The Role of Goals and Attention

on

Memory for Distance

in

Real and Virtual Spaces

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PhD

2011

The Role of Goals and Attention
on
Memory for Distance
in
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A thesis submitted in partial fulfilment of the requirements of Northumbria University for the degree of Doctor of Philosophy.

Research undertaken in the Department of Psychology, School of Life Sciences and also the School of Built and Natural Environment, Northumbria University.

June 2011

Abstract

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Navigating in an environment generally involves a goal. However, to date, little is known about the influence of goals on immediate memory for distance and time in 'cognitive maps.' The main aim of the thesis is to investigate the role goals play in memory for distance and time experienced during movement through a range of types of environment, and to begin to unpack the mechanisms at play. A secondary goal of the thesis is to examine the fidelity of virtual environments with respect to memory for distance and time.

There has been a recent surge in the utilisation of Virtual Reality (VR) in research and practice. However, it remains unclear to what extent spatial behaviour in virtual environments captures the experience of Real Space. The environments tested in the thesis allow direct comparison of immediate memory for distance traversed and time spent in real human mazes versus VR versions of the same mazes.

The first series of experiments tested the effects of goals varying in urgency and desirability on memory immediate memory for distance and time in real and virtual straight paths and paths with multiple turns. The results show reliable effects of goals on memory for distance and time. Moreover, the studies discount the influence of arousal and mood as an explanation for these effects, and suggest that goals may mediate attention to the environment.

The second series of experiments investigated the role of attention in memory for distance and time in VR and in mentally simulated environments using verbal, visual, and auditory cues. The results of these studies show some evidence that attention in one's environment influences memory for that environment.

Overall, the results reveal that both goals and deployment of attention affect the representations people construct of their environments (cognitive maps) and subsequent recall. Implications are discussed more broadly with regard to research in spatial cognition.

Table of Contents

Abstract i

Table List i

Table of Figures iii

Appendix List vii

Acknowledgments viii

Author's declaration ix

SECTION I -COGNITIVE MAPS 10

CHAPTER 1. 11

Introduction 11

1.1. Cognitive Maps and Spatial Representations of the Environment 12

1.1.1. Egocentric versus Allocentric Spatial Representations 20

1.1.2. How Representations Form 25

1.2. Distortions in Cognitive Maps 26

1.2.1. Hierarchical Organisation 27

1.2.2. Reference Points 39

1.2.3. Influence of Structure of the Environment 41

1.3. Modes of Learning 47

1.3.1. Maps 47

1.3.2. Virtual Reality (VR) 49

1.4. Summary and Précis of the Thesis 52

SECTION II-GOALS 55

CHAPTER 2. 56

Introduction 56

2.1 Historical Context 57

2.2. Goals in Spatial Cognition 60

2.3. Goals and Metric Properties 65

2.4. Distortions from a different perspective 69

2.5. Summary 72

CHAPTER 3. 75

The Effect of Goals in Real and Virtual Space 75

3.1. Experiment 1. 76

Selection of Goal Scenarios 76

3.1.1. Method 77

3.1.1.1. Experimental Design 77

3.1.1.2. Participants 77

3.1.1.3. Materials 78

3.1.1.4. Procedure 78

3.1.2. Results 79

3.1.3. Discussion 81

3.2. Experiments 2 and 3. 82

The Effects of Goals on Immediate Memory for Distance and Time in Real and Virtual Environments; Straight Path 82

