a strategy were more accurate at reproducing the durations.

4.4.2.2. Time 2 Duration

To ensure both intervention conditions had similar time 1 duration scores, three independent-samples t-tests were conducted for the three school years, with a between-subjects factor of condition (strategy, suppression). There was no significant difference between strategy and suppression groups for duration scores at time 1 in Year 2, *t*(33)=-1.49, *p*>0.05, Year 4, *t*(34)=0.08, *p*>0.05, or Year 6, *t*(34)=-1.61, *p*>0.05. As children were assigned to the same strategy or suppression condition as the sequencing task, there was also no difference between the two groups in terms of academic ability.

Children's short-term duration abilities at time 1 and time 2 were examined (Table 4.6); lower scores represented greater accuracy.

Table 4.6: Duration score at time 1 and time 2 for strategy and suppression conditions

	Strategy				Suppression			
	Time 1		Time 2		Time 1		Time 2	
	M	SD	M	SD	M	SD	M	SD
Year 2 (N=35)	5.27	2.48	3.63	1.19	4.11	2.13	6.02	2.04
Year 4 (N=36)	2.20	0.98	2.88	1.24	2.23	1.34	4.54	1.00
Year 6 (N=36)	2.49	1.31	2.00	0.65	1.90	0.84	4.64	1.62

A mixed-design ANOVA was conducted, with a within-subjects factor of time tested (time 1, time 2) and between-subjects factors of age (Years 2, 4, 6) and condition (strategy, suppression). There was a main effect of time tested on duration score, $F(1,101)= 30.13$, $p<0.01$, $\eta_p^2=0.23$. Scores at time 2 were less accurate than at time 1; the negative effects of the articulatory suppression technique outweighed the positive effects gained by teaching children a counting strategy. A main effect of condition was found, $F(1,101)=12.29$, $p<0.01$, $\eta_p^2=0.11$; children in the strategy condition performed better than children in the suppression condition. A main effect of age was also found, $F(2,101)=28.66$, $p<0.01$, $\eta_p^2=0.36$, with older children displaying greater accuracy. Tukey’s analysis found this difference to lie between Year 2 and Year 4 ($p<0.01$) as well as Year 2 and Year 6 ($p<0.01$). The interaction between condition x age was not significant, $F(2,101)=0.25$, $p>0.05$, $\eta_p^2=0.01$. However, there was a significant interaction between condition x time tested, $F(1, 101)=70.33$, $p<0.01$, $\eta_p^2=0.41$ (see Figure 4.7). There was also a significant interaction between condition x time tested x age, $F(2,101)=3.17$, $p<0.05$, $\eta_p^2=0.06$.

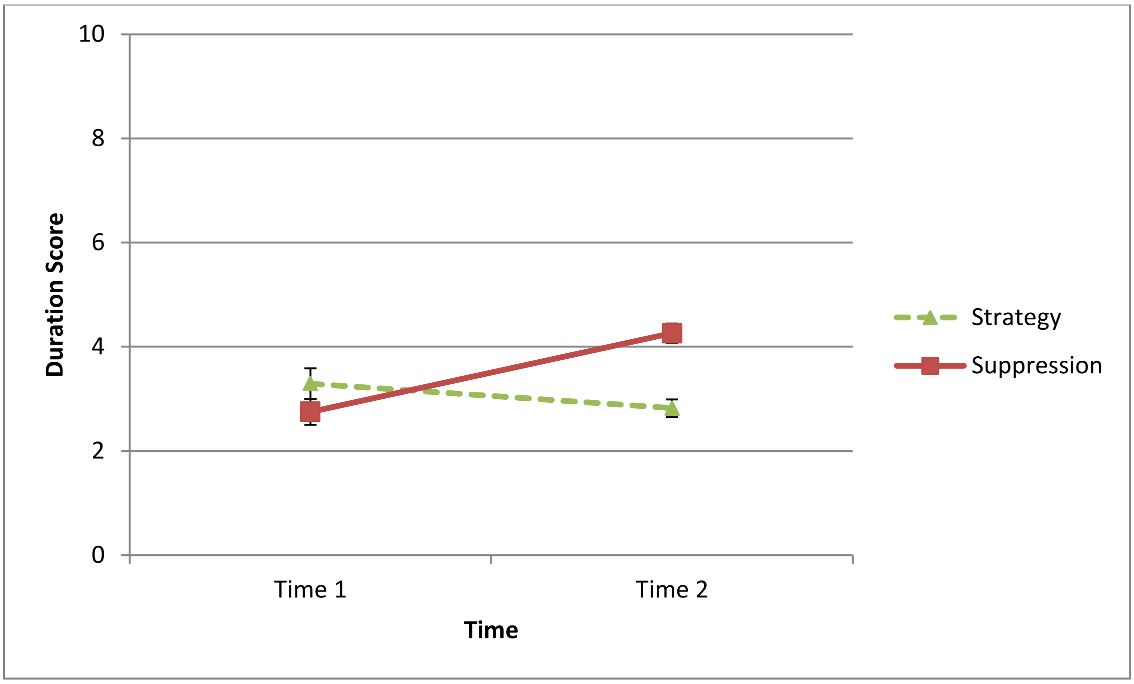


Figure 4.7: Condition x time interaction (across age groups) for duration score

In order to examine this three-way interaction further, mixed-design ANOVAs were conducted on the strategy and suppression conditions separately, with a between-subjects factor of time tested (time 1, time 2) and a within-subjects factor of age (Years 2, 4, 6). In the strategy condition, there was a significant effect of time tested, $F(1,50)=4.60$, $p<0.05$, $\eta_p^2=0.08$; children were more accurate at time 2, compared to time 1. There was also a main effect of age, $F(2,50)=18.76$, $p<0.01$, $\eta_p^2=0.43$. Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.01$), as well as between Year 2 and Year 6 ($p<0.01$), with older children showing greater accuracy. The interaction between time tested x age was significant, $F(2,50)=8.75$, $p<0.01$, $\eta_p^2=0.26$. This was explored further through two separate one-way ANOVAs for time 1 and time 2, with a between-subjects factor of age (Years 2, 4, 6). At time 1, there was a main effect of age, $F(2,50)=17.32$, $p<0.01$, $\eta_p^2=0.42$; Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.01$), as well as between Year 2 and Year 6 ($p<0.01$). At time 2, there was also a main effect of age, although the effect size was reduced, $F(2,50)=10.41$, $p<0.01$, $\eta_p^2=0.29$; Tukey's analysis revealed this difference to lie between Year 2 and Year 6 ($p<0.01$), as well as between Year 4 and Year 6 ($p<0.05$).

Examining the suppression condition, there was a significant effect of time tested, $F(1,51)=88.80$, $p<0.01$, $\eta_p^2=0.64$; children's performance was less accurate at time 2, compared to time 1.There was also a main effect of age, $F(2,51)=10.97$, $p<0.01$, $\eta_p^2=0.30$, with older children showing increased accuracy. Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.01$), as well as between Year 2 and Year 6 ($p<0.01$). The interaction between time tested x age was not significant, $F(2,51)=0.94$, $p>0.05$, $\eta_p^2=0.05$. However, examination of the means suggested that the difference between the youngest and oldest children was greater at time 1 (2.21) compared to time 2 (1.38). This was explored further through two separate one-way ANOVAs for time 1 and time 2, with a between-subjects factor of age (Years 2, 4, 6). At time 1, there was a main effect of age, $F(2,51)=10.87$, $p<0.01$, $\eta_p^2=0.30$; Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.01$), as well as between Year 2 and Year 6 ($p<0.01$). At time 2, the effect of age was still significant, although the effect size was reduced, $F(2,51)=4.73$, $p<0.05$, $\eta_p^2=0.16$; Tukey's analysis revealed this difference to lie between Year 2 and Year 4 ($p<0.05$), and between Year 2 and Year 6 ($p<0.05$).

4.5. Discussion

4.5.1. Impact of Strategies

4.5.1.1. Increases in Performance

The aim of the current study was to examine whether age increases in performance on short-term temporal memory tasks could be attenuated by teaching children a strategy, or suppressing their ability to use a strategy. Testing at time 1 revealed similar patterns to those seen in Experiment 2, with children showing age increases in their sequencing and duration abilities (see also Arlin, 1986; Espinosa-Fernandez et al., 2004; McCormack et al., 2000; Szelag et al., 2002; Visu-Petra et al., 2008). The proportion of children spontaneously implementing a strategy also increased with age, in line with Experiment 2 and previous strategy literature (Espinosa-Fernandez et al., 2004; Kail, 1990; Kreutzer et al., 1975); this lack of spontaneous strategy use supports the production deficiency hypothesis (Flavell et al., 1966).

Teaching children strategies to aid temporal abilities led to increases in performance for both the sequencing and duration tasks, in line with hypothesis 1; this supports previous research highlighting the benefits gained from strategy teaching (Bebko, 1979; Cox et al., 1989; Gruenenfelder & Borkowski, 1975; Guttentag, 1984; Johnston et al., 1987; Schwenck et al., 2009). In addition to supporting the sequencing literature, the current research appears to be the first study to illustrate the benefits that teaching rhythmic counting has on reproducing durations. Teaching children a counting strategy provided rhythm to the durations, resulting in a greater consistency between presentation and reproduction phases; previous research highlighting the importance of rhythm when dealing with durations supports this finding (Levin & Wilkening, 1989; Saito, 2001; Saito & Ishio, 1998; Wilkening et al., 1987; see section 3.5.2.). In addition, providing children with a cumulative rehearsal strategy increased the amount of information that they could retain in the phonological loop; this rehearsal reduced decay, preserving the sequence and thus increasing the accuracy of children's responses (Gathercole, 1999).

4.5.1.2. Attenuated Age Effects

The implementation of strategies across the 6-11 year age range also attenuated the age effects seen; the difference in performance between the oldest and youngest children was reduced as a result of employing a cumulative rehearsal or counting strategy, supporting hypothesis 3. The attenuated age effects suggest that younger children's performance was enhanced to a greater extent by the strategies, compared to older children. The smaller proportion of younger children using rehearsal and counting strategies may account for this difference; these children were provided with a novel way of completing the tasks, which led to greater increases in performance compared to not utilising a strategy (or utilising a less effective strategy). Nevertheless, the fact that age effects were still present, despite children of all ages being taught the same strategy, is indicative of a utilisation deficiency (Bjorklund & Green, 1992; Bjorklund et al., 1997; Miller, 1990; Miller & Seier, 1994; Schwenck et al., 2007). The 6 and 7 year olds who were taught the same strategy as the 10 and 11 year olds still showed performance deficits in comparison to the older children, possibly reflecting a reduced ability to use the strategies in an optimal manner.

A possible explanation for the fact that age effects remained in the strategy group may be due to reduced cognitive resources in the younger children. In a discussion of the development of strategic memory, Bjorklund (2010) notes that the use of memory strategies requires children to possess an awareness of the goals associated with the task, to understand that a strategy can aid performance and to monitor how well the strategy is working. However, these processes require mental effort; this is a limited resource that shows developmental increases during childhood (Case, 1985; Cowan et al., 2005; Kail & Miller, 2006; Pascual-Leone, 1970). Bjorklund, Schneider, Cassel, and Ashley (1994) highlighted the fact that strategies are effortful cognitive processes. Some of the positive effects gained from teaching a strategy may be off-set by the fact that young children may use some of their limited cognitive resources to implement these strategies, leaving fewer resources to complete the task (Case, 1985; Cowan et al., 2005). Guttentag (1984) used a tapping task as an indication of how much mental effort a cumulative rehearsal strategy required when trying to recall items from a list. Seven to 9 year old children experienced more interference to their tapping (i.e. a reduction in their tapping rate) when using the rehearsal strategy, compared to 11 and 12 year olds; this indicates that the strategy required greater mental effort for younger children. When considering the counting strategy employed in the duration task, older children may find counting less attentionally demanding than younger children; the younger children may require additional attentional resources in order to count in even a basic fashion (St Clair-Thompson, 2007; St Clair-Thompson, 2010). Therefore the positive effect of strategy use may be somewhat offset in younger children by the need for additional resources to implement the strategy.

As illustrated in section 3.5.3., children’s knowledge may also impact upon the effectiveness of strategy use, at least for the duration task. Experiment 2 revealed a relationship between children’s knowledge about time concepts and their ability to reproduce short-term durations; this is likely due to their ability to understand the concept of a second, and thus how to effectively mark the passage of time. At time 2 in the current study, older children showed superior reproduction when using the counting strategy despite the fact that the younger children were taught the same strategy; a more extensive knowledge base about time concepts and duration may have led to improved ability to make use of the strategy (Bjorklund, Muir-Broaddus, & Schneider, 1990; Kee, 1994; Schneider & Bjorklund, 1998). Research examining the impact of a variety of factors on children’s memory has found knowledge to account for differences in performance more than factors such as intelligence and metamemory (Alexander & Schwanenflugel, 1994; Hasselhorn, 1992). Schneider and Sodian (1997) also claimed that ‘there is no doubt that strategic processing is dependent on the availability and accessibility of relevant knowledge’ (p.447). Increases in time knowledge may therefore lead to increasing benefits gained by employing a counting strategy.

For the sequencing task, articulation speed may also play a role in the differential effects that the cumulative rehearsal strategy had on performance across the three school years. The benefit gained from a rehearsal strategy is reliant on the speed that children can articulate; older children can rehearse items at a more rapid pace, meaning that fewer items decay in the phonological store. According to Gathercole and Baddeley (2014), recoding visual information into a verbal form for rehearsal is believed to develop as children become skilled readers; children are able to translate visual forms (i.e. colours) into a linguistic form more effectively (see section 3.5.1. for further discussion). In the current study, younger children may have had a slower rate of articulation; this may have reduced the benefit they gained from the cumulative rehearsal technique compared to the older children.

This therefore suggests that the strategies taught were able to increase children's temporal performance, for both the sequencing and duration tasks. The results indicated that the use of these strategies attenuated the age effects slightly; this is likely to be due to the fact that more of the younger children were employing a strategy at time 2 than they were at time 1. However, this increased strategy use is not to suggest that the younger children were using the cumulative rehearsal and counting strategies with optimal efficiency; the fact that the age effects remained suggests that older children were achieving more benefit from their use.

4.5.2. Impact of Suppression

4.5.2.1. Reductions in Performance

The current study also aimed to examine the impact of suppression on children's temporal performance. Articulatory suppression was found to significantly reduce children's ability to recall sequences or reproduce durations (hypothesis 2); this is in line with previous research demonstrating the disruptive effect of suppression techniques (Ang & Lee, 2008; Hutton & Towse, 2001; Miles et al., 1996; Saito & Ishio, 1998). Asking children to repeat a syllable whilst completing the temporal tasks disrupted their use of phonological memory codes (Hitch & Halliday, 1983); they were thus unable to rehearse the colours of the stimuli or count along with the shapes.

The phonological loop is believed to play a central role in children's ability to recall sequences and durations. The working memory model (Baddeley & Hitch, 1974) specifies that visual material (i.e. the different colours in the current study) automatically enters the visuospatial store, but sub-vocal articulation is required in order to keep this information in the phonological storage system. Research has shown that impairing the phonological loop results in recall based on visual storage alone. Hitch, Woodin, and Baker (1989) found that a suppression task removed the phonological similarity effect (i.e. confusion for items that sound the same), but introduced a visual similarity effect (i.e. confusion for items that look the same); this further highlights a transition from phonological to visual processing during articulatory suppression. By preventing rehearsal through the phonological loop with a suppression task, Hitch et al. (1989) found that 11 year olds displayed memory for pictures at levels similar to 5 year olds. The phonological loop therefore appears to play a key role in children's ability to recall visual sequences.

For the duration task, the articulatory suppression technique also prevented the phonological loop from being used to monitor the duration of the presentation phase; children were therefore reliant upon a more intuitive sense of time, rather than the ability to count. This extends the limited research into the effect of articulatory suppression on time estimation in adults (Franssen, Vandierendonck, & Van Hiel, 2006; Rattat & Droit-Volet, 2012). Research by Franssen et al. (2006) showed a reduction in reproduction accuracy caused by suppression; this led the authors to conclude that the articulatory loop (i.e. the active part of the phonological loop) is involved in timing behaviour. Similarly, the pulse count proposed by duration models (see section 1.5.1), in which the current duration is recorded, is thought to use the articulatory loop in order to keep track of the duration.

It is also possible that a reduction in attentional resources is responsible for the reduced accuracy seen in the suppression condition; the current duration count requires continuous updating to keep track of the most recent count, so diverting attention away from this process is therefore likely to disrupt accuracy. However, Franssen et al. (2006) found that accuracy for extremely short durations (for which it would be impossible to count, e.g. 800ms) was still reduced during an articulatory suppression task. Their research also showed that attentional distractors such as additional speech, tones or music did not impair duration reproduction. Furthermore, researchers employ articulatory suppression tasks under the assumption that they are not too cognitively demanding, as no attention is required to repeat a syllable. Further research is required to examine the precise mechanisms that are disrupted through articulatory suppression when completing duration reproduction tasks.

4.5.2.2. Attenuated Age Effects

Compared to time 1, children in the suppression condition at time 2 showed attenuated age effects; this indicates that the performance of the older children was more similar to the younger children when rehearsal or counting was prevented (hypothesis 3). Although older children’s performance was more disrupted than younger children’s performance in comparison to time 1, the older children still performed better at time 2 than the younger children. When examining the percentage increase in error from time 1 to time 2 in the suppression condition, Year 2 children showed a 14% increase in error for the sequencing task, compared to 47% in Year 6. Similarly, Year 2 children showed a 46% increase in error from time 1 to time 2 for the duration task, compared to 144% in Year 6. At time 1, older children were more likely to employ a rehearsal strategy or count along with the duration, and therefore the articulatory suppression task prevented the phonological loop from being used to rehearse the order of the stimuli or maintain the correct duration. However, older children still possessed an advantage in their ability to retain a sequence or monitor durations; this indicates that factors other than strategy use play a part in temporal memory.