3.2.1. Method Outline 83

3.2.1.1. Measurement 83

3.2.2. Methodology 84

3.2.2.1. Procedure 85

3.2.2.2. Materials 87

3.2.2.3. Walking Pace and Speed in VR 89

3.2.2.4. Presentation 90

3.2.2.5. Experimental Design 91

3.2.2.6. Participants 91

3.2.3. Results 92

3.2.3.1. Preliminary Analyses 92

3.2.3.2. Main Analyses 93

3.2.4. Discussion 97

3.3 Experiments 4 and 5. 98

3.3.1. Methodology 99

3.3.1.1. Materials 99

3.3.1.2. Walking Pace and Speed 101

3.3.1.3. Participants...102

3.3.1.4. Experimental Design 102

3.3.2. Results 103

3.3.2.1. Preliminary Analysis 103

3.3.2.2. Main Analysis..104

3.3.3. Discussion 109

3.4. Further Combined Analysis 111

3.4.1. Experiments 2 and 4. 111

Real Space Straight Path versus Real Space Path with Turns 111

3.4.1.2. Design 111

3.4.2.2. Results 112

3.4.2.3. Discussion 116

3.4.3. Experiments 3 and 5. 116

VR Straight vs. VR Complex Path – Combined Analysis 116

3.4.3.1. Design 116

3.4.3.2. Results 116

3.4.3.3. Discussion 120

3.5. General Discussion 120

CHAPTER 4. 122

The Influence of Arousal on Distance Estimation; Experiment 6 122

4.2. Method...127

4.2.1 Design 127

4.2.2. Materials 128

4.2.3. Participants 128

4.2.4. Procedure 128

4.3. Results 129

4.3.1. Heart rate, Mood State and Anxiety measures 129

4.3.2. Distance Estimation 130

4.4. Discussion 130

4.5. General Discussion 131

4.6. Conclusion 133

SECTION III-ATTENTION 135

CHAPTER 5. 136

Influence of Attention and Time 136

5.1. Attention 137

5.2 Time 143

5.2.1 Attention and Time 145

5.3.2. Summary 150

5.4. From Time to Distance 151

CHAPTER 6. 156

Influence of Attention on Distance Estimation 156

6.2. Experiment 7. 158

The Influence of Visual and Auditory Distracters in VR on Distance Estimation 158

6.2.1. Method 160

6.2.1.1. Materials 160

6.2.2.2. Walking Pace and Speed 162

6.2.2.3. Participants 163

6.2.2.4. Presentation 163

6.2.2.5. Procedure 163

6.2.2.6. Experimental Design 164
6.2.3. Results 165
6.2.3.1. Preliminary Analysis 165
6.2.3.2. Main Analysis 165
6.2.4. Discussion 168
6.3. Experiment 8. 169
The Role of Attention and Goals through Imagined Traversal 169
6.3.1. Method 172
6.3.1.1. Materials 173
6.4.1.2. Environmental Stimuli 176
6.4.1.3. Attentional Stimuli 177
6.4.1.5. Mental Walking Pace 180
6.4.1.6. Speed of walk 180
6.4.1.7. Step lengths 181
6.4.1.8. Path Segment Length 181
6.4.1.9. Arrangement 182
6.4.1.10. Turning 184
6.4.1.11. Experimental Design 185
6.4.1.12. Participants 185
6.4.1.13. Presentation 185
6.4.1.14. Procedure 186
6.4.1.15. Data Treatment 188
6.4.1.16. Dependent Variables 189
6.4.2. Results 189
6.4.2.1. Distance Estimation 190
6.4.3. Discussion 199
6.5. General Discussion 200

6.6. Conclusion 201

SECTION IV - GENERAL DISCUSSION AND CONCLUSION 202

CHAPTER 7. 203

7.1. Chapter Overview 203

7.2. Summary of Results 203

7.3 Methodological Concerns 208

7.4. Theoretical Implications 211

7.5. Future Directions 214

7.6. Applications 216

7.7 General Conclusion 219

Appendix 220

References 226

Table List

Tables **Page**

Table 1.1: Properties of Types of Description Perspectives (Taylor & Tversky, 1996). 22

Table 3.1: Descriptive Statistics for Combined Desirability and Urgency According to Scenario from the Questionnaire.. 79

Table 3.2: Results of Three-Way Repeated Measures ANOVA for Scenario Identification...... 80

Table 3.3: Identification of step lengths from real space experiment for use in VR experiments 90

Table 3.4: Illustration of 2 x 3 between participants design for Experiments 2 and 3, according to Environment Type and Scenario.. 91

Table 3.5: Results of the 1 – Way ANOVA for pace of walk and time spent in the environments in Experiments 2 and 3... 93

Table 3.6: Between Participants ANOVA for Distance Estimation on Experiments 2 and 3. ... 94

Table 3.7: Between Participants ANOVA for Time Estimation on Experiments 2 and 3. 95

Table 3.8: Results of the 1-Way ANOVA for pace of walk and time spent in the environments in Experiment 4 and 5. 103

Table 3.9: Between Participants ANOVA for Distance Estimation on Experiments 4 and 5. . 104

Table 3.10: Results of the one-way ANOVA on ratio distance estimation (metres) for complex path in Real Space and VR, in Experiments 4 and 5. 105

Table: 3.11: Between Participants ANOVA for Time Estimation on Experiments 4 and 5. 107

Table 3.12:. Between Participants ANOVA for Urgency Reports on Experiments 4 and 5..... 108

Table 3.13: Between Participants ANOVA for Distance Estimation Ratio according to Scenario and Path Structure in Real Space (Experiments 2 and 4). 112

Table 3.14: Results of the one-way ANOVA on ratio distance estimation (metres) for path structure in real space according to scenario, in Experiments 2 and 4............................. 114

Table 3.15: Between Participants ANOVA for Time Estimation Ratio according to Scenario and Path Structure in Real Space (Experiments 2 and 4). 115

Table 3.16: Between Participants ANOVA for Distance Estimation Ratio according to Scenario and Path Structure (Experiments 3 and 5).. 117

Table 3.17: Between Participants ANOVA for Time Estimation Ratio according to Scenario and Path Structure (Experiments 3 and 5). 119

Table 6.1: A 2 Way Mixed ANOVA for Distance Estimation Ratio According to Attention and Modality in Experiment 7 166

Table 6.2: Results of the 4 – way ANOVA on Distance Estimation in Experiment 8 192

Table 6.3: Results of the mixed ANOVA on distance estimation according to scenario, first or second half of route and attention distracter in Experiment 8.. 196

Table of Figures

Figures **Page**

Figure 1.1: Illustration of 14 unit T-Alley Maze (Tolman, 1948) 13

Figure 1.2: Illustration of Morris Water Maze – adapted from ratbehaviour.org....................... 15

Figure 1.3: Elements in Cognitive Maps (O'Keefe & Burgess, 1996)... 17

Figure 1.4: The functional architecture of the model of encoding and retrieval of the spatial context of an event (Burgess, Becker, King and O'Keefe, 2001)...................................... 24

Figure 1.5: Map illustrating the relationship between San Diego, California and Reno, Nevada (Pastorino and Doyle-Portillo, 2010) 28

Figure 1.6: Hierarchical representation of states and cities in the Unites States (McNamara, 1986).. 30

Figure 1.7: Arrangement of objects into regions (McNamara, 1986).. 31

Figure 1.8: An example of one of the maps used in the studies of the subjective organization of spatial memory (McNamara, Hardy, and Hirtle, 1989). 33

Figure 1.9: Ordered tree for the map in Figure 1.8. (McNamara, Hardy, and Hirtle, 1989)....... 34

Figure 1.10: Map of Central Ann Arbor (Hirtle & Jonides, 1985) 36

Figure 1.11: Individual ordered trees derived from the recall data of each subject (Hirtle & Jonides, 1985). 37

Figure 1.12: Allocentric view of paths – not to scale. (Sadalla & Magel, 1980)........................ 42

Figure 1.13: An example of the distance estimation judgement of paths A and B. (Sadalla & Magel, 1980).. 43

Figure 1.14: Map of the environment used from Thorndyke (1981). 44

Figure 2.1: Maslow's (1943) Hierarchy of Needs (Kenrick, Griskevicius, Neuberg & Schaller (2010).. 57

Figure 2.2: Map of Grinnell College campus, with the six analysed regions of interest (ROIs) depicted: buildings, streets, street names, peripheral and central areas and compass rose (Bruyné, & Taylor, 2009) 63

Figure 2.3 a: visual measure; b: haptic measure (adapted from Bhalla & Proffitt, 1999) 71

Figure 3.1: Main Effect of Urgency and Desirability on Scenario 80

Figure 3.2: an allocentric view of the real space straight path.. 88

Figures 3.3a: and 3.3b: provide an egocentric view of the real space path and the identical VR path.. 89

Figure 3.4: Allocentric view – Experiments 2 and 3 straight environment (15.4 metres).......... 89