A possible explanation for the persistence of age effects on the sequencing task is due to visual processing. Research has shown age effects when children have to recall unnameable shapes, i.e. shapes which cannot be sub-vocally rehearsed (Pickering, Gathercole, Hall, & Lloyd, 2001; Visu-Petra et al., 2008). This indicates developmental increases in the capacity of the visuospatial sketchpad (Logie & Pearson, 1997); removing the use of the phonological loop (due to the shapes being unnameable) resulted in a reliance on the visual element of the sequence alone. In the current study, older children showed a sequencing advantage, despite that fact that the suppression task removed their use of the phonological loop. These children therefore appeared to retain memory for the sequence in some form of visual storage. This supports the conclusions of Hitch et al. (1989), who asserted that when older children are given pictures which are readily nameable, they establish both phonological and visual memory codes. If younger children have a less developed visuospatial sketchpad (Logie & Pearson, 1997) , then a reliance on the visuospatial sketchpad as a result of the suppression task will still result in age effects.

4.5.3. Application of Research

The findings of this research may be beneficial to educational settings. Children as young as 6 and 7 years of age had clear increases in short-term temporal memory performance as a result of teaching strategies. Previous research has shown that average- and low-achieving children can benefit from teachers who provide strategy suggestions in the classroom (Moely et al., 1992). Ornstein, Coffman, and McCall (2005) found that 6 and 7 year olds taught by teachers who emphasised strategy instructions displayed a higher level of strategy use when completing memory tasks, compared to children whose teachers who did not employ this teaching practice. This higher level of strategy use was maintained into the next school year, suggesting that this teaching style had a large impact upon behaviour.

Additional research (Carr, Kurtz, Schneider, Turner, & Borkowski, 1989; Kurtz, Schneider, Carr, Borkowski, & Rellinger, 1990) has also found cultural differences in strategy use, which in turn impact upon performance. German children were found to display an advantage on strategic memory tasks, compared to American children. The suggestion put forward to explain this difference is due to children’s experiences of strategies; German teachers were found to teach their pupils more strategies, whilst German parents also encouraged their children to participate in games which require strategy use. The current findings add further support to the impact that teaching children a strategy can have on memory performance, extending this finding to temporal memory tasks. Incorporating the teaching of strategies into the National Curriculum could therefore increase strategy use in children, thus benefitting memory performance.

4.5.4. Further Areas of Research

Although this research has demonstrated the impact that strategies can have upon the tasks that children are taught a specific strategy for, further research would be required to see whether children are able to maintain these strategies over time and across different situations. Previous research has shown that strategy transfer is possible (Loosli, Buschkuehl, Perrig, & Jaeggi, 2012; St Clair-Thompson, Stevens, Hunt, & Bolder, 2010), although results have been mixed (Gruenenfelder & Borkowski, 1975; Lee et al., 2012; St Clair-Thompson et al., 2010). In particular, no such research appears to exist into the long-term retention of a counting strategy to mark the passage of time. Such an experiment could focus on teaching children a counting strategy in a similar method to the current study, before asking children to complete an additional task which would benefit from the counting strategy at a later point in time; if children were able to remember and implement the counting strategy for this new situation, then this would suggest a long-term retention of the technique.

Individual differences in the impact that strategies have upon children’s performance cannot be discounted. A strategy that helps one child may prove to be too difficult for another child to implement successfully, whilst individual differences in strategy preferences must also be considered (Pressley, Goodchild, Fleet, Zajchowski, & Evans, 1989). The strategies outlined in this chapter are only two of a variety of different methods that could be implemented within a classroom setting. Some strategies may be more effective for older children, whilst other strategies may benefit children of different academic abilities. Further strategy examples could include employing rhythmic behaviours to monitor durations (e.g. tapping out a tune), or using elaboration techniques to remember sequences (e.g. assigning a story to a sequence of shapes). This is an area for further research.

4.5.5. Conclusion

In conclusion, these results provide a clear indication of the impact that strategies can have upon children’s short-term temporal memory performance. Gains in performance are shown through teaching a cumulative rehearsal and counting technique, leading to attenuated age effects. Nevertheless, older children still show superior performance on these temporal tasks; a variety of factors may be responsible for this advantage. Articulatory suppression was found to reduce temporal accuracy, indicating the role of the phonological loop for both short-term sequencing and duration abilities. Further research into a variety of strategies, as well as the potential transfer of strategy use, is required.

Chapter 5: Children's Dating of Experienced Events

5.1. Introduction

Dating is the ability to place an event in time. As outlined in section 1.3.1., an event can be dated based upon location- or distance-based processes (Friedman, 1993). Location-based judgments require the use of contextual information to uncover when an event occurred, such as the month of the year or day of the week. Conversely, distance-based judgments relate to how long ago the event occurred, centred on how a particular property of memory varies, such as its vividness; older events are generally less vivid than more recent events, meaning that they are judged as occurring longer ago.

Friedman and Lyon (2005) proposed three necessary components in order to date an event: the episodic memory of the event itself, temporal information about when the event occurred, and executive processes to integrate this information. Adults are thought to predominantly date an event by relating their episodic memories to their general knowledge of time patterns, i.e. location-based dating (Friedman, 1987; Friedman & Wilkins, 1985). In contrast, young children lack a thorough understanding of these time patterns (Davies & Fuery, 2009). Friedman and Kemp (1998) hypothesised that the use of location information (i.e. conventional knowledge about time patterns) undergoes a greater developmental change, compared to the use of distance information (i.e. the vividness of an event). Friedman and Lyon (2005) suggest that this is due to significant changes from early to middle childhood in the amount of temporally useful information that children have available to date events. Indeed, as shown in Experiment 1 in this thesis, children's time knowledge does develop over the primary school years, with young children having less complete knowledge about temporal concepts than older children (see section 2.5.1). It is therefore likely that children's memories for past events contain very little temporal structure. However, it is thought that children who are not yet able to understand time patterns are still able to make distance-based judgments, based upon their impressions of temporal distances (Friedman, 1991).

5.1.1. Episodic Memory for Dating

Research into children’s dating capabilities has examined their ability to date public or annual events, such as birthdays or Christmas (Friedman, 1992a, 2000, 2002; Friedman et al., 1995; Friedman & Kemp, 1998; see section 1.3.2.) When asking children to make relative recency judgments on these annual events (i.e. which event occurred first/last), children below 9 years of age have been shown to struggle, performing at levels below chance (Friedman, 1992a; Friedman et al., 1995). However, as outlined in section 1.3.3., research examining children’s dating of annual events is influenced by semantic knowledge about these events, rather than relying on their memory for specific information about the event in question.

As a result, researchers have also explored children’s ability to date relatively novel events, such as hospital visits, days out and school productions (Friedman, Cederborg, et al., 2010; Friedman, Reese, et al., 2010; Pathman, Doydum, et al., 2013; Pathman, Larkina, et al., 2013). These events, which do not occur annually, are therefore solely reliant upon children’s memory for when they occurred. Whilst some studies have found age increases in children’s ability to date events between 4 to 8 years (Pathman, Larkina, et al., 2013), research has shown no age-related increases in dating performance between 8 to 12 years (Friedman, Reese, et al., 2010). In contrast to children’s poor accuracy at making relative recency judgments between annual events, research using novel events has found relatively high levels of accuracy when making relative recency judgments; 6 and 8 year olds have been found to perform at levels above chance (Pathman, Doydum, et al., 2013; Pathman, Larkina, et al., 2013).

Section 1.3.4. highlighted the problems encountered in temporal memory research when relying upon naturally-occurring events. Issues include dating inaccuracies in parental judgments, and differences in the events experienced (i.e. events producing different levels of emotion or salience). Staged events provide a way to more tightly control the events to be dated, both in terms of when the event occurs and what the children experience. By controlling two events separated by a period of time, researchers are able to assess children’s ability to distinguish between which event occurred first or last, as well as examining their accuracy at dating the events using a number of timescales. The former method does not require children to possess any semantic temporal information (i.e. distance-based), whilst the latter method involves using knowledge of the days of the week, months of the year and the seasons to make such judgments (i.e.

location-based). Previous staged events employed to examine dating abilities include lessons on teeth brushing, science demonstrations and teaching children novel facts and actions (Friedman, 1991; Friedman & Lyon, 2005; Tang et al., 2007). Both Friedman (1991) and Friedman and Lyon (2005) found age increases when dating events on several timescales (between 4 and 8 years, and 4 and 14 years of age respectively).

5.1.2. Impact of a Delay on Dating Ability

A factor that may affect children's dating ability is the amount of time between children experiencing an event and having to make dating estimates. Staged event research has employed delays between the first event and the testing session of 1 week (Tang et al., 2007), 7 weeks (Friedman, 1991) and 3 months (Friedman & Lyon, 2005). Although it is advised that delays are minimised in the criminal justice system (Home Office, 2011), the time between children experiencing an event and the case going to trial has been found to vary between 5 and 7 months (Flin, Bull, Boon, & Knox, 1990; Flin, Davies, & Tarrant, 1988). Examining the effect of a long delay will be beneficial to explore the impact of such an extended time period on children's ability to date an event.

The current study therefore aimed to examine children's ability to date two staged events after a relatively long delay. This study was designed retrospectively to take advantage of the fact that the same children took part in the first two experiments of the thesis; these involved watching an episodic film and making temporal judgments (Experiment 1), and completing two short-term computer tasks (Experiment 2). These events were separated by a delay of approximately 3 months, whilst the delay between the first event occurring and the testing period was approximately 7 months. Relative recency judgements were made (i.e. which event occurred first), and children were also asked to date the two events on a number of timescales.

5.1.3. Semantic Temporal Memory for Dating

In addition to examining children's ability to date experienced events, researchers have also begun to examine children's semantic memory for concepts related to dating, e.g. being able to think flexibly about the days of the week or the months of the year (see section 1.6.). Davies and Fuery (2009) found that children had poor recall of when events such as school holidays and special assemblies occurred. Improvements in accuracy were shown from 4 to 11 years, although only the oldest children provided reliable estimates. Friedman, Reese, et al. (2010) also examined 8 to 12 year olds' semantic memory for dating information; this was done through asking children a number of questions to assess their understanding of the order of the months. The results revealed a correlation between children’s ability to think flexibly about the months of the year and their accuracy in dating parent-nominated events.

Due to the limited number of studies examining the link between semantic and episodic dating ability, further research exploring this relationship was required. The current study therefore examined children’s knowledge of dating concepts through the creation of a semantic memory dating questionnaire. Similar to Experiment 1 in this thesis, this allowed further exploration of the link between children’s semantic temporal knowledge about dating information and their episodic temporal memory for dating events.

5.2. Aims and Hypotheses

The aim of the current study was to examine how well children could date two experienced events, both in relation to each other and on a number of timescales, as well as children’s grasp of semantic dating concepts. It was hypothesised that:

1. Children’s dating abilities would increase with age, particularly for location-based questions

2. Children’s dating accuracy would be greater for the event occurring most recently, due to a stronger trace strength

3. Children’s semantic memory for dating concepts would increase with age

The current study also aimed to examine whether there was a relationship between dating ability (as assessed by the timescale questions) and semantic memory for dating (as assessed by the dating questionnaire). Although previous research indicated that there might be a link between these two aspects of dating memory, the results from Experiment 1 in the current thesis suggested that these two areas would be independent; as a result, no firm hypothesis was made.

5.3. Semantic Memory Dating Questionnaire Pilot Study

A pilot study was conducted with a small sample of children to ensure understanding of the semantic dating questionnaire.

5.3.1. Method

5.3.1.1. Participants

Participants were the same 26 children (M=12, F=14) tested in the pilot study of the main semantic memory dating questionnaire in Experiment 1 of the thesis (see section 2.3). Thirteen children were selected from a Year 2 class (mean age = 7 years 4 months, range = 6 years 11 months to 7 years 10 months, M=6, F=7) and 13 children from a Year 4 class (mean age = 9 years 5 months, range = 9 years 0 months to 9 years 10 months, M=6, F=7).

5.3.1.2. Materials

The questions in the dating questionnaire were based upon those used by Davies and Fuery (2009), as well as information from the IXL Learning website (see section 2.3.1.2. for more information). Eight questions were included (see Appendix K for questions and scoring).

5.3.1.3. Procedure

Children were seated in a quiet room and read each question by the experimenter. Responses were recorded on a copy of the questionnaire, in sight of the child. Children were then thanked and given a sticker.

5.3.2. Results and Discussion

Question Nine (‘what month is your birthday in?’) was removed from analysis due to all children answering correctly. Cronbach’s alpha analysis (a measure of internal consistency) revealed the 8-item questionnaire to have a value of 0.64. Tests of normality revealed the data to be normally distributed.

Children’s responses were coded as either correct or incorrect and percentage accuracy scores were calculated. Year 4 children answered a greater percentage of dating questions correctly, compared to children in Year 2 (Table 5.1).

Table 5.1: Percentage of questions correct on the pilot dating questionnaire

	Year 2		Year 4	
	M	SD	M	SD
Dating Questions Correct (%)	41.35	26.70	61.54	15.70

A one-way ANOVA, with a between-subjects factor of age (Years 2, 4) revealed a significant difference between the two year groups in the percentage of questions answered correctly, $F(1,24)=5.52$, $p<0.05$, $\eta_p^2=0.19$.

The individual questions were also examined to ensure that they successfully distinguished between abilities. Children were split into high, medium and low ability, based on the percentage of questions they answered correctly overall. This was achieved by ranking the children according to the percentage of questions they answered correctly, then dividing the 26 children into three groups: low ability (13-38%, $N=10$), medium ability (50-62%, $N=8$) and high ability (75-88%, $N=8$). All children answered Question Nine correctly, meaning this question was excluded from analysis. The frequency of correct answers for the remaining seven questions followed the expected pattern, with a greater proportion of the higher ability children answering correctly. The results therefore suggested that the questions were able to distinguish between both age and ability.

Examining children’s understanding, it was clear that they had some difficulty in distinguishing between seasons and months; for the question asking children which season Christmas occurred in, 46% of children provided a month as a response. Due to all children correctly answering the question about the month in which their birthday occurred, this was removed from the main questionnaire and replaced with a question assessing what month they started in their new class. It was hoped that this would allow greater differentiation between age and ability. Finally, the question asking children the date that Halloween occurs proved difficult in terms of classification. Whilst 77% of

Year 4 children knew it occurred in October, only 23% provided the full answer of '31st October'. As a result, this question was altered on the main questionnaire to ask children the date that Christmas occurs; it was believed that as more emphasis is placed upon this holiday, children would be more aware of the exact date it occurs. The final dating questionnaire contained seven questions.

5.4. Method

5.4.1. Participants

Participants were 63 children from a primary school in Barnsley, South Yorkshire (M=33, F=30). Children were taken from the sample tested in Experiment 1 and Experiment 2 of the thesis; six children from the first two experiments were not available to take part in the current study. Children were from three school years: 22 children from Year 2 (mean age = 6 years 9 months, range=6 years 4 months to 7 years 2 months, M=11, F=11), 21 children from Year 4 (mean age = 8 years 10 months, range= 8 year 4 months to 9 years 3 months, M=10, F=11) and 20 children from Year 6 (mean age = 10 years 8 months, range=10 years 3 months to 11 years 2 months, M=12, F=8).

5.4.2. Materials

5.4.2.1. Dating Questions

Children were asked eight questions about the short-term and episodic tasks experienced during the first two experiments of the thesis; the recency judgment and time difference questions were asked once, whilst the remaining three timescale questions were asked twice (once for each task; see Table 5.2).

Table 5.2: Dating questions asked about the staged event

Category	Question
Recency Judgment (x1)	One of the two things you did was quite a long time ago, and one was not as long ago. Which one did you do first?
Time Difference (x1)	How long was there between the two different events?
Day of the week (x2)	What day of the week was it?
Month of the year (x2)	What month was it?
Season (x2)	What season was it?

5.4.2.2. Semantic Memory Dating Questionnaire

Seven questions assessed children's knowledge of dating concepts; this list of questions was created following the administration of the pilot questionnaire (see section 5.3.). Questions assessed children's ability to date events on timescales (i.e. location questions) and their ability to judge how long ago events occurred (i.e. distance questions). Two questions also assessed children's ability to think flexibly about days and months (see Appendix L).

5.4.3. Procedure

Children experienced the short-term task between November and December (Experiment 2, see Chapter 3). The episodic task occurred in February (Experiment 1, see Chapter 2). Testing occurred during June, ten months into the school year. The weather for all testing dates for Experiments 1, 2 and 3 was typical of the season it occurred.

The same researcher who conducted Experiments 1 and 2 conducted all aspects of the dating task. The location for testing was also the same for all three experiments, in the same small music room; this room was away from any noise and there were no clocks in sight. Children were given the opportunity to leave the testing sessions at any time, although all children were happy to participate and showed no confusion at any of the instructions given. All children successfully completed all aspects of testing (see Appendix M for full task instructions).

Children were tested in a quiet room in the school by the same experimenter who conducted the short-term and episodic events with the children. Recall was first tested to ensure that children remembered the two events. The relative recency question was asked first, before the remaining seven questions about the two events were then read verbally to the child and their answers were recorded by the experimenter (see Table 5.2 for the list and order of questions). Half of the children were questioned about the short-term task first, and half questioned about the episodic task first. If children did not provide an answer to the question, their response was classified as incorrect. Children did not ask for clarification on any of the questions, indicating no confusion about the procedure. Children then completed the semantic memory dating questionnaire, before being thanked and given a sticker.

5.4.4. Scoring

Several scoring systems were used for the different dating questions:

1. Time difference: Responses between 2 and 3 months were coded as correct for the time difference question, as the delay ranged between 11 and 12 weeks.
2. Day of the week: Responses were classed as correct if the correct day was provided. With the exception of one child in Year 2, all children answered with a weekday, indicating that they were able to reason that the events could not have occurred at a weekend as they are not at school on a Saturday or Sunday. Chance levels for correctly selecting one of the seven days was 14%, whilst for correctly selecting one of the schooldays it was 20%.
3. Month of the year: Testing took place between November and December. In line with previous research (Friedman, 1991; Friedman & Lyon, 2005), children who experienced the short-term task in November were classified as correct if they responded with the correct month or the months on either side (i.e. October and December). Children who experienced the task in December were classified as correct if they responded with November, December or January. As all children experienced the episodic task in February, the months of January, February and

March were classified as correct. Children therefore had a 25% chance of providing a correct response.

4. Season: The short-term task was classified as occurring in autumn or winter, whilst the episodic task was classified as occurring in winter or spring. Similar to the boundary adjustments made by Pathman, Larkina, et al. (2013), these classifications took into account the variable nature of the British weather, e.g. November is traditionally cold and wet. Children therefore had a 50% chance of providing a correct response.
5. Correct correspondence: Correspondence between children’s responses to the month and season questions was also analysed. This was done to see whether children were able to link these two dating scales together, i.e. providing a month that fell within the season given, such as July occurring in the summer. Due to the variable nature of the British weather, and in line with similar adjustments made by Pathman, Larkina, et al. (2013), Winter was classed as November, December, January and February, spring was classed as February, March, April and May, summer was classed as May, June, July and August, whilst autumn was classed as September, October, November and December. The chance of successfully choosing the correct month with each of the seasons was 33%.
6. Dating questionnaire: See Appendix K for the scoring method used.

5.5. Results

Children were first asked about the events to ensure that they remembered completing the two tasks. All children were able to provide some detail about the short-term and episodic tasks to indicate recall of the events. For example, children of all ages were able to recall what the film was about (e.g. ‘making space items’), whilst they were also able to describe the two short-term tasks when asked what they did on the computer (e.g. ‘remembering shapes and counting’).

5.5.1. Relative Recency

Analysis was first conducted on the percentage of children correctly stating that the short-term event occurred first (Table 5.3).

Table 5.3: Accuracy on the relative recency task

	Year 2 (N=22)	Year 4 (N=21)	Year 6 (N=20)
Correct Relative Recency Judgment (%)	68.18	76.19	50.00

The level of chance for the relative recency judgment was 50%. One-sample chi-square tests were conducted for each age group to examine whether children were able to accurately judge which of the two events occurred first. For Year 2, the number of children providing the correct answer (15) did not significantly deviate from chance levels (50% correct), $\chi^2(1,N=22)=2.91$, $p>0.05$. Similarly, the number of Year 6 children providing the correct answer (10) was not at levels above chance, $\chi^2(1,N=20)<0.001$, $p>0.05$. However, the number of Year 4 children correctly answering the relative recency question (16) was greater than expected by chance, $\chi^2(1,N=21)=5.76$, $p<0.05$. A chi-square test failed to show reliable differences between the three age groups, $\chi^2(2, N=63)=3.24$, $p>0.05$, suggesting similar levels of performance.

5.5.2. Dating Accuracy

The percentage of children answering each question correctly was calculated (Table 5.4). Similar to Pathman, Larkina, et al. (2013), an overall dating score was created by collapsing the results of the day, month, season and correspondence questions; this was done for each of the two events (short-term and episodic). These scores were then converted into a percentage. This method of analysis provided a more comprehensive impression of children’s ability to date different aspects of experienced events, rather than examining their performance on each timescale individually.

Table 5.4: Percentage of correct answers to questions about the staged events

	Chance Level	Year 2 (N=22)	Year 4 (N=21)	Year 6 (N=20)
Relative Recency	50%	68.18	76.19	50.00
Time Difference	N/A	4.55	4.76	25.00
STM Day of the Week	14% (7 days) 20% (5 days)	13.64	28.57	30.00
EM Day of the Week	14% (7 days) 20% (5 days)	4.55	23.81	20.00
STM Month of the Year	25%	13.64	4.76	20.00
EM Month of the Year	25%	40.91	52.38	55.00
STM Season	50%	36.36	38.10	65.00
EM Season	50%	50.00	80.95	70.00
STM Correspondence	33%	36.36	42.86	70.00
EM Correspondence	33%	27.27	66.67	75.00
STM Dating Score (%)	N/A	25.00	28.57	46.25
EM Dating Score (%)	N/A	30.68	55.95	55.00

A mixed-design ANOVA was conducted on the short-term and episodic dating scores; there was a within-subjects factor of event (short-term, episodic) and a between-subjects factor of age (Years 2, 4, 6). A main effect of event was found, $F(1,60)=16.71$, $p<0.01$, $\eta_p^2=0.22$; children were more accurate at dating the episodic event. There was also a main effect of age, $F(2,60)=6.35$, $p<0.01$, $\eta_p^2=0.18$, with older children performing better. Tukey's analysis revealed this difference to be approaching significance between Year 2 and Year 4 (p=0.07), whilst the difference between Year 2 and Year 6 was significant (p<0.01). There was no significant difference between Year 4 and Year 6 (p>0.05). Finally, the interaction between event x age was found to be significant, $F(2,60)=3.99$, $p<0.05$, $\eta_p^2=0.12$ (see Figure 5.1).

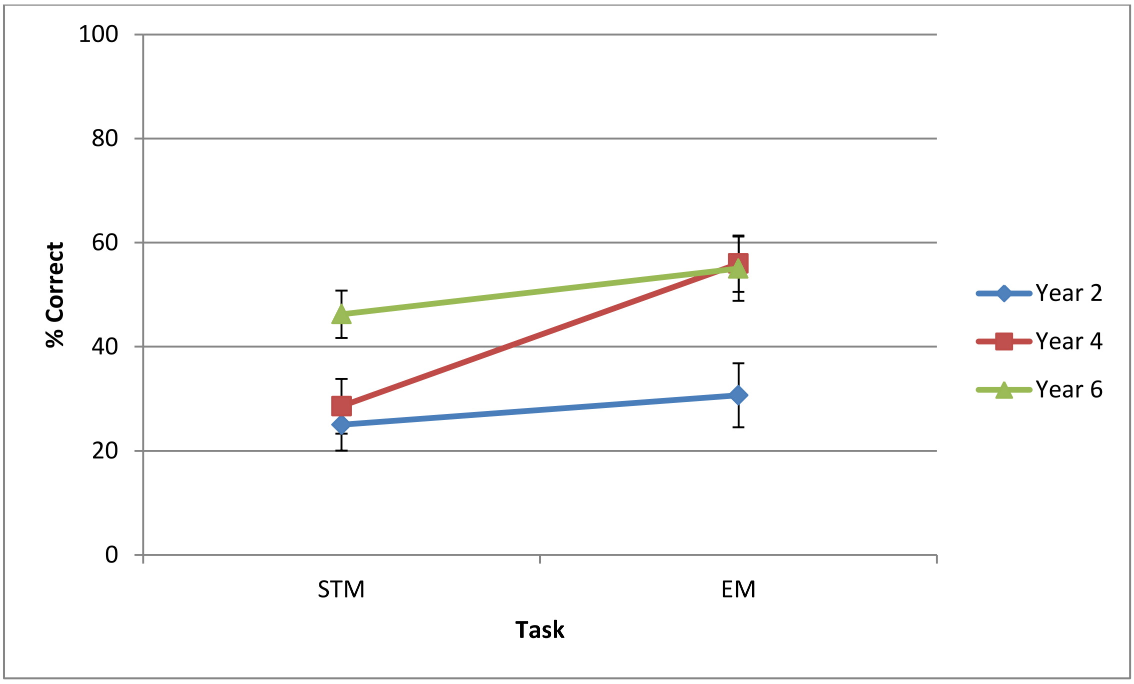


Figure 5.1: Task x age interaction for the STM and EM dating scores

To explore this interaction further, three paired-samples t-tests were conducted on the dating scores for each school year, with a within-subjects factor of task type (short-term, episodic). There was no significant effect of task type in Year 2, $t(21)=-1.05$, $p>0.05$, or Year 6, $t(19)=-1.32$, $p>0.05$. However, there was a significant effect of task type in Year 4, $t(20)=-4.81$, $p<0.01$; children were more accurate when dating the episodic task than the short-term task.

A total dating score was also calculated; this collapsed all 10 questions to produce a reflection of children's overall dating ability (Table 5.5).

Table 5.5: Total dating score across all 10 questions about the staged events

	Year 2 (N=22)	Year 4 (N=21)	Year 6 (N=20)
Total Dating Score (%)	29.55	41.90	48.00

A one-way ANOVA was conducted on the total dating score, with a between-subjects factor of age (Years 2, 4, 6). There was a main effect of age, $F(2,60)=5.75$, $p<0.01$, $\eta_p^2=0.16$, with older children showing greater levels of performance. Tukey's analysis revealed this difference to be approaching significance between Year 2 and Year 4 ($p=0.07$), whilst the difference was significant between Year 2 and Year 6 ($p<0.01$). The difference between Year 4 and Year 6 was not significant ($p>0.05$).

5.5.3. Semantic Memory Dating Questionnaire

Children's performance on the semantic memory dating questionnaire increased with age (Table 5.6).

Table 5.6: Percentage of questions correct on the dating questionnaire

	Year 2 (N=22)		Year 4 (N=21)		Year 6 (N=20)	
	M	SD	M	SD	M	SD
Dating Questions Correct (%)	37.01	31.69	58.49	23.42	75.71	16.77

A one-way ANOVA was conducted, with a between-subjects factor of age (Years 2, 4, 6). Analysis revealed a significant increase in semantic dating knowledge with age, $F(2,60)=12.69$, $p<0.01$, $\eta_p^2=0.30$. Tukey's analysis found this difference to lie between Year 2 and Year 4 ($p<0.05$), as well as between Year 2 and Year 6 ($p<0.01$). The difference between Year 4 and Year 6 was approaching significance ($p=0.08$).

The relationship between children's performance on the semantic memory dating questionnaire and their overall dating score was explored to see whether there was a link between dating knowledge and dating ability. Partial correlations, controlling for age in months, revealed no significant correlation between semantic dating knowledge and dating ability, *r*(60)=0.21, *p*>0.05. Further analysis was then conducted to see if there was a relationship between children’s knowledge of timescales and their ability to date events using two key timescales: days of the week and months of the year. There was no correlation between children’s accuracy at dating the two events using the day of the week timescale and their performance on the two questions related to manipulating days of the week (e.g. ‘How many days is it until Saturday?’), *r*(60)=-0.05, *p*>0.05. Similarly, there was no correlation between children’s accuracy at dating the two events on the month of the year timescale and their performance on either of the two questions assessing knowledge about the months events occurred (e.g. ‘What month did you start your new class?’), *r*(60)=0.02, *p*>0.05, or the two questions asking children to manipulate months (e.g. ‘How many months ago was April?’), *r*(60)=0.08, *p*>0.05.

5.6. Discussion

The current study utilised the fact that Experiment 1 and Experiment 2 were conducted on the same sample of children, separated by a period of three months; this resulted in a naturally occurring dating experiment.

5.6.1. The Effect of Delay

A primary aim of the current study was to examine the impact of a longer delay upon children’s ability to date two experienced events. Whilst previous staged event research examining dating abilities has employed delays of between 1 week and 3 months (Friedman, 1991; Friedman & Lyon, 2005; Tang et al., 2007), the present research design utilised a delay of 7 months between the first event and the testing session. This may account for children’s relatively poor performance on the temporal location questions, compared to previous research utilising smaller delays. For example, in the study by Friedman and Lyon (2005), in which there was a 3 month delay between the event and testing, 53% of 6 and 7 year olds were able to state the correct month that the event occurred; this is in contrast with 14% of 6 and 7 year olds in the current study, who experienced the short-term event approximately 7 months before. Likewise, 67% of 6 and 7 year olds in Friedman and Lyon’s study were able to provide the correct season, compared to just 36% in the current study. When examining the current 6 and 7 year olds' ability to date the episodic event (i.e. testing was 4 months later rather than 7 months), there was less of a discrepancy between the accuracy levels in these two studies (a difference of 12% for month judgments and 17% for season judgments). This greater accuracy when dating the more recent of the two events supports hypothesis 2 and the theory that more distant events have weakened trace strengths, resulting in poorer dating performance on a number of timescales (Brown et al., 1985; Friedman, 1992a; Friedman & Kemp, 1998). These findings therefore suggest that when utilising a larger delay between an experienced event and the testing session, children display a greater difficulty in dating events using location-based processes.

5.6.2. Relationship between Aspects of Temporal Memory

The current research also aimed to examine the development of children's semantic dating memory during childhood, and its relationship with children's dating abilities. The dating questionnaire revealed age increases across the primary school years in children's knowledge about dating concepts (hypothesis 3). This suggests that with increasing age, children were more able to think flexibly about the days of the week and the months of the year, as well as knowing when annual and experienced events occurred. The fact that the oldest children also displayed high levels of correspondence between their season and month judgments suggests that they possessed a good understanding of the relationship between these timescales.

However, this understanding on the questionnaire and children's correspondence between their month and season judgments did not translate to performance on the location-based dating questions; there was no correlation between children's performance on the questionnaire and their ability to date the two events on a number of timescales. Children's accuracy levels on the dating questionnaire suggest that they had some understanding about temporal concepts, such as the days of the week and the months of the year. Despite this, having a greater grasp of the months of the year or the days of the week, and being able to think flexibly about these timescales, seemed to provide no benefit when having to date the events. As discussed in the introduction of this chapter, Friedman and Lyon (2005) proposed three necessary components in order to date an event: episodic memory of the event itself, temporal information about when the event occurred, and executive processes to integrate this information. Children were able to recall the event when questioned, implying accurate episodic memory for the event. Similarly, children's performance on the dating questionnaire suggests that they possess an understanding of temporal timescales to date events. It is therefore possible that children may have difficulty when attempting to integrate this information; further development of children's executive functioning skills may be required before this integration can occur successfully.

5.6.3. Age Effects in Dating

In addition to exploring the impact of a delay and the relationship between semantic and episodic dating abilities, the current research also aimed to examine the development of age effects across the primary school years for both location- and distance-based dating. Increases in dating ability were shown with age for the location-based questions; older children were more accurate in dating the two events on a number of timescales compared to the younger children (hypothesis 1). Whilst there was an overall increase in dating abilities from 6 to 11 years, post-hoc analysis revealed that the difference between the two oldest groups (8 to 11 years) was not significant; it therefore appears that the development of dating events on a number of timescales may slow down towards the end of the primary school years.

In contrast to the age increases for location-based questions, no age effects were found when examining distance-based judgments, i.e. children's performance on the relative recency task; there was no difference across the primary school years in children's ability to remember which of the two events occurred first. Only the 8 and 9 year olds performed at levels above chance, whilst half of the oldest children incorrectly believed that the episodic task had been experienced first. Age increases in location-based dating, but not distance-based dating, supports the hypothesis by Friedman and Kemp (1998) that the use of location-based information undergoes a greater developmental change compared to distance information. The relatively poor levels of performance by children when making recency judgments contrast with distance theories which imply that events are stored in memory in the order that they occur, with more recent events at the forefront (Murdock, 1974); if this was the case then one would assume that the children would have shown a high level of accuracy when judging which of the two events was the most recent.

5.6.4. Application to Forensic Settings

Uncovering the effect of a delay on children's ability to date an event may have important implications for forensic settings. As highlighted in the introduction of this chapter, it is advised that the amount of time between a witness experiencing an event and giving evidence should be kept to a minimum. Nevertheless, researchers have discovered a delay of between 5 and 7 months (Flin et al., 1990; Flin et al., 1988).

The current research has highlighted poorer performance by children when longer delays are introduced, compared to research with shorter durations (Friedman, 1991; Friedman & Lyon, 2005; Tang et al., 2007). As children are often the only witnesses in sexual abuse trials (Chae, 2010), it is important to increase the accuracy of their temporal recall by minimising the delay. This research illustrates that even by 11 years of age children's memory for when exactly an event occurs is relatively poor after a delay of approximately seven months.

Previous research into non-temporal recall has uncovered an increase in the number of errors made when recalling an event after a delay of several months, compared to more immediate recall (Flin, Boon, Knox, & Bull, 1992; Jones & Pipe, 2002). Additionally, research has also shown that children's susceptibility to suggestions may also increase following a delay, as a result of a weakening of the memory trace strength (Oates & Shrimpton, 1991; Ornstein, Gordon, & Larus, 1992); this is particularly important to consider in a legal setting, where the phrasing of temporal questions may be leading and thus affect the outcome of a trial.

Further research should more thoroughly investigate the effect of delay on children's dating performance systematically, with a variety of different delays employed, in order to provide the legal system with a more accurate picture of the impact of a delay on temporal recall. This information will hopefully maximise the coherence of a child's testimony and ensure that they are perceived as credible witnesses, thus increasing the likelihood of reaching the correct verdict (Klettke et al., 2010; Voss et al., 1999).

5.6.5. Further Areas of Research

Previous research has shown some inconsistency in children's accuracy when making relative recency judgments. Whereas some studies have shown performance at levels below chance when dealing with annual events (Friedman, 1992a; Friedman et al., 1995), research examining novel events has shown high levels of accuracy in children as young as 6 and 8 years of age (Pathman, Doydum, et al., 2013; Pathman, Larkina, et al., 2013). It may therefore have been expected that the current study would also find high levels of accuracy when making relative recency judgments, as the events in question were novel to the children. However, only Year 4 children were performing at levels above chance. It is possible that the lack of accuracy when making relative recency judgments in the current research is due to the fact that the two events shared many similar features; both events took place in the same room in the school with the same researcher, and both involved making sequencing and duration judgments. The two events may therefore have been less distinct from each other than those used by Pathman, Doydum, et al. (2013) and Pathman, Larkina, et al. (2013), such as a trip to a museum and a birthday party; these two examples would have involved very different locations, activities and people. As the current study was designed retrospectively after the two tasks had been conducted, it was not possible to vary the conditions of the events to test for this, e.g. testing in a different area of the school or with a researcher of the opposite gender. Further research would therefore be useful to examine whether changing such variables would impact upon the accuracy of children's relative recency judgements.

5.6.6. Conclusion

This study has uncovered an increase in location-based dating across the primary school years, whilst distance-based dating showed no age-related increases. Semantic temporal memory for dating concepts was shown to increase with age, although an understanding of these concepts was not linked to dating performance. The impact of a delay on dating abilities was evident, with poorer performance compared to research employing smaller delays. Further investigation is required into the impact of changing contexts on relative recency judgments, as well as the effect of systematically varying the delay between an event occurring and children's attempt to date it on a number of timescales.

Chapter 6: Exploring the Impact of a Timeline Tool on Temporal Memory

6.1. Introduction

Timeline tools provide a way to enhance children's temporal memory (Busby Grant & Suddendorf, 2009; Friedman & Kemp, 1998; Gosse & Roberts, 2014; Hudson & Mayhew, 2011). Timelines create a method for children to structure their accounts when trying to recall temporal information about an event. As time is an abstract concept, giving children a physical representation provides a way to communicate their temporal understanding in a more concrete way.

The benefit of a timeline tool when recalling sequencing information was highlighted by Hope, Mullis, and Gabbert (2013); timelines allow individuals to record everything that they can remember first, before they then use the timeline tool to structure their account from start to finish. By first focusing on recall before the sequencing aspect of the task, timeline tools free up cognitive resources. Timeline tools also provide participants with the opportunity to place several different activities within a single time fame in order to visually relate the relationship between these different events (van der Vaart, 2004). When employing a timeline tool to aid duration judgments, children are not required to possess an understanding of temporal concepts, such as seconds or minutes; young children have difficulty in understanding such units of time (Friedman, 2000). Removing the need to understand these timescales with a timeline tool still allows children to provide an impression of the duration of different events, regardless of their understanding of time (Friedman, 1990).

Although a small amount of research has been conducted using timelines, Gosse and Roberts (2014) stressed that there is no published research examining whether timeline tools can produce reliable information; they note that 'despite the widespread use of timelines in applied settings to compensate for children's limitations, there is very little scientific research on the effectiveness of timeline recall' (p.38). The current research therefore aimed to examine the impact that a timeline tool would have on children's episodic sequencing and duration performance.

6.1.1. Sequencing

Research examining the use of a timeline tool has tended to focus on children’s ability to date isolated events in time (e.g. a birthday party or a football match; Busby Grant & Suddendorf, 2009; Hudson & Mayhew, 2011), rather than sequencing elements of an event relative to each other. These timelines have also examined relatively long time periods, e.g. days, weeks, months and years, rather than looking at the elements within a single event. For example, Hudson and Mayhew (2011) required children to place parent-nominated events (e.g. a friend’s party) up to 31 days in the past and 31 days in the future, whilst Busby Grant and Suddendorf (2009) used events such as when the child slept in a cot and when they would get married. In these cases, children were provided with these isolated events to be sequenced. No study appears to have employed a staged event in order to examine the effectiveness of a timeline tool to aid children’s sequencing of elements within a single event.

A prominent characteristic in studies employing timeline tools is a lack of a control condition; no research appears to have compared children’s performance using a timeline tool to more traditional forms of temporal memory assessment, such as free-recall. Positive results seen when using timeline tools may also have been achieved if more traditional questioning methods had been employed, such as verbal or written free-recall techniques. For example, Gosse and Roberts (2014) asked children to temporally locate parent-nominated events from the last week along a timeline representing a day. The authors suggested that using a timeline tool to indicate the time of day that the events occurred enabled children to reconstruct temporal information; children aged between 7 and 8 years produced similar time of day estimates to their parents. Based on previous research (e.g. Friedman, Cederborg, et al., 2010), 7 and 8 year olds might be expected to be less accurate than their parents when verbally reporting such temporal information, in contrast to their similar levels of performance when using a timeline tool. However, without employing a control condition, the benefits gained from a timeline tool cannot be known for sure. Caution thus has to be taken when claims are made that timeline tools significantly aid temporal memory performance, unless direct comparisons are made with other methods. The current study will directly compare the use of a timeline tool and a free-recall technique to examine the effect of both methods upon children’s sequencing ability.

One study examining the effectiveness of a timeline tool when sequencing elements within a single episodic event was conducted on an adult sample by Hope et al. (2013). Participants witnessed a film clip of a staged event, in which an assault and robbery occurred. Participants were divided into one of two conditions: a timeline condition and a control condition. When attempting to recall what they had seen, participants in the timeline condition were provided with two sets of cards: person description cards for information about the different individuals, and action cards for information about the different actions. Participants were instructed to use a different card to represent each individual and action. A timeline tool was then introduced, upon which participants placed the cards in chronological order, from start to finish. Participants in the control condition were provided with a booklet to write down the event as they remembered it. The results showed that participants using the timeline tool provided more correct information (M=43 items) than participants in the control condition (M=31 items). The timeline tool also resulted in a greater sequencing ability compared to the free-recall technique; participants using the timeline tool made fewer sequencing errors (M=1.02 errors), compared to the control condition (M=2.03 errors). This research suggests that a timeline tool can help to not only recall more information about an individual event, but also to sequence this information more accurately.

The current research therefore aimed to see whether the timeline tool used by Hope et al. (2013) could be extended for use with children. To ensure that children were comfortable with writing relatively large amounts of information, 9 and 10 year olds were selected for the initial pilot study, with the intention of further age groups being recruited if the timeline tool was found to be effective. A more emotionally-neutral film was chosen due to the age of the children; a visit to a veterinarian surgery was considered less distressing than an assault and robbery. The nature of using separate person description and action cards was considered too challenging for children to understand, so a simplified version of the task was therefore created; children were given only the action cards to write about the different elements within the film, before sequencing the cards along the timeline.

A factor which may play a role in the effectiveness of a timeline tool is working memory (Baddeley & Hitch, 1974). Working memory ability has been shown to play a key role in children’s temporal abilities, such as monitoring durations or following a sequence of instructions (Gathercole, Alloway, Willis, & Adams, 2006; Gathercole, Durling, Evans, Jeffcock, & Stone, 2008; Mantyla et al., 2007). Although children may have an understanding of temporal concepts, they may face problems when trying to recall both contextual information and temporal patterns at the same time (Friedman, 1992a). Gosse and Roberts (2014) therefore suggested that a timeline tool showing the whole timescale in question (i.e. from start to finish) would reduce children's cognitive load by reducing the need to hold both contextual information and sequencing information in mind at the same time.

Working memory capacity has been shown to vary widely among children of the same age (Gathercole & Alloway, 2008); this variation is believed to be driven by differences such as information processing speed and the ability to retain information whilst engaging in another task (Towse & Hitch, 2007). For children with a lower working memory capacity, having to recall large amounts of information about an event in the correct order may be very cognitively demanding and lead to performance difficulties. Not only does the child have to try and remember the different elements that they witnessed, but they must hold all this information in their memory whilst trying to extract these elements in the correct order. The current research therefore aimed to investigate whether a timeline tool would enable children to free up working memory resources and lead to increased accuracy on a sequencing task, particularly for children with lower working memory capacity.

6.1.2. Duration

Timeline tools also allow children to use pictorial representations to indicate the duration intervals between events (Friedman, 1990) or to represent how far away an event is in the past or the future (Friedman, 2000, 2002; Friedman & Kemp, 1998). Such a method reduces the reliance upon children's understanding of time concepts, such as minutes or hours. Studies examining children's knowledge of duration have previously relied upon verbal questioning, asking children how long events lasted for (e.g. Friedman, Cederborg, et al., 2010). As seen in Experiment 1 and recent literature, children's verbal estimates of durations lack precision (Friedman, Cederborg, et al., 2010; see also section 2.5.6.), whilst young children have difficulty with semantic temporal concepts related to duration (Davies & Fuery, 2009; see also section 2.5.1.). A timeline tool which reduces the reliance on time concepts, and instead relies upon pictorial representations placed along a linear scale, may reduce the difficulties children face when making duration judgments.

One such study using a timeline tool to examine duration abilities was conducted by Friedman (1990). This research assessed children’s ability to translate duration information about daily events into physical representations along a timeline. Children were required to place a marker along a timeline marked 1-10 to indicate the amount of time between events such as waking to having breakfast, or dinner to bedtime. Performance increases were shown between 3 and 9 years of age, with older children more able to differentiate between durations of different lengths (e.g. placing a greater distance between lunch-bedtime than bath-bedtime). Although this study examined several pairs of duration intervals across the day, these judgments were made individually, i.e. children were presented with one pair of activities, before the pair was removed from the timeline and another pair was displayed. There does not appear to be any research available which examines children’s ability to represent the duration of intervals between several different pairs of events across an entire day; this would allow children to assess their duration interval judgments, relative to each other. The current study therefore aimed to explore children’s ability to represent the duration intervals of nine daily activities from the start of the day to the end of the day.

In order to remove the possibility of individual differences in children’s experiences of daily activities influencing children’s judgments, a scripted story about a typical school day from the perspective of a young boy was employed. This ensured that children of all age groups heard the same account of the day, limiting the possibility of variations in daily routines affecting judgments unnecessarily. Although research into the effectiveness of timeline tools has examined adult performance on sequencing tasks (Hope et al., 2013), there exists no such adult data on a timeline task related to the duration of daily activities. The current study therefore employed an additional adult sample to provide a normative ‘benchmark’ to allow comparisons with children’s performance. All instructions were kept identical for both adult and child samples to ensure that this could not adversely affect the results of any comparisons.

6.2. Aims and Hypotheses

The aim of the current study was to investigate whether adopting a timeline tool would increase children's ability to recall more information about a witnessed event, as well as their ability to sequence such information more accurately. The study also aimed to examine whether children with lower working memory abilities would benefit more from the use of the timeline tool when sequencing elements within an event. A further aim of the study was to examine whether children were able to translate mental representations of duration intervals between events onto a physical timeline. It was hypothesised that:

1. Children in the temporal timeline condition would recall significantly more information about the event, and in the correct sequence, compared to the control condition
2. Children with lower working memory scores would benefit more from the temporal timeline tool compared to children with higher working memory scores

Due to the exploratory nature of the duration aspect of the study, no hypothesis was made about children's performance on the task.

6.3. Method

6.3.1. Participants

Participants for both the sequencing and duration tasks were 16 children (M=8, F=8) from a Year 5 class at a primary school in Barnsley, South Yorkshire. Children were between 9 and 10 years of age (mean age = 9 years 11 months, range = 9 years 6 months to 10 years 5 months).

An adult sample was also employed in the duration task; due to time constraints during testing, these participants were only able to take part in the duration aspect of the study. Fifteen Psychology A-Level students (M=5, F=10) were recruited from three sixth form colleges across Yorkshire; these students were attending a research open day within the School of Psychology at the University of Leeds (mean age = 17 years 3 months, range

= 16 years 10 months to 17 years 9 months). Students were selected at random from a larger pool attending the open day.

6.3.2. Design

A between-subjects design was used for the sequencing task; children were randomly assigned to either an experimental (N=8) or control (N=8) condition. Children in the experimental condition used a timeline to sequence the information they recalled, whilst children in the control condition completed a free-recall writing task. The order that children completed the sequencing and duration tasks was counterbalanced.

6.3.3. Materials

6.3.3.1. Sequencing Film

Children viewed a 10 minute film from the Child’s Eye Media DVD ‘People Who Help Us 2’. This film followed two young children as they visited a veterinary surgery and shadowed a veterinarian. Activities undertaken included worming a cat, clipping a rabbit’s nails, x-raying a dog and visiting an animal hospital.

6.3.3.2. Temporal Timeline

A timeline tool was created using laminated A4 paper. A red line measuring 100cm was marked with the words ‘Start’ and ‘End’. The same timeline tool was used for both the sequencing and duration aspects of the experiment.

6.3.3.3. Working Memory Measure

A backwards digit recall task was administered; this was created using a random number generator, and based on previous digit spans (see Appendix O for task). Children had to repeat a sequence of two numbers in a backwards fashion, and the length of the number string increased by one digit after four of six possible trials were completed correctly. Once children answered three trials of the same length incorrectly, the task was terminated.

6.3.3.4. Duration Story and Activity Cards

A story was created for the duration task, based upon a typical school day (see Appendix P for activity cards). This subject was chosen to allow comparisons with the research conducted by Friedman (1990), as well as to ensure an equal level of understanding across all age groups; the scripted story also ensured that any variability in children's individual routines was reduced. Nine laminated activity cards about activities described in the story were created: alarm, breakfast, teeth brushing, car to school, lunch, games, car home, bath and bed (see Appendix K). These activities were chosen to create durations between the events of differing lengths. The activity cards measured 5cm x 5cm with a 2.5cm arrow protruding from the top, allowing the children to point to a location along the timeline.

6.3.4. Procedure

Testing was conducted during April, eight months into the school year. The same researcher conducted all aspects of the tasks. Testing was completed in the same small break-away class room, away from any noise and with no clocks in sight. Children were given the opportunity to leave the testing sessions at any time, although all children were happy to participate and showed no confusion at any of the instructions given. All children successfully completed all aspects of testing (see Figure 6.1 for order of tasks). All children completed the sequencing task before the duration task (see Appendix N for sequencing instructions and Appendix P for duration instructions).

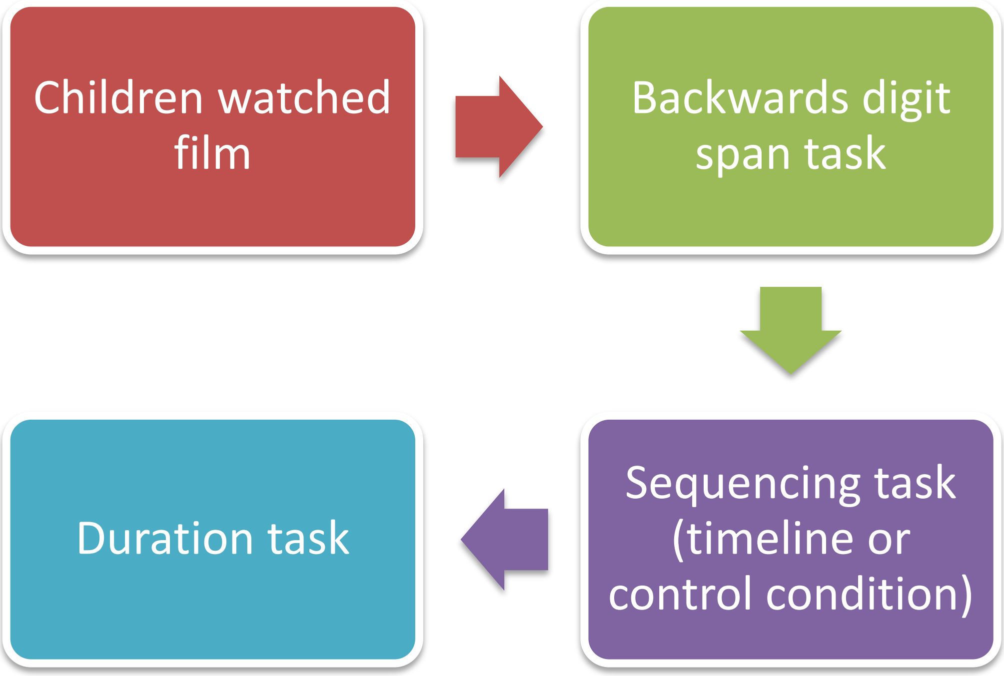


Figure 6.1.: Order of task completion for Experiment 5

6.3.4.1. Sequencing Task

All children were tested individually. They were told that they would watch a short film about two children visiting a veterinarian's surgery. The child was instructed to watch the film carefully and not talk, but they were not informed as to what they would be doing afterwards, i.e. no reference was made to a memory test. After watching the film, the child was then told that the experimenter would say some numbers out loud, and the child had to say the numbers in the reverse order; the backwards digit recall task was then administered.

After completing the backwards digit recall task, the child was told that they would be remembering some things about the film they had watched. Children in the experimental (timeline) condition were given a pile of blank white cards, a quarter of the size of an A4 sheet of paper. They were asked to write down everything that they could remember about the film on the cards in front of them, using a new card for each event or action that they could recall. To help the child to understand this instruction, the experimenter provided children with a verbal example about a trip to the zoo to ensure understanding of what constituted a different event. The researcher told the child that they would write a new card for the coach journey there, then one about seeing the lions, then one about having a picnic. The child then completed the card writing task about the film they had seen. After the child indicated that they had finished writing the cards, the experimenter checked that they could not recall any further information. The timeline tool was then laid out and its concept was explained (see Appendix J for full instructions). The child was then asked to place their cards along the timeline in the order that the events happened, from the start of the film to the end of the film.

After completing the backwards digit recall task, children in the control condition were given several blank sheets of A4 paper. The child was then asked to write about the film they had just watched; they were asked to write down everything that they could remember about what happened in the film, in the order that it occurred from start to finish. The children in the control condition were not shown the timeline.

6.3.4.2. Duration Task

After completing the sequencing task, the child was informed that they would now complete another task about a boy’s day. They were told that they would hear a story about a boy named Alex and a typical day in his life. The experimenter then read the following story:

> Alex was woken up by his alarm clock. He got out of bed, put on his dressing gown and went downstairs for his breakfast. After he had finished, Alex went

> back upstairs, put on his uniform and brushed his teeth. He got in the car and his mother dropped him off at school. Alex played in the playground with his friends until it was time to go inside. At lunchtime, Alex ate his packed lunch in the school hall with his friends. Alex then went into the playground and played until the bell rang. After lunch, Alex's class had games all afternoon and they played cricket. Alex’s dad picked him up at the end of school and he went home. After tea, Alex played on his computer. Alex then had a bath, put his pyjamas on and went to bed.

After the experimenter read the story out loud, the child was then shown the timeline tool. They were shown nine laminated activity cards, which displayed the key events from the story. The experimenter showed the child these cards one at a time, labelling what they were illustrating, before the child was handed the cards. Children showed no confusion with any of the pictures shown to them. The cards were in the correct order from the story so that they were not required to remember the sequence of events; this was made clear to the child. The experimenter told the child that they had to place the cards along the timeline to shown when the different events happened in the day. They were told to leave different sized gaps between the cards to represent different lengths of time. The child was told that the time between some events might be quite short, so those cards should be placed close together, whilst the time between other events might be much longer, so those cards should be placed further apart. The experimenter made this concept clearer by using four additional cards showing a girl getting on a plane, flying in the plane, landing in the plane and on a coach to illustrate both short and long durations. When the child confirmed that they understood the task, the child was told to place the nine cards along the timeline. Once the child was happy with their placement, the experimenter measured the location of the nine events to the nearest millimetre. Children were thanked and given a sticker.

The adult participants were tested individually within the School of Psychology at the University of Leeds during June, in a small testing cubicle. The adults received exactly the same instructions as the child sample; they were told that in order to make comparisons between themselves and a group of children, they would be given the same instructions as 9 and 10 year olds. All adults then completed the duration task outlined above.

6.3.5. Scoring

6.3.5.1. Sequencing Task

The total number of words that the child had written was first calculated. The film was divided into 22 elements, which expanded on the five main topics covered in the film: 1) meeting the veterinarian, 2) Tom the cat receiving treatment, 3) Jessica the rabbit getting her nails clipped, 4) meeting Lucy the three legged dog, 5) visiting the animal hospital. The 22 elements further separated these five topics into several individual activities (see Table 6.1 for individual elements).

Table 6.1: Individual elements within the film

Element Number	**Description**
1	Alex and Hannah arrive at the surgery
2	Veterinarian welcomes them
3	Children put on uniforms
4	Veterinarian shows them the medicine
5	Sarah arrives with Tom the cat
6	Veterinarian examines cat’s teeth
7	Veterinarian checks for fleas
8	Veterinarian listens to heartbeat
9	Cat has an injection
10	Children see a pot of worms
11	Veterinarian gives cat a worming tablet
12	Tom the cat and Sarah leave
13	Veterinarian and children wash their hands
14	Jessica the rabbit has her nails clipped
15	Lucy the three legged dog arrives
16	Children see the x-rays of the dog’s leg
17	Children count the screws in the x-ray image
18	Children visit the veterinary hospital
19	Children talk about Ewok the cat and his collar
20	Veterinarian gives the cat eye drops
21	Girl feeds the cat
22	Boy records the cat’s information on a chart

As children were not provided with the elements to sequence, and could only sequence the items that they recalled, the sequencing scoring system used in the previous sequencing tasks in Experiments 1, 2 and 3 was considered to be an inappropriate form of scoring. Using this scoring system, a child who recalled three elements from later in the film (e.g. items 7, 15 and 21) would obtain a score of 31; this high score would be due to the fact that there is a large discrepancy between position 1 and item 7, position 2 and item 15 and so forth. In contrast, a child who recalled the same number of elements from the beginning of the film (e.g. items 1, 4 and 6) would obtain a score of 5. The scoring systems used by Pathman, Doydum, et al. (2013) for a similar type of sequencing task were considered to be more appropriate:

1. Total pairs: Items were examined in pairs, and a point was assigned if the items occurred in the correct ascending order, i.e. the second item in the pair occurred later in the film than the first item in the pair. For example, both 1-2 and 9-13 would receive a point, regardless of the fact that there were items missing in between 9-13. If the items were in the wrong order, i.e. the second item in the pair came before the first item in the pair (4-3 or 18-14), no point was assigned.
2. Adjacent pairs: This scoring system provided a greater level of temporal precision. Items were examined in pairs, and a point was assigned if the items occurred in the correct consecutive ascending order, i.e. items occurred next to each other. Using the above examples of 1-2 and 9-13, only the first pair would receive a point, as the second pair omitted three items.

Two researchers scored a sub-sample of responses to ensure inter-rater reliability.

6.3.5.2. Duration Task

Participants’ placements of the activity cards were measured from the start line to the tip of the arrow, to the nearest millimetre. The length of the timeline utilised by the participant was calculated by subtracting the placement of the first activity card (alarm) from the placement of the last activity card (bed). The intervals between pairs of activities (e.g. between alarm and breakfast) were also recorded by measuring the distance between items to the nearest millimetre.

6.3.5.3. Working Memory Measure

A working memory score was calculated based upon the total number of trials completed correctly (M=12.63, SD=3.65). Children’s working memory scores were used to assign them to one of two groups: above-average ability, i.e. scores above the mean of 12.63 (N=9, M=15.22, SD=2.11, range=13-18), and below-average ability, i.e. scores below the mean of 12.63 (N=7, M=9.29, SD=2.11, range=7-12).

6.4. Results

6.4.1. Sequencing

6.4.1.1. Item Recall

The number of words written and the number of elements recalled (maximum=22) were calculated (Table 6.2). Mean scores were calculated for both the experimental (timeline tool) and control (free-recall writing task) conditions, as well as the working memory groups (above-average, below-average).

Table 6.2: Recall of information from the film

		Number of Words		Elements Recalled	
		M	SD	M	SD
Experimental	Above-Average WM (N=5)	88.60	29.69	7.80	1.64
	Below-Average WM (N=3)	89.67	50.29	10.00	2.65
	Total (N=8)	89.00	35.02	8.63	2.20
Control	Above-Average WM (N=4)	201.75	70.60	9.50	3.87
	Below-Average WM (N=8)	97.00	63.76	7.75	4.86
	Total (N=8)	149.38	83.75	8.63	4.17

A two-way ANOVA was conducted on the number of words written, with between-subjects factors of condition (experimental, control) and working memory (above-average, below-average). The effect of condition was approaching significance, $F(1,12)=4.72$, $p=0.05$, $\eta_p^2=0.28$, with children in the control group writing more. The effect of working memory was also approaching significance, $F(1,12)=3.49$, $p=0.09$, $\eta_p^2=0.23$, with children in the above-average group writing more.

Similarly, the interaction between condition x working memory was approaching significance, $F(1,12)=3.64$, $p=0.08$, $\eta_p^2=0.23$. To analyse this further, separate independent-samples t-tests were conducted on the two working memory groups, with a between-subjects factor of condition (experimental, control). For above-average working memory, there was a significant effect of condition, $t(7)=3.28$, $p<0.05$; children in the control condition wrote more than children in the experimental condition. This effect was not significant for below-average working memory, $t(5)=0.16$, $p>0.05$. Separate independent-samples t-tests were also conducted on the two conditions, with a between-subjects factor of working memory (above-average, below-average). In the experimental condition, there was no significant effect of working memory, $t(6)=0.04$, $p>0.05$. Conversely, in the control condition the effect of working memory was approaching significance, $t(6)=-2.20$, $p=0.07$; children with above-average working memory wrote significantly more than children with below-average working memory.

A two-way ANOVA was next conducted on the number of elements recalled, with between-subjects factors of condition (experimental, control) and working memory (above-average, below-average). There was no significant effect of condition, $F(1,12)=0.03$, $p>0.05$, $\eta_p^2<0.01$. The effect of working memory was also non-significant, $F(1,12)=0.02$, $p>0.05$, $\eta_p^2<0.01$. Finally, the interaction between condition x working memory on the number of detailed elements was not significant, $\mathrm{F}(1,12) = 1.29$, $\mathrm{p}>0.05$, $\eta_\mathrm{p}^2=0.01$.

6.4.1.2. Sequencing Ability

Two measures of sequencing ability were calculated: total pairs and adjacent pairs (Table 6.3).

Table 6.3: Sequencing ability (total pairs and adjacent pairs)

		Total Pairs		Adjacent Pairs	
		M	SD	M	SD
Experimental	Above-Average WM (N=5)	7.55	3.78	2.50	2.38
	Below-Average WM (N=3)	5.75	4.50	2.00	2.00
	Total (N=8)	6.75	3.99	2.25	2.05
Control	Above-Average WM (N=4)	6.40	1.67	2.40	1.67
	Below-Average WM (N=8)	8.33	3.06	3.00	1.73
	Total (N=8)	7.13	2.30	2.63	1.60

A two-way ANOVA was conducted on the total pairs score, with between-subjects factors of condition (experimental, control) and working memory (above-average, below-average). There was no significant effect of condition, $F(1,12)=0.13$, $p>0.05$, $\eta_p^2=0.01$, or working memory, $F(1,12)<0.01$, $p>0.05$, $\eta_p^2<0.01$. The interaction between condition x working memory for the total pairs sequenced correctly was also non-significant, $F(1,12)=1.34$, $p>0.05$, $\eta_p^2<0.01$.

A two-way ANOVA was also conducted on the more precise adjacent pairs score, with between-subjects factors of condition (experimental, control) and working memory (above-average, below-average). The effect of condition was not significant, $F(1,12)=0.20$, $p>0.05$, $\eta_p^2=0.02$. There was also no effect of working memory,

$F(1,12)<0.01$, $p>0.05$, $\eta_p^2<0.01$. Lastly, the interaction between condition x working memory was not significant, $F(1,12)=0.30$, $p>0.05$, $\eta_p^2=0.03$.

6.4.2. Duration

6.4.2.1. Placement of Activities

The placement of the nine activity cards along the timeline tool was first examined, as well as the proportion of the timeline utilised (Table 6.4).

Table 6.4: Placement of activity cards along the timeline (in cm)

	Children (N=16)		Adults (N=15)	
	M	SD	M	SD
Alarm	3.25	2.43	2.65	3.83
Breakfast	10.17	3.62	8.78	4.52
Teeth Brushing	19.44	5.45	15.52	4.76
Car to School	28.86	6.94	22.16	4.24
Lunch	43.84	9.22	39.59	5.93
Games	54.25	11.25	48.67	6.87
Car Home	66.78	12.85	63.08	8.59
Bath	78.35	11.97	81.75	9.71
Bed	88.93	12.79	90.83	10.79
Percentage of Timeline Utilised	85.68	12.86	88.18	11.90

Independent-samples t-tests were conducted for each of the nine activities, with a between-subjects factor of age (children, adults). There was a significant effect of age for the placement of two of the nine activity cards: ‘Teeth Brushing’, $t(29)=2.13$, $p<0.05$, and ‘Car to School’, *t*(29)=3.22, *p*<0.01; children placed these activity cards significantly further along the timeline than adults. There was no significant difference between the adult and child sample for the remaining seven activities (p>0.05). An independent-samples t-test was also conducted for the percentage of the timeline utilised, with a between-subjects factor of age (children, adults). There was no significant difference between the two groups, *t*(29)=-0.56, *p*>0.05.

6.4.2.2. Duration Intervals

The duration intervals between pairs of activities were calculated for all eight pairs (Table 6.5).

Table 6.5: Duration intervals between activities (in cm)

	Children (N=16)		Adults (N=15)	
	M	SD	M	SD
Alarm to Breakfast	6.92	2.05	6.13	1.89
Breakfast to Teeth	9.28	2.40	6.74	1.60
Teeth to Car	9.41	2.67	6.64	1.06
Car to Lunch	14.99	4.71	17.43	5.03
Lunch to Games	10.41	3.12	9.07	2.78
Games to Car	12.53	3.73	14.41	3.61
Car to Bath	11.58	3.47	18.67	4.84
Bath to Bed	8.63	2.02	7.38	1.98

Eight separate independent-samples t-tests were conducted for the different activity pairs, with a between-subjects factor of age (children, adults). There was a significant difference between the two age groups for three of the activity pairs: ‘Breakfast to Teeth’, $t(29)=3.44$, $p<0.01$, ‘Teeth to Car’, $t(19.88)=3.84$, $p<0.01$, and ‘Car to Bath’, $t(29)=-4.72$, $p<0.01$. Children produced larger duration intervals between ‘breakfast to teeth’ and ‘teeth to car’ compared to the adults. In contrast, children produced a smaller duration interval for ‘car to bath’ compared to the adults.

Similar to the methodology used by Friedman (1990), the placement of the activity cards was converted into units of time. The mean distances along the timeline were converted into hours and minutes in order to produce a rough estimation of the duration intervals between each pair (see Figure 6.2). It was estimated that the fictional boy's typical day would start at 7:30am and end at 8:00pm. As a result, each centimetre on the timeline was equated to 7 minutes and 48 seconds.

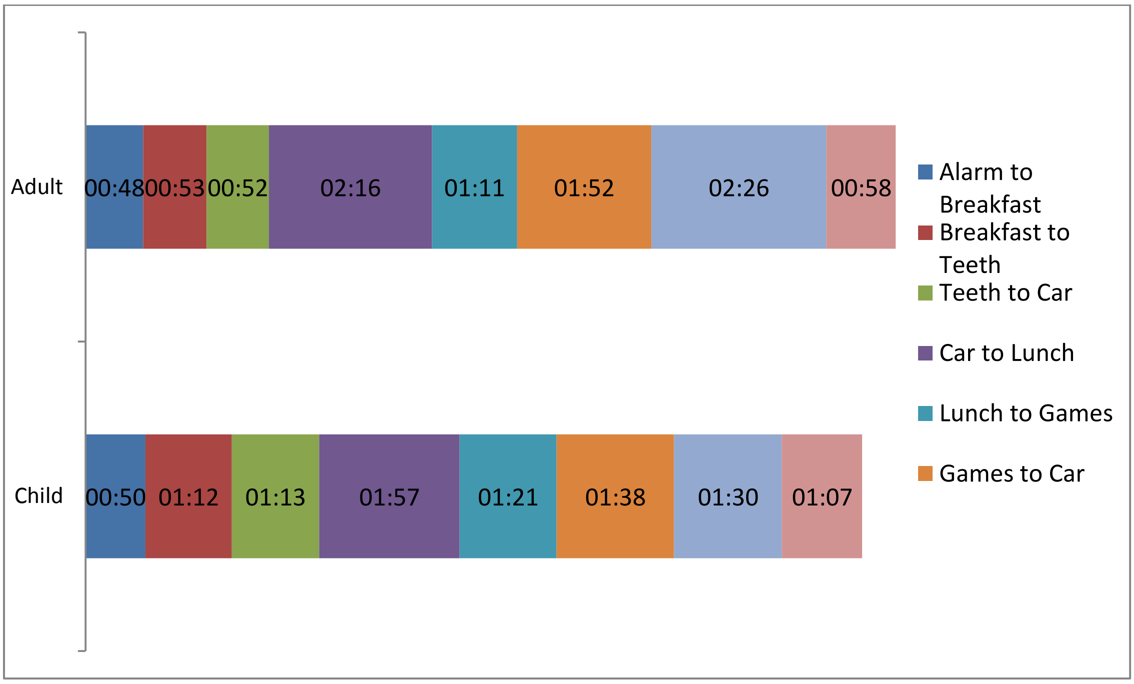


Figure 6.2: Duration intervals between activity pairs (in hours and minutes)

This visual representation of the fictional boy's day indicates that similar patterns were displayed by both the children and the adults; this indicates that both age groups judged the relative durations between the different activities in a similar way.

6.5. Discussion

6.5.1. Sequencing

One aim of the current experiment was to examine whether a timeline tool would aid children's recall of a sequence of elements within a single event, compared to a free-recall technique. The results suggest that the timeline tool did not significantly improve the amount of information recalled (i.e. the number of elements remembered out of 22) or children's sequencing ability compared to a free-recall technique; this finding disputes hypothesis 1. Children who simply wrote their account in a linear fashion (i.e. from start to finish) were found to perform at similar levels to children using the timeline tool. The average number of elements recalled in both groups was eight out of a possible 22; this suggests that children were recalling approximately 35% of the contents of the film. Despite the fact that there was only a delay of approximately 10 minutes before recalling what they had seen, children were not remembering a large proportion of the different elements of the film. It is possible that if children had recalled more of the elements of the film, a difference in sequencing ability between the two methods may have emerged; when a greater number of elements require sequencing, the timeline tool may prove to be advantageous.

This lack of benefit gained from a timeline tool is in contrast to the findings of Hope et al.'s (2013) research with an adult sample; Hope's study found that the use of a timeline resulted in both a greater amount of information recalled and a superior sequencing ability. These contrasting findings suggest that 9 and 10 year olds may not achieve the same benefits from segmenting their accounts into individual elements before dealing with the sequencing aspect of the task. It may be that the concept of not automatically recalling information in the correct sequential order (i.e. just focusing on recalling the information before worrying about the order) proved to be too confusing for the children. It was envisaged that children in the timeline tool would write down any element of the film that came to mind, in no particular order, and then take time to put these items in the correct sequence. However, the majority of children in the timeline condition spent a long amount of time thinking about the order of the different elements whilst writing on the cards, and then a minimal amount of time simply laying down the cards onto the timeline in the same order they were written. This behaviour of relatively automatic ordering supports memory literature showing that episodic memory is temporally clustered, with temporal order playing an important role during sequencing (Howard & Kahana, 1999; Unsworth, 2008). The finding that children instinctively try to preserve the sequence when recalling details about an event is also supported by research showing that children as young as 3 years of age include order information in event representations; when recalling a story or experience, children tend to talk about the elements in a linear order, from start to finish (Mandler, 1984; Nelson, 1986; Nelson & Gruendel, 1986). Recalling information from an event in any order, regardless of the temporal sequence, may therefore have proved to be too unfamiliar a task to the children, and as a result they maintained the correct order when creating the activity cards.

An alternative explanation for these contrasting findings may be due to differences in the methodology employed in the two studies. The current study simplified the timeline task so as not to overwhelm the children; whereas Hope et al. (2013) had both action and person cards, the current study used only action cards. As a result, the reduced demands of the task may have resulted in the timeline tool no longer being an effective way to improve performance; it may be that the timeline tool is only beneficial when a more complex design is employed, requiring multiple forms of information. The current experiment was intended to be an initial pilot study to examine whether children as young as 9 years of age were able to utilise the timeline tool and cope with the task demands. It was evident through observing the children, as well as examining the results, that children were able to grasp the timeline methodology. Further research which develops the current methodology, employing the more complex design of separate person and action cards, would reveal whether there is still a discrepancy in the timeline's usefulness with adult and child samples.

The differential effects of the timeline tool on children with above-average and below-average working memory was also explored; it was hypothesised that children who had a poorer working memory capacity would achieve a greater benefit from using the timeline tool compared to a free-recall writing technique (hypothesis 2). There was no significant difference between the two working memory groups for either the number of elements recalled or sequencing ability. This suggests that working memory did not impact upon children's ability to sequence an event, either when using a sequencing aid (i.e. the timeline tool) or when recalling the information freely. It is possible that the task was not cognitively demanding enough for working memory capacity to affect performance. Previous research has found that remembering the sequence of several classroom instructions is affected by working memory, with low-ability children performing poorly (Gathercole et al., 2006; Gathercole et al., 2008); such a task involves carrying out actions (e.g. placing a pencil in a basket) whilst still trying to remember the remaining sequence. In contrast, the current task of remembering the order of a number of elements in a film after a ten minute delay did not require any concurrent resource-demanding activities. It is possible that if children were required to conduct similar actions to the elements seen in the film (e.g. giving a toy cat a tablet, brushing its fur) then working memory abilities may have impacted upon performance. Nevertheless, the fact that children with low working memory were able to perform at similar levels to children with high working memory is reassuring; these children appear just as capable of sequencing, regardless of whether using a timeline technique or a simple free-recall writing task.

One factor which was affected by children's working memory was the amount of information written; overall, children with above-average working memory abilities wrote more information than below-average children. The interaction between working memory and condition revealed that although there was no difference between the two working memory groups in the timeline condition, in the control condition there was a significantly greater number of words written by the above-average children. As research has shown a link between working memory and both reading and writing skills (Gathercole, Pickering, Knight, & Stegmann, 2004; Swanson & Berninger, 1996), it is possible that when given a free-writing task, the above-average children were more confident in their writing abilities and therefore wrote more. Although there was a difference in the amount written, both above- and below-average children recalled the same number of elements on average (8 out of 22). This suggests that children with working memory difficulties were still able to convey the key aspects of the film, but did so by using fewer words than children with more advanced working memory skills.

As previously noted, the current research was intended to be a pilot study in order to examine the effects of a timeline tool on children's sequencing ability. Although only a small number of children were tested, there was no significant difference between the experimental and control condition in the number of items recalled or the sequencing ability (using both a lenient and more sensitive scoring system). Examination of the means revealed extremely small differences between the two groups; it is therefore unlikely that the lack of a significant difference is due to a power issue. In terms of further directions for this research, it is possible that younger children may achieve more benefit from the use of a timeline tool. In order for younger children to participate in the research, modifications would have to be made to the methodology due to the reliance on children's writing abilities; younger children could dictate their account verbally to an experimenter, whilst the experimenter writes down their account. Alternatively, the beneficial effects of the timeline tool may appear at a later stage in development; additional research exploring the impact of this sequencing aid across a broad range of ages would provide an answer to this question. Changes to the methodology employed, such as using an experienced episodic event instead of a film clip, or employing a longer delay between the event and the sequencing task, would also further develop this area of research.

6.5.2. Duration

The current study also aimed to examine children's ability to represent a typical day through the placement of activity cards along a timeline. Both a child and an adult sample were employed to explore whether there were age-related differences in performance. By 9 and 10 years of age, it appears that children are able to convert information about the duration of events into positions along a timeline. There was no difference between the adult and child sample in the positions that items were placed along the timeline for seven of the nine activities. This indicates similar perceptions about when the events occurred during the day; children used the timeline to place items across the full spectrum available, rather than 'bunching' the items at the beginning or in the middle of the timeline.

Children's ability to differentiate between the intervals separating events lends support to image models of sequencing (Friedman, 1983); these models postulate that information is stored about the intervals separating elements within a sequence (see section 1.4.1.). The 9 and 10 year olds in the current study were able to represent short intervals (e.g. brushing teeth to getting in the car) and long intervals (e.g. getting the car to school and having lunch). Other explanations for sequencing in children, such as semantic code models (e.g. Seymour, 1980), consider only isolated information to be stored about the different elements in a sequence. The fact that the children in the current experiment were able to make relative judgments about nine sequential events over the timespan of a day implies that additional information is stored about where elements occur in a sequence, relative to the other elements involved. This is only a tentative conclusion however, and further research into the direction of the events being sequenced (i.e. forwards or backwards) and the impact of changing reference points (e.g. starting at midday) is required before firmer conclusions can be made about the processes responsible for the witnessed performance.

The findings of this study highlight the fact that by 9 and 10 years of age, children were able to convert information about the durations of events into positions along a timeline, and placed items in similar locations to adults. As seen in Experiment 1 and other research, children are not always able to show precision in their verbal duration estimates (Friedman, Cederborg, et al., 2010; see also section 2.5.6.), However, the removal of time units in their judgments when using the timeline resulted in performance at fairly similar levels to adults. The timeline tool thus removed the requirement for children to understand the concept of seconds, minutes and hours. This suggests that when the need for these time concepts is removed, children are able to provide rough estimates that are not too dissimilar from those made by adults. This finding may have implications for legal settings. Although children may not be confident in their ability to provide an answer to the question ‘How long did [the event] last for?’ they may be capable of representing this duration information along a timeline representing a day, using markers to indicate when the event started and finished. Although this would not provide precise information for the child’s testimony, such a method may still deliver a limited insight into what occurred.

When distances along the timeline were converted into rough units of time, both adults and children seemed to show some difficulty in estimating the durations between the first four, relatively short, activities. In contrast, the converted durations of some of the longer activities were more representative of the estimated true durations. Making methodological alterations to the timeline, such as using a bigger scale (i.e. longer than 100cm) or smaller activity cards, would uncover whether this difficulty was due to the design of the timeline or a true inability to estimate smaller duration intervals. Alternatively, time markers could also be placed along the timeline to provide children with more reference points; a clock displaying 7am at one end, 12pm in the middle and 8pm at the other end may provide more structure to the timeline and therefore increase accuracy. As this was only an initial pilot study to examine the use of a timeline tool, further research is also needed to discover at what age children can understand and use such a tool to represent durations. Younger children who have not yet grasped an understanding of units of time may particularly benefit from using a visual representation of the day. Finally, making direct comparisons between the placement of items along a timeline and children’s verbal estimates of the durations between activities would highlight whether this methodology produces a superior form of duration representation, whilst complimenting more traditional forms of duration questioning.

6.5.3. Conclusion

In conclusion, although a timeline tool has previously been shown to increase both the amount of information and the ability to sequence events in an adult population, the same effects do not seem transferable to 9 and 10 year olds when using a more simplified version of the timeline tool. Working memory does not appear to play a role in the impact that a timeline tool has on children's sequencing ability; children with above- and below-average working memory skills showed similar levels of performance when using the timeline tool, suggesting that breaking the task up into recall and sequencing is not more beneficial to children with poorer working memory capacity.

The results of this experiment also showed that a timeline tool can be an effective way for children between 9 and 10 years of age to represent duration intervals between daily activities, without reliance upon units of time. Children as young as 9 years of age were able to grasp the process of translating duration information into a physical representation along a timeline. Further research into the benefits of a timeline tool for both sequencing and duration tasks would be worthwhile.

Chapter 7: General Discussion

7.1. Overview

The aim of this thesis was to investigate the development of children's temporal memory across the primary school years; several under-researched areas were identified and explored. Experiments 1 and 2 set out to examine the relationship between three key areas of temporal memory: semantic memory, episodic memory and short-term memory, and the potential link between these three distinct areas. Experiment 2 also aimed to consider the development of children's metacognitive awareness of their abilities on short-term temporal tasks, both in terms of performance judgments and their spontaneous use of strategies across the primary school years. Following on from this, the aim of Experiment 3 was to assess the impact that teaching and suppressing the use of strategies had on short-term temporal abilities. Experiment 4 attempted to examine the development of children's dating abilities after experiencing two events, separated by a relatively long delay. Finally, Experiment 5 aimed to develop a timeline tool to aid performance on both a sequencing and duration task.

This chapter will first highlight the original contributions to knowledge made by the thesis. The key findings of the five experiments will then be outlined, highlighting underlying themes and more specific results to emerge from each chapter. The main possibilities for future research will be discussed, before the implications of these findings are highlighted, both in a legal and educational setting.

7.2. Original Contributions to Research Area

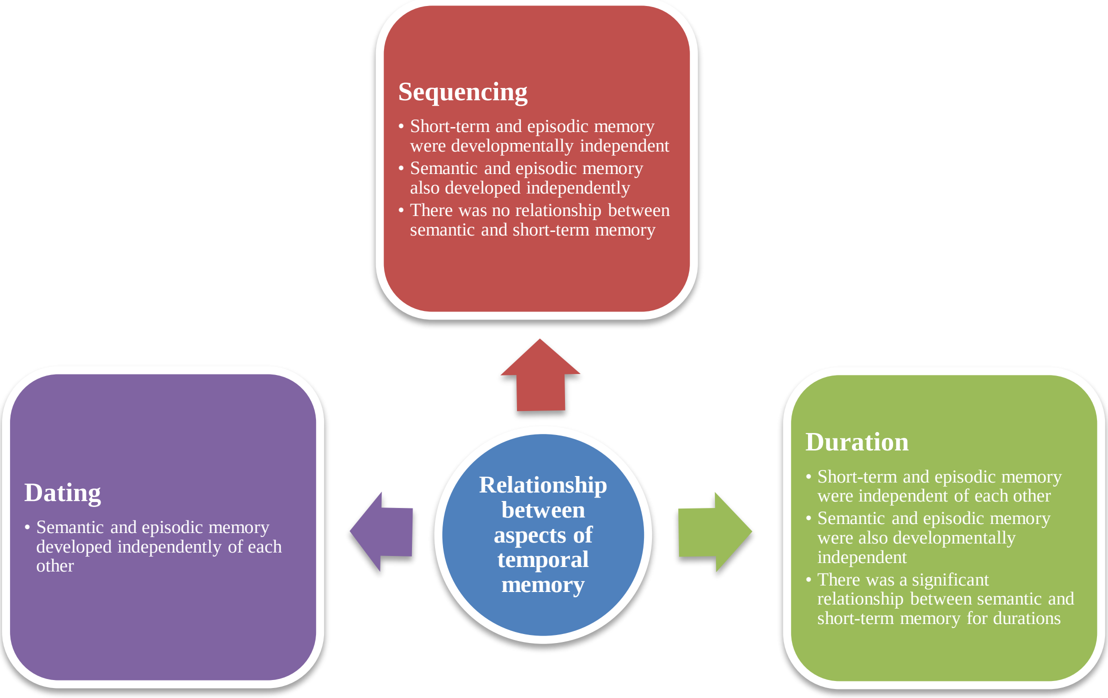
The thesis has made several novel contributions to our understanding of temporal memory in children. The original contributions made to the existing literature are outlined in the points below:

- The relationship between aspects of temporal memory: Although research has tentatively begun to explore the link between episodic and semantic memory when related to dating (Friedman, Reese, et al., 2010), Experiments 1, 2 and 4 were the first rigorous explorations of the relationship between semantic, short-term and episodic temporal memory related to sequencing, duration and dating.

- Semantic time knowledge: The time knowledge questionnaire designed by Davies and Fuery (2009) was expanded upon in Experiments 1 and 4, with a sequencing section created and additional questions devised for the remaining sections (general, duration and dating). The method used to administer the questionnaire was also standardised to allow comparisons across age groups.
- Children's metamemory perceptions: Very little research had been conducted examining metamemory for temporal tasks (Visu-Petra et al., 2008); Experiment 2 was the first study to combine an examination of changing perceptions of performance, both before and after completing a task, with difficulty estimates and descriptions of strategy use. This produced a comprehensive overview of children's short-term temporal metamemory.
- Short-term duration strategies: Whereas the importance of rhythm when monitoring durations has been highlighted previously (Levin & Wilkening, 1989), Experiment 3 appears to be the first known study to investigate the impact of teaching children a rhythmic counting strategy in order to increase reproduction accuracy.
- Impact of delay on dating: Experiment 4 expanded upon the field of dating staged events by extending the delay between the event and testing period; whereas previous research has examined delays of up to 3 months (Friedman & Lyon, 2005), this experiment employed a delay of 7 months between children experiencing the event and having to make dating judgments.
- Timeline tools for sequencing: Previous research has examined the use of a timeline tool with an adult sample to see if it proves beneficial for sequencing performance (Hope et al., 2013). Experiment 5 extended the tool for use with children by simplifying the methodology used.
- Representing durations using a timeline tool: Whereas Friedman (1990) examined children's ability to judge the durations between daily activities on a pair-by-pair basis (i.e. one pair at a time), Experiment 5 extended this methodology to investigate how well children could use a timeline tool to represent the durations between several events over the course of a day.

7.3. Summary of Key Findings

The findings of the five experiments can be separated into two broad themes. Firstly, a large focus of the thesis was on exploring the relationships between short-term, semantic and episodic temporal memory; the findings of three of the experiments conducted showed relative independence between these three areas (Figure 7.1).



Sequencing

- Short-term and episodic memory were developmentally independent
- Semantic and episodic memory also developed independently
- There was no relationship between semantic and short-term memory

Dating

- Semantic and episodic memory developed independently of each other

Duration

- Short-term and episodic memory were independent of each other
- Semantic and episodic memory were also developmentally independent
- There was a significant relationship between semantic and short-term memory for durations

Figure 7.1: Schematic representation: Relationship between aspects of temporal memory

Secondly, several of the experiments explored the impact that different methodologies had upon children's temporal abilities. Strategy use was found to increase performance, whilst timeline tools were found to aid children's representations of episodic durations; this suggests that methodological alterations can impact upon temporal abilities (Figure 7.2).

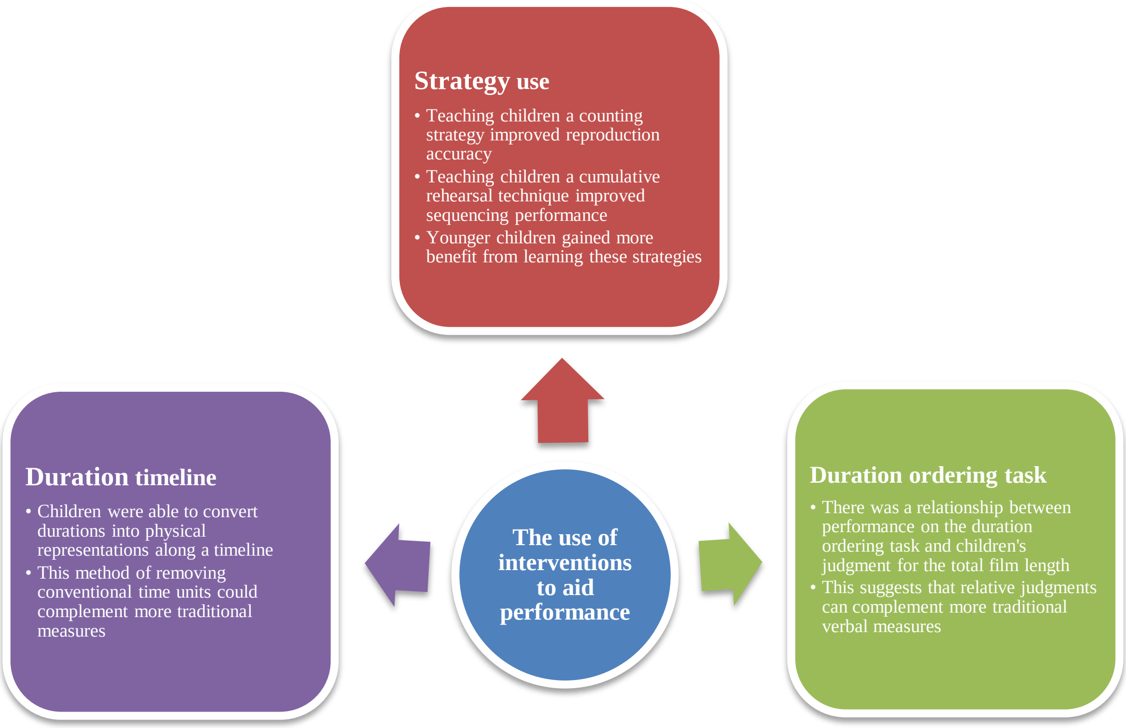


Figure 7.2 Schematic representation: Impact of temporal interventions

The key findings of each experiment in the thesis will now be discussed in more detail.

7.3.1. Experiment 1: Episodic and Semantic Temporal Memory

Experiment 1 aimed to examine the developmental trajectory of temporal memory for novel events and semantic memory for temporal concepts. The study also aimed to explore whether there was a relationship between these two forms of temporal memory. Children were shown to display an increase in semantic temporal memory with age; performance on a novel time questionnaire revealed increases in knowledge from 6 to 11 years. In contrast, children of all ages were found to perform similarly when completing relative judgment tasks about the order elements occurred within an event (sequencing), and the amount of time each element lasted for (duration). Despite the lack of performance increases for these relative tasks, older children displayed a performance advantage when making verbal estimates about durations; this indicated development in the use of time units. Unlike previous suggestions in the literature about the potential links between semantic and episodic temporal memory, performance was not found to be related between time knowledge and temporal judgments about an experienced event. This suggests that these two areas of temporal memory are developmentally independent.

7.3.2. Experiment 2: Short-Term Temporal Memory and Metamemory

Experiment 2 explored the developmental trajectory of children’s short-term temporal memory, and its relationship to children’s performance on both episodic and semantic temporal tasks. Metamemory perceptions of performance on such tasks were also recorded, whilst an adult sample allowed further examination of the development of short-term sequencing and duration abilities. Both sequencing and duration performance was found to increase with age across the primary school years and into adulthood; older participants were more accurate when recalling a sequence of shapes and reproducing short durations. There was a correlation between participants’ performance on these two tasks, suggesting similar underlying constructs. In contrast, short-term temporal memory was found to be independent of performance on the episodic tasks from Experiment 1; this indicates that children’s short-term temporal judgments did not impact upon their ability to recall episodic temporal information. Children’s reproduction accuracy on the duration task was related to their knowledge about general and duration time concepts, indicating that an understanding of this temporal information was beneficial when monitoring and reproducing durations.

In terms of metamemory development, there were no age differences in the perception of performance, either before or after completing the task; this suggests that although the youngest children were not performing as well as the older children or adults, they did not perceive their performance to be any worse. Perceptions of performance did not tend to alter substantially from pre- to post-performance on either of the two tasks. Although difficulty ratings increased with age for the sequencing task, the duration task showed similar ratings across all age groups. Finally, younger children were less likely to spontaneously employ a strategy to aid their performance on the two tasks; this is particularly suggestive of a production deficit in the 6 and 7 year olds.

7.3.3. Experiment 3: Impact of Strategies and Suppression

Following on from the strategy findings of Experiment 2, Experiment 3 looked at the effects of teaching children strategies to aid their performance on the two short-term temporal tasks. Half of the children were taught a cumulative rehearsal technique for the sequencing task and a counting strategy for the duration task. Conversely, the impact of an articulatory suppression technique was also examined in the remaining half of the children to see whether performance would be inhibited by a lack of strategy use. Children first completed the two tasks without any form of strategy instruction, in order to produce a baseline measure of performance; these results mirrored those found in Experiment 2. Children who were taught strategies displayed a performance advantage at time 2 compared to time 1 for both tasks; these strategies led to better sequencing and more accurate duration reproductions. In contrast, children who were prevented from using a strategy saw their performance decrease from time 1 to time 2; repeating a syllable prevented children from rehearsing the names of the colours or counting along with the duration.

Age effects were reduced in both the strategy and suppression conditions; providing children of all ages with the same strategy, or removing strategy use, reduced the difference in performance between the youngest children and the oldest children. However, the fact that these age effects persisted, despite similarities in the strategies used, implies that other factors (e.g. greater time knowledge or articulatory speed) may impact upon short-term temporal memory performance.

7.3.4. Experiment 4: Children’s Dating Abilities

As the same sample of children completed both Experiments 1 and 2, Experiment 4 examined the ability of these children to date the short-term and episodic tasks following a delay. The two events were separated by 3 months, whilst the delay between experiencing the first event and the testing session was 7 months. Children’s ability to answer semantic dating questions was also explored to see if their dating knowledge was related to their task performance. The results showed no age increases in children’s distance-based dating (i.e. relative recency judgments), with similar levels of performance across the three school years. In contrast, the ability to make location-based judgments (i.e. dating events on several timescales) showed performance increases with age; older children were more capable of dating events according to the day of the week, month of the year and season that they occurred. Children showed a greater accuracy when dating the more recent of the two events, highlighting the impact of a delay on temporal memory. Finally, although semantic dating memory was found to increase with age, there was no correlation between performance on the dating questionnaire and children's ability to date two events; this suggests that semantic and episodic dating memory are relatively independent of each other.

7.3.5. Experiment 5: The Effectiveness of a Timeline Tool

Experiment 5 explored the impact of using a timeline tool on children's ability to sequence events and make duration estimates. Children who were assigned to the timeline condition produced event cards that were later sequenced from start to finish. These children achieved no benefit from the timeline tool compared to a control condition who wrote their account from start to finish; both groups recalled the same amount of information and displayed similar levels of sequencing accuracy. These findings were in contrast to a similar methodology (albeit involving additional components) used with an adult sample. In addition, working memory was not found to impact upon children's temporal performance; children with below-average working memory capacity were no less accurate in their sequencing abilities than those with above-average capacity.

When employing the timeline tool to make duration estimates about when daily activities occur, children were found to be able to convert their mental representations of time onto a physical representation. Performance between adults and children was similar, suggesting that when time units are not required, 9 and 10 year olds can represent durations to a similar level of accuracy as adults.

7.4. Further Considerations and Future Directions

Throughout each chapter, potential areas for further research have been suggested in order to make the findings more robust or to allow the exploration of additional research avenues. This section will examine the main themes underlying these suggested further areas of research. These suggestions are based both on methodological limitations of the current research, as well as the results obtained.

7.4.1. Generalising Findings to Different Settings

The current studies aimed to employ tight control over extraneous variables; this ensured that all children experienced the same events, which were carefully controlled by the experimenter. However, this may have reduced the opportunity to generalise the findings from a controlled classroom setting to more naturalistic settings; children's performance in a relatively stress-free classroom environment may not be representative of their temporal abilities in more emotionally-charged circumstances. Although it would be unethical to induce stressful situations when testing children's temporal memory, extending the methodology employed in the current studies to activities experienced outside of the classroom may result in greater confidence when drawing conclusions about children's temporal abilities in more naturalistic settings.

The level of involvement in the activities witnessed may also impact upon children's performance. In Experiment 1, children watched a film showing a researcher making space items. Similarly, in Experiment 5, children witnessed two children discovering what occurred at a veterinarian's surgery. This methodology was again chosen so that children had identical experiences of the events in question. However, in both of these experiments, children were not active participants in what was occurring. It may therefore be difficult to extend these findings to situations in which children are actively involved in the events in question. Research has shown that direct experience of an event, rather than mere observation, leads to more complete, accurate and organised accounts when recalling information (Baker-Ward, Hess, & Flannagan, 1990; Murachver, Pipe, Gordon, Owens, & Fivush, 1996). Additional research, in which children either make craft items or personally experience an outing, may be fruitful to ensure that the current findings can be generalised to more naturalistic settings. Although such methodological changes would reduce the tight levels of control seen in the current experiment, the findings from both approaches may complement each other, thus increasing the applicability of the findings to a broader range of settings.

7.4.2. The Effect of Delay upon Performance

The impact of a delay on children's temporal memory performance is an additional area for research in several of the studies conducted. In Experiment 1, children completed the temporal tasks after a delay of approximately 4 hours. Based upon the impact that a delay can have on temporal memory (as seen in Experiment 4), it would be interesting to see how well children were able to complete the episodic sequencing and duration tasks after a more substantial delay; this may lead to the emergence of age effects between the three school years.

Experiment 4 focused on the impact that a large delay would have upon children's dating of two staged events. Although it was found that children were more accurate when dating the more recent of the two events, the fact that the study was designed retrospectively meant that the impact of delay was not manipulated systematically. Employing several conditions, with varying delays between the event occurring and testing, would allow firmer conclusions to be drawn about the impact of time upon dating abilities.

Finally, Experiment 5 utilised a delay of only 10 minutes between witnessing the event and employing the timeline tool to sequence the different elements. Extending the period between witnessing the event and making temporal judgments may increase the effectiveness of the timeline tool; it may be that when children are unable to remember sequences as clearly, the task of using event cards to move the different elements around may be more beneficial than a free-recall writing task. However, as children recalled an average of only eight out of the 22 elements in the film after 10 minutes, increasing the delay further may result in insufficient information recalled to allow sequencing to occur. Nevertheless, these additional explorations of the impact of a delay on temporal memory performance across the primary school years would strengthen the conclusions drawn.

7.4.3. Widening the Age Range Examined

The current research examined the development of temporal memory across the primary school years; the age groups tested ranged from 6 to 11 years. However, the results obtained from of some of the experiments conducted would be further advanced by studying additional age groups. As seen in Experiment 1, even by 11 years of age, all children were still not answering all of the questions on the semantic temporal questionnaire correctly; performance was still particularly poor on the duration section in even the oldest year group. Extending the age range employed to include secondary school pupils would produce a clearer picture of when exactly children can reliably make accurate duration judgments. As highlighted in the introduction (see Chapter 1), research into temporal memory in secondary school pupils (i.e. 12 years and older) is less common. Uncovering the development of temporal memory past the more researched age ranges would therefore be insightful.

An additional area of research in the thesis that would benefit from extending the age range studied is Experiment 5. This was intended only as a pilot study in order to see whether the concept of using a timeline tool for sequencing could be extended from adults to children. As noted in the chapter discussion, the current study examined a limited age range of 9 to 10 years; the benefits of the timeline tool may only emerge when this age range is extended to capture both younger and older children. Similarly, the use of the timeline for duration judgments may prove to be even more beneficial when employed with an age range that struggles to use conventional units of time with any accuracy; the 6 and 7 year olds who lacked detailed temporal knowledge in Experiment 1 may have benefitted in particular. Extending Experiment 5 to a wider age range would potentially shed further light upon the effectiveness of such an intervention aid.

An alternative way to examine the development of temporal memory over a range of ages is through the use of a longitudinal design. The current cross-sectional design used in this thesis provides only a snapshot of children’s temporal memory, and comparisons between different groups of children have to be made in order to infer any developmental differences. Tracking the development of children’s temporal memory periodically at regular intervals would result in more robust evidence about temporal memory development across the primary school years. Although such longitudinal research would be more methodologically challenging and time consuming to conduct, the field of temporal memory would benefit from this more detailed insight.

7.5. Research Implications

The results of the experiments carried out in this thesis have helped to shed more light upon a relatively under-researched area of memory development. These findings may have implications outside of the laboratory, in both legal and educational settings.

7.5.1. Legal Settings

Primarily, the lack of a relationship between semantic, short-term and episodic temporal memory highlights the fact that it is difficult to predict child witnesses' accuracy when making temporal judgments, based upon their performance on other temporal tasks. Unlike the recommendations made by Davies and Fuery (2009), the results arising from this thesis imply that it would not be wise for legal practitioners to take into account children's time knowledge in order to predict the accuracy of their temporal memory for experienced episodic events. Similarly, it does not appear that predictions about episodic temporal accuracy can be made following the completion of simple computer tasks designed to assess short-term temporal memory. As noted by Friedman and Lyon (2005), legal practitioners display a tendency to gauge children's temporal understanding, using this information to decide whether children are able to make temporal judgments. The current findings of no clear relationship between time knowledge and episodic memory related to sequencing, duration or dating strongly suggests that relying on such understanding would be unwise.

Experiment 4 revealed the impact that a delay can have upon children's ability to date events. Unlike previous staged research which employed lesser delays between the experienced events and testing, the current research extended this delay to 7 months. The poorer levels of performance seen in comparison to those found by studies with a smaller delay (e.g. Friedman & Lyon, 2005), as well as the superior dating performance for the more recent of the two events, suggests a weakening of children's temporal dating memory following large delays. Studies have shown that the time between children experiencing an event and the case going to trial varies between 5 and 7 months (Flin et al., 1990; Flin et al., 1988); the current results stress the importance of asking children to date an event at the earliest possible opportunity, before this temporal information decays and accuracy is reduced.

Finally, the findings of Experiment 5 highlight the additional benefits that could be gained from employing a timeline tool to aid duration judgments, alongside more traditional verbal questioning. Children's verbal estimates have been shown to be less accurate than those made by adults (Friedman, Cederborg, et al., 2010). However, the current study found that when using a timeline tool to transfer mental durations into physical representations, there was very little difference between adults and children in their placements of when the activities occurred. Removing the need for conventional time units by employing a timeline to gauge children's duration perceptions could provide additional insights into the duration of events, whilst also complementing the verbal responses obtained during questioning.

7.5.2. Educational Settings

It is possible that some of the methodologies and findings from this thesis could be beneficial to the education sector. The semantic temporal memory questionnaire designed in Experiments 1 and 4 could potentially provide teachers with a simple way to establish children's semantic temporal understanding; analysis of the results revealed that the questions asked were able to differentiate between the highest and lowest performing children. Administering the questionnaire at the beginning of each school year would provide an insight into the areas of temporal memory which children have fully grasped, and those areas where they may need additional work. As outlined in Chapter 2, the National Curriculum sets out when children should learn about temporal concepts; in Year 1 this includes the days of the week and months of the year, in Year 2 this involves learning about the number of seconds in a minute and the number of minutes in an hour, and in Year 3 this includes learning how to compare the durations of daily events (Department for Education, 2013). There is no additional temporal teaching outlined in the National Curriculum from ages 8 and 9 onwards. Children who struggled to grasp such concepts at the time of teaching could therefore be identified in later school years and additional teaching could be provided.

The results of the strategy research in Experiment 3 further highlight the importance of strategic teaching in classrooms. The current study discovered that alongside the performance increases achieved when using sequencing strategies (e.g. cumulative rehearsal), benefits can also be gained from employing strategies related to duration. The simple counting technique taught, which children of all ages grasped after only a couple of minutes' training, could be taught as part of the National Curriculum to aid children's time monitoring skills. Previous research has shown that strategic teachers produce more strategic learners, who then independently employ strategies to aid their learning and performance (Moely et al., 1992; Ornstein et al., 2005). This novel finding suggests that children as young as 6 and 7 years of age can be taught a way to effectively monitor the passing of time.

7.6. Conclusion

This thesis examined the under-researched area of temporal memory across the primary school years. Together, the findings of these studies offer an insight into the developmental differences between age groups, the relationship between the different aspects of temporal memory, and the impact of using tools or techniques to aid performance. It appears that the development of short-term, semantic and episodic temporal memory is relatively independent; there are very few links between these areas for either sequencing, duration or dating. Whilst younger children are less likely to spontaneously employ strategies to aid their temporal abilities on short-term tasks, simple strategy teaching can lead to performance improvements. The importance of delay on children's ability to accurately date when an event occurred was also highlighted. Finally, although a timeline tool was not proven to be effective for sequencing, children can successfully use such a visual representation to express their duration understanding. There remain several potential areas of development, both in terms of the populations studied and the methodology employed in doing so. Although this thesis is the first step towards understanding temporal memory across the primary school years, it is only through additional research that a greater understanding of the development of children's memory for time can be achieved.

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Appendix A: Ethics Certificate

Certificate of ethical approval
#11-0266

Title: Children's temporal memory development

Supervisor: Amanda Waterman

Date of approval: 15 December 2011

This certificate confirms that the named project has received approval from the ethics committee. This certificate can be used in student projects. The name of the student will not be listed, but can be requested from the ethics committee.

Ethics committee of the Institute of Psychological Sciences, Leeds University

Appendix B: Initial School Contact Letter

LAM Lab (*Language and Memory Lab*)

Institute of Psychological Sciences

University of Leeds

Leeds LS2 9JT

Tel: (General Enquiries) (0113) 343 5724

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UNIVERSITY OF LEEDS

Dear __________,

My name is Zoe Marshall and I am a PhD student at the University of Leeds in the Institute of Psychological Sciences. I am part of LAM Lab, a group of leading researchers in language and memory development. My PhD is supervised by Dr Amanda Waterman and Professor Mark Mon-Williams, both of whom have extensive experience of working alongside schools to improve our understanding of how children's cognitive development relates to the educational context.

I am writing to you because we are recruiting local schools who would be interested in working in partnership with us on future research projects. Currently I am interested in how children develop an understanding of temporal information, for example, the concepts of dating, sequencing and duration, as well as time-telling. Typically, this research involves coming into school over several days, arranged at the school's convenience, and administering test with children on an individual basis. I have an Enhanced CRB check, and our research adheres to the strict ethical guidelines of the British Psychological Society, including anonymity of the children's responses.

To say thank you for taking part we provide schools with book tokens, as well as a report on our research findings. In addition, we are very happy to come back into the school to talk to the children about our research and our work as experimental scientists, with the aim of helping children to see how science works in the outside world.

If you are potentially interested in working in partnership with us, then please do email me. I will be very happy to come into school to meet with you to discuss this further, or to answer any queries via email or telephone.

Yours sincerely,

Z. Marshall

Zoe Marshall

Email:z.marshall10@leeds.ac.uk

Appendix C: Parental Consent (Exp. 1-4)

LAM Lab (*Language and Memory Lab*)

Institute of Psychological Sciences

University of Leeds

Leeds LS2 9JT

Tel: (General Enquiries) (0113) 343 5724

Fax: (0113) 343 5749

UNIVERSITY OF LEEDS

Dear Parent/ Carer,

My name is Zoe Marshall and I am a PhD student at the University of Leeds. I am investigating children's developing knowledge about time. I have been given permission by [head teacher] to come into the school and carry out some research in your child's class. I will be working with children on an individual basis in a quiet area of the school. Your child will answer some questions about time, watch a film about making space items, and complete a short computer task which requires them to remember the order of some shapes. Children are always told that it is OK if they don't know an answer, are given lots of encouragement and positive feedback, and receive a small sticker at the end of the session to say thank you.

The project is supervised by Dr Amanda Waterman, at the Institute of Psychological Sciences, who specialises in children's cognitive development. Dr Waterman has worked with many primary schools in the North of England. I have an enhanced CRB check and all the research will be carried out in accordance with the strict ethical guidelines as laid out by the British Psychological Society. These include keeping your child's data and their results anonymous and confidential, and giving each child the opportunity not to take part if they do not wish to be involved.

If you have any questions about the research, please feel free to contact me at z.marshall10@leeds.ac.uk, as I will be more than happy to answer your queries. If you would prefer your child NOT to participate in the experiment, please complete the form below and return it to your child's class teacher.

Kind regards,

Z. Marshall

Zoe Marshall

I do NOT want my child to take part in the Leeds University memory research.

Name of child: ____

Appendix D: Parental Consent (Exp. 5)

LAM Lab (*Language and Memory Lab*)

Institute of Psychological Sciences

University of Leeds

Leeds LS2 9JT

Tel: (General Enquiries) (0113) 343 5724

Fax: (0113) 343 5749

UNIVERSITY OF LEEDS

Dear Parent/ Carer,

My name is Zoe Marshall and I am a PhD student at the University of Leeds. I am investigating children's developing knowledge about time. I have been given permission by [head teacher] to come into the school and carry out some research in your child's class. I will be working with children on an individual basis in a quiet area of the school. Your child will be shown a short video about caring for animals and then write about what they have seen. They will also listen to a short story and put some pictures in the correct order. Children are always told that it is OK if they cannot conduct the task, are given lots of encouragement and positive feedback, and given a small sticker at the end of the session to say thank you.

The project is supervised by Dr Amanda Waterman, at the Institute of Psychological Sciences, who specialises in children's cognitive development. Dr Waterman has worked with many primary schools in the North of England. I have an enhanced CRB check and all the research will be carried out in accordance with the strict ethical guidelines as laid out by the British Psychological Society. These include keeping your child's data and their results anonymous and confidential, and giving each child the opportunity not to take part if they do not wish to be involved.

If you have any questions about the research, please feel free to contact me at z.marshall10@leeds.ac.uk, as I will be more than happy to answer your queries. Alternatively you can contact my supervisor Dr Amanda Waterman at a.h.waterman@leeds.ac.uk. If you would prefer your child NOT to participate in the experiment, please complete the form below and return it to your child's class teacher.

Kind regards,

Z. Marshall

Zoe Marshall

I do NOT want my child to take part in the Leeds University memory research.

Name of child: ____

Appendix E: Pilot Temporal Memory Questionnaire and Scoring (Exp. 1)

Question Category	Question	Scoring (Correct Answers)	Remain in Questionnaire?
General	1) How many months are there in a year?	12	Yes
	2) How many days are there in a week?	7	Yes
	3) How many hours are there in a day?	24	Yes
	4) How many minutes are there in an hour?	60	Yes
	5) Thomas is eating his tea. What time is it likely to be?	4pm – 7pm	No
	6) Jessica is eating her breakfast. What time is it likely to be?	6am – 9am	No
	7) What time is shown on this clock? [3:00]	3:00	Yes
	8) What time is shown on this clock? [7:20]	7:20	Yes
Duration	9) How long does your dinner break last, including eating and playtime?	1 hour - 1 hour 15 minutes	Yes
	10) How many hours are you at school for in a day?	6-7 hours	Yes

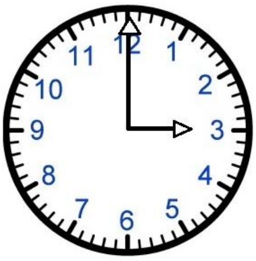
Question Category	**Question**	**Scoring (Correct Answers)**	**Remain in Questionnaire?**
	11) How long does morning break last for?	15 minutes	Yes
	12) How long do your summer holidays last?	6 weeks	Yes
	13) Alex and Sam go fishing. They leave at 1 o’ clock in the afternoon and they get home at 5 o’ clock in the afternoon. How long were they gone for?	4 hours	Yes
	14) It started snowing at 11 o’ clock in the morning and stopped 3 hours later. What time did it stop snowing?	2:00	Yes
	15) How long does it take to brush your teeth?	1-3 minutes	No
	16) How long does it take for the register to be taken?	1-3 minutes	No
Sequencing	17) Which of these three events will happen next? ○ Christmas ○ Halloween ○ Valentine’s Day	[Dependent on time of testing, but only one correct answer]	Yes
	18) What month comes before May?	April	Yes
	19) What month comes after August?	September	Yes
	20) What season comes before spring?	Winter	No
	21) What season comes after summer?	Autumn	No
	22) What day comes before Friday?	Thursday	Yes

Question Category	Question	Scoring (Correct Answers)	Remain in Questionnaire?
	23) What day comes after Tuesday?	Wednesday	Yes
	24) What year came before 2002?	2001	Yes
	25) What year came after 2006?	2007	Yes
	26) Number these daily events in the order that they happen from 1 (first) to 5 (last): ○ Morning break ○ Eating tea ○ Going to bed ○ Lunchtime ○ Getting dressed	Correct sequence: Getting dressed, morning break, lunchtime, eating tea, going to bed	No

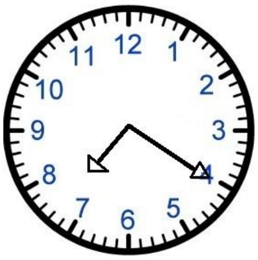
Appendix F: Temporal Memory Questionnaire (Exp. 1)

General Time Questions

1) How many months are there in a year?
2) How many days are there in a week?
3) How many hours are there in a day?
4) How many minutes are there in an hour?
5) What time is shown on this clock?



6) What time is shown on this clock?



Duration Questions

7) How long does your dinner break last, including eating and playtime?
8) How many hours are you at school for in a day?
9) How long does morning break last for?
10) How long do your summer holidays last?
11) Alex and Sam go fishing. They leave at 1 o' clock in the afternoon and they get home at 5 o' clock in the afternoon. How long were they gone for?

12) It started snowing at 11 o’ clock in the morning and stopped 3 hours later. What time did it stop snowing?

Sequencing Questions

13) Which of these three events will happen next?

    Christmas

    Halloween

    Valentine’s Day

14) What month comes before May?
15) What month comes after August?
16) What day comes before Friday?
17) What day comes after Tuesday?
18) What year came before 2002?
19) What year came after 2006?

Appendix G: Script and Items from the Episodic Film (Exp. 1)

Hello boys and girls. Today I’m going to show you how to make a space scene. We’re going to make lots of different things to put in our scene that you might find if you went exploring in space.

First, we’re going to make our **moon box**. We need a big cardboard box with all the flaps cut off [*point at the cut off edges*]. I’m going to stick some black paper to the three sides to make them look like outer space [*stick black paper to the three sides*]. We’re now going to make some space hills. I’m going to screw up some tissue and stick it to the bottom of the box [*stick tissue in two places using sellotape*]. The bottom now has to be covered in tin foil to look like the surface of the moon [*smooth foil along the bottom and over the hills, tuck under edge*]. Our space box is now done; this can be put to one side for later [*move out of view*].

Now we’re going to make a **moon buggy** for travelling across the moon in. We need the top of an egg carton, which we’re going to cover in tin foil to make it shiny [*cover egg carton in tin foil*]. Now we need to add wheels to our buggy; I’ve got four cardboard circles here. I’m going to attach the wheels using these special pins, called ‘split pins’ [*push through the cardboard wheel and egg carton, and fold legs down*]. That’s our moon buggy complete [*place out of view*].

We’re going to make an **alien** to go in our scene now. We need one of these pom-poms for our alien’s body. Let’s stick some of these eyes on to the body [*stick two eyes on to the body*]. We now need to stick his body on to his legs so that he can walk [*stick body on legs*]. Finally, we need to give him an antenna on the top of his head [*stick on to head*]. The alien is finished [*place out of view*].

Next, we’re going to make a **spaceman** to do some exploring around our planet. We have some body parts here which we can colour in. I’m going to give our spaceman some brown hair [*colour*] and an orange face. I’ll make his helmet green and his suit red [*colour*]. He’s going to have a purple belt, so I’ll make this long strip purple [*colour*]. His hands will be orange, his suit will be red and his arm bands will be purple [*colour* *both arms*]. Finally, his boots are going to be black with a red bottom and purple leg bands [*colour both legs*]. His belt must now be stuck on to his body in the middle, all the way around [*stick belt on to red toilet roll*]. Now we need to attach his head at the top, his arms at the sides and his legs at the bottom [*stick all the body parts on*]. Our spaceman is ready [*move out of view*].

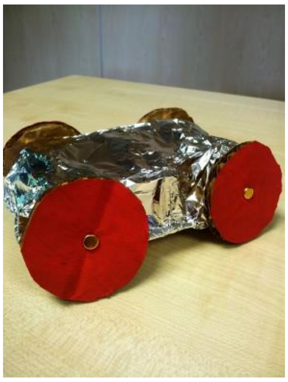
To make a **planet** to hang from our box, we need to blow up a balloon. We're not going to blow the balloon up all the way though as we want it to fit in our space box [*blow up balloon almost full*]. We now need to attach some string to our planet so we can hang it [*tie a piece of string to the balloon*]. That's our planet done, ready to be explored [*move out of view*].

We need a **rocket** to go exploring in. This toilet roll is the base of our rocket. We now need to create the cone. Take a big red circle and cut into it half way like this [*cut circle*]. Now fold it to make a cone, and stick the side down like so [*stick down on the inside*]. Now we need to stick the cone on to the rocket's body [*put sellotape on the inside of the tube so it comes out of the top, then stick it to the cone*]. Finally, we need some windows in our rocket. Let's stick two smaller red circles on to the body, like this [*glue the circles to the rocket body*]. Our rocket is now finished [*move out of view*].

Everything is now complete for our space box. Once you put everything together, this is what we end up with [*move already completed space box into view*]. You're now ready to do some space exploring. Safe travels!

Planet

Alien



Space Buggy

Rocket

Space Scene

Spaceman

Appendix H: Task Instructions (Exp. 1)

So this morning you watched a video about making different things you'd find in space. I want you to tell me all the different things that you can remember. Can you remember anything else? Can you remember any more?

I've got some pictures here that show the six things the lady made. So we've got.... [show the shuffled cards and identify them; for items the child forgot, check that they remember the item].

[Counterbalance task order] Some of the things the lady made in the video took a short time to make, and others took a longer time to make. I'm going to shuffle these pictures and I want you to put them on the table in front of you in the order of the amount of time that they took the lady to make. So at this end we'll have the one that was the quickest to make, then you have to put them in order all the way to the one that took the longest for her to make. We've got these pieces of paper here to remind you which end is the shortest and which is the longest. Does that make sense?

I'm going to shuffle the pictures again now and we're going to do another task with them. I want you to put the pictures in the order that they were made on the video. So the first thing the lady made would go at this end of the table, then the second thing she made, then the third thing she made, all the way to the last thing that she made, which will go here. Do you think you can do that?

You're doing really well so far. Now I have four questions I want you to try and answer about the video [counterbalanced order]:

How long did it take the lady to make the planet?

How long did it take the lady to make the rocket?

How long did it take the lady to make the spaceman?

And how long did the video last in total, so how long did it take the lady to make all six of the space items?

Appendix I: Task Instructions (Exp. 2)

Sequencing

We’re going to do a task on the computer now; some shapes are going to appear on the screen and you have to try and remember what order they are shown to you. I’ll show you an example and then you can have a try for yourself.

So we have to touch the screen where it says ‘Start’. The shapes will come up like this, one at a time and you have to remember the order. We now have this screen showing us all the shapes that we saw. We have to click on them in the order we saw them. So this one happened first; I’ll touch it on the screen and it turns black, do you see? This one happened second, so I’ll do the same. And finally this one happened last. When we’ve picked all the shapes, we have to press this red button here that says ‘End’ so we can move on to the next go. You have a practice now.

You had to remember three shapes there; for the proper task, you’re going to have to remember six shapes in a row. I want to know how well you think you will do on this task. On a scale from 0-10, with 0 being very bad and 10 being very good, how well do you think you will do on the task [show scale]? Now we’re ready to start; keep going until you see a ‘well done’ image.

Now you’ve done the task lots of time, I want to see how well you think you’ve done. On a scale from 0-10, with 0 being very bad and 10 being very good, how well do you think you did on the task [show scale]? And on a scale from 0 to 10, with 0 being very easy and 10 being very hard, how hard was the task [show scale]? And lastly, how did you remember the order the shapes were shown?

Duration

We’re going to do a different task now. We’re going to see a shape come on the screen for a while and then it will disappear. We have to watch how long it is on for. We’ll then see another screen with a start and a stop button, and we have to try to show how long the shape was on the screen for.

Let me show you; we press the start button like the last task to show we’re ready. Now we have to press the ‘Start’ button. Let’s watch the shape while it is on the screen. Now it’s disappeared, we have to press this green button here and then wait for the same amount of time we saw the shape for. I think it was on the screen for this long, so I’m going to press the red button now. You have a go now.

There are going to be short ones, medium ones and long ones; you just have to press the green button, wait for the same amount of time and then press the red button. I want to know how well you think you will do on this task. On a scale from 0-10, with 0 being very bad and 10 being very good, how well do you think you will do on the task [show scale]? Now we’re ready to start; keep going until you see a ‘well done’ image.

Now you’ve done the task lots of time, I want to see how well you think you’ve done. On a scale from 0-10, with 0 being very bad and 10 being very good, how well do you think you did on the task [show scale]? And on a scale from 0 to 10, with 0 being very easy and 10 being very hard, how hard was the task [show scale]? And lastly, how did you know how long to wait for?

Appendix J: Task Instructions (Exp. 3)

[Instructions for time 1 the same as Appendix I]

Sequencing Time 2

First we are going to do the circles task, where you have to remember the colours in the right order.

Strategy: When you see each circle I want you to say the colour of that circle out loud; so if you saw a blue circle you'd say 'blue'. Then when you see the next circle, I want you to add it to the colour you just said. So if you saw a red circle next, you'd say 'blue, red'. I want you to keep doing this for all six circles. You're going to have to say them quite quickly near the end as there'll be less time to fit it all in. Keep saying the colours of the circles out loud until you have to click on the circles in the right order. We'll do a practice so you can see me do it, then you can have a go. Now let's see how well you can do.

Suppression: When you see each circle I want you to say 'la la la' out loud, and keep saying it out loud while you see all the circles. Say it quite quickly, but not so you get your words muddled up. It should be at this speed [demonstrate]. Keep saying until you've seen all the circles. We'll do a practice so you can see me do it, then you can have a go. Now let's see how well you can do.

Duration Time 2

Now we are going to do the time task, where you have to wait for the same amount of time that you saw the picture for.

Strategy: I want you to count along from the second the picture comes up to when it disappears. You might have counted last time, but this time I want you to count by saying the word 'elephant' after you say the number. So you'd go '1 elephant, 2 elephant, 3 elephant'. Try not to leave a gap between saying them, but don't say them so quickly you get muddled up. You can stop counting when the picture disappears. Then I want you to press the start button and do the same thing again – so count in elephants until you get up to the same number as before, and press stop. We'll do a practice so you can see me do it, then you can have a go. Now let's see how well you can do.

Suppression: For the time task, where you have to wait for the same amount of time that you saw the picture for, I want you to say ‘la la la’ over and over again from when the picture comes up to when it disappears. Say it quite quickly, but not so you get your words muddled up. It should be at this speed [demonstrate].Keep saying it until the picture disappears. You’ll then have to press the start button, wait for the same amount of time you saw the picture for, and press stop. We’ll do a practice so you can see me do it, then you can have a go. Now let’s see how well you can do.

Appendix K: Pilot Dating Questionnaire and Scoring (Exp. 4)

Question	**Scoring (Correct Answers)**	**Remain in Questionnaire?**
1) What month is your birthday in?	[Check class register]	No – Replaced with 'What month did you start your new class?' [September]
2) What date is Halloween?	31st October	No – Replaced with 'What date is Christmas?' [25th December]
3) What month is Bonfire Night in?	November	Yes
4) What season is Christmas in?	Winter	No
5) How many months ago was May?	[Dependent on month in question, only one correct answer]	Yes
6) How many months is it until August?	[Dependent on month in question, only one correct answer]	Yes
7) How many days is it until Saturday?	[Dependent on day in question, only one correct answer]	Yes
8) How many days ago was Sunday?	[Dependent on day in question – only one correct answer]	Yes

Appendix L: Dating Questionnaire (Exp. 4)

Dating Questions

1) What month did you start your new class?
2) What date is Christmas?
3) What month is Bonfire Night in?
4) How many months ago was April?
5) How many months is it until December?
6) How many days is it until Saturday?
7) How many days ago was Sunday?

Appendix M: Task Instructions (Exp. 4)

Do you remember when you came to see me and did some different things on the computer? What did you have to do?

Do you remember when you came to see me and you watched a film? What was the film about?

One of the two things you did with me was quite a long time ago, and one was not as long ago. Which one did you do first?

How long was there between the two different events happening?

Episodic Task

I'm going to ask you some questions about when you watched the film about space. What day of the week was it?

What month was it?

What season was it?

Short-Term Task

Now I'm going to ask you some questions about when you did the computer tasks. What day of the week was it?

What month was it?

What season was it?

Appendix N: Timeline Instructions for Sequencing Task (Exp. 5)

I've got a DVD here which is about children visiting different people who help us. I'm going to show you the DVD and I want you to watch it carefully as we're going to do an activity afterwards.

Experimental Condition

I've got some cards here that I'm going to give to you. I want you to write down as much as you can remember about what you saw on the video for me. I want you to make a new card for every new activity that the children did. So if you'd watched a video about going to the zoo, you'd write down what you could remember about the coach trip there on one card, all about seeing the lions on another card and you'd write everything about having a picnic on another card. Does that make sense? You can have as many cards as you want.

That's brilliant. Now I've got a timeline here which you can use to put all your cards on in the order that they happened. This side is the start, so you'd put the first activity that the children did here. This side is the end, so you'd put the last activity that the children did here. I want you to do this will all the cards so if somebody else was to look at your timeline, they could understand what order everything happened. Does that make sense?

Control Condition

I want to see how much you can remember about the DVD. I've got a couple of pieces of paper here that I'm going to give you. I want you to write down as much as you can remember about what you saw on the video for me. I want you to write it down in the order that it happened. So if you'd watched a video about going to the zoo, you'd write down what you could remember about the coach trip there, then all about seeing the lions, then everything you can remember about eating a picnic. Does that make sense?

Appendix O: Working Memory Measure – Backwards Span Task and Instructions (Exp. 5)

Now we’re going to do a special kind of number task. I’m going to say some numbers to you, and you have to repeat them back to me, but in the backwards order to what they were said. So if I was to say ‘two, four’, you would say ‘four, two’. Does that make sense? Let’s have a practice. So what would you say if I said ‘five, seven’? [Child responds; if incorrect then explain again and provide another example]. Now these numbers are going to get longer and harder as we go along, but try your best. I will tell you when we’re going to stop.

Length	**Sequence**	**Correct Answer**
2	91	19
2	28	82
2	14	41
2	62	26
2	23	32
2	48	84
3	450	054
3	956	659
3	821	128
3	308	803
3	436	634
3	147	741
4	6384	4836
4	9219	9129
4	2069	9602
4	6814	4186
4	7608	8067
4	5917	7195
5	17936	63971

5	51302	20315
5	40910	01904
5	17628	82671
5	75308	80357
5	91706	60719
6	975071	170579
6	610498	894016
6	637083	380736
6	851806	608158
6	395062	260593
6	519361	163915
7	5761281	1821675
7	1748562	2658471
7	4976816	6186794
7	3754813	3184573
7	2931249	9421392
7	1658279	9728561
8	65328551	15582356
8	29708863	36880792
8	19462230	03226491
8	71139720	02793117
8	49513936	63931594
8	90768803	30886709
9	278963508	805369872
9	519573490	094375915
9	640912942	249219046
9	273009869	968900372
9	669286598	895682966
9	820901170	071109028

Appendix P: Task Instructions, Distancing Story and Activity Cards (Exp. 5)

I’m going to tell you a story about a boy's day. I'm going to read it out loud to you and I want you to try and remember as much of it as you can, as I've got another task for you to do afterwards.

“Alex was woken up by his alarm clock. He got out of bed, put on his dressing gown and went downstairs for his breakfast. After he had finished, Alex went back upstairs, put on his uniform and brushed his teeth. He got in the car and his mother dropped him off at school. Alex played in the playground with his friends until it was time to go inside. At lunchtime, Alex ate his packed lunch in the school hall with his friends. Alex then went into the playground and played until the bell rang. After lunch, Alex's class had games all afternoon and they played cricket. Alex’s dad picked him up at the end of school and he went home. After tea, Alex played on his computer. Alex then had a bath, put his pyjamas on and went to bed.”

I have some picture cards here showing the different activities in Alex’s day. Let’s look at each one [show child the nine pictures and label them]. I’ll give you these cards to hold; they’re in the correct order that they happened, so you don’t need to worry about remembering the order. I want to see if you can show me *when* the different activities happened. I've got a timeline here which I want you to put the cards on. This line represents the whole day, so this end is first thing in the morning, and this end is last thing at night. If you think the activity on the card happened early on, you'd place it at this end. If you think it happened close to the end of the day, you'd place it at this end. If you think one activity happened soon after another, you'd place the two cards quite close together. If you think more time passed between them, you'd leave a gap and place the cards further apart. Do you understand?

I’m going to show you an example with these cards here. These show Sally going on holiday; I’ll show you how to place things close together when there’s not much time, and far apart when there’s a long time between them. So here’s Sally getting on the plane here, and here’s Sally flying in the plane; these pictures go quite close together as there’s not much time between the two events. There’s then a big gap here until the plane lands, as she’s going a long way. Then Sally gets on a coach to go to her hotel, so we put it fairly close to the picture of the plane landing. Does this make sense?

Now it's your turn to place the picture cards about Alex’s day on the timeline. Remember, the cards are already in the correct order. If someone was to look at your timeline afterwards, they should be able to tell what activities happened close together and what activities happened far apart. You can move the cards as much as you like, just tell me when you're happy with where you've put them.

Alarm Clock

Breakfast

Brush Teeth

Car to School

Lunch

Cricket

Car Home

Bath

Bed