Figure 3.5: Main Effect of Scenario on Distance Estimation, in Experiments 2 and 3, with standard error bars (+/- 1 SE)... 95

Figure 3.6: Trend of Effect of Scenario on Time Estimation, in Experiments 2 and 3, with standard error bars (+/- 1 SE)... 96

Figure 3.7: – an egocentric view of Experiment 4; real space complex path (15.4 metres) 99

Figure 3.8: An egocentric view of the entrance to the real space complex path; Experiment 4 100

Figure 3.9: Egocentric view of the VR complex path; Experiment 5 102

Figure 3.10: Allocentric view of the entrance to the VR complex environment; Experiment 5102

Figure 3.11: Interaction between Scenario and Environmental Condition on Distance Estimation Ratio, in Experiments 4 and 5 – path with turns, with standard error bars (+/- 1 SE)...... 106

Figure 3.12: Interaction between Scenario and Environmental Condition on Time Estimation Ratio, in Experiments 4 and 5 – path with several turns, with standard error bars (+/- 1 SE). 108

Figure 3.13: Main effect of Path Type and Interaction in Real Space on Ratio Distance Estimation in Experiments 2and 4. 113

Figure 3.14: Main effect of Path Type and Interaction in Real Space on Ratio Time Estimation in Experiments 2 and 4.. 115

Figure 3.15: Main Effect of Goals and Structure in VR on Distance Estimation Ratio, in Experiments 3 and 5.. 118

Figure 3.16: Main Effect of Goals and Structure in VR on Time Estimation Ratio, in Experiments 3 and 5.. 120

Figure 4.1: Why the effect of goals? An overview of the contributory mechanisms 123

Figure 4.2.: Overview of results investigating the effect of goals. Highlighting that the scenario inductions did not increase arousal, but influenced mood states. 130

Figure 5.1: Experimental procedure of Posner (1980)... 139

Figure 5.2: Behavioural data for time and colour choice response trials, adapted from Coull et al. (2004)... 147

Figure 5.3: As participants paid progressively more attention to time, brain activity increases, most notably in preSMA, as well as in a network of other cortical and striatal areas. Adapted from Coull et al. (2004) 148

Figure 5.4: As participants paid progressively more attention to the colour attributes of a stimulus, brain activity increases in the visual cortex (V4), notably in the right hemisphere. Adapted from Coull et al. (2004). 149

Figure 6.1: Allocentric views of the two VR paths... 161

Figure 6.2: Egocentric view of the second section of the first half of the Visual Distracter VR path. (19.44m)... 162

Figure 6.3: Mean Distance Ratio Estimations According to Attention Condition, in Experiment 7, with standard error bars (+/- 1SE).. 167

Figure 6.4: Mean Distance Ratio Estimations According to Modality, in Experiment 7, with standard error bars (+/- 1SE)... 167

Figure 6.5: Description of the Route used in Experiment 8... 174

Figure 6.6: Configuration of Route with Attention Distractors in the First Half in Experiment 8 178

Figure 6.7: Configuration of Route with Attention Distractors in the Second Half in Experiment 8 179

Figure 6.8: Sample of steps chart... 181

Figure 6.9: Illustration of turning circle used in Experiment 8.. 182

Figure 6.10: Arrangement in Experiment 8 183

Figure 6.11: Turning in Experiment 8 184

Figure 6.12: Actual and remembered Segments, Experiment 8... 190

Figure 6.13: Main effect of Position on Distance Estimation, in Experiment 8, with standard error bars (+/- 1SE). 193
Figure 6.14: Two-Way Interaction between Half and Position on Distance Estimation in Experiment 8.. 193
Figure 6.15: Three-Way Interaction between Attention Distracter, Half and Turns on Distance Estimation in Experiment 5 with standard error bars (+/- 1SE)....................................... 194
Figure 6.16: Distances estimated for the Control Condition according to the first and second half of the route and the presentation of attentional stimuli in Experiment 8. 197
Figure 6.17: Distances estimated for the High Urgency Condition according to the first and second half of the route and the presentation of attentional stimuli in Experiment 8....... 198
Figure 6.18: Distances estimated for the Low Urgency Condition according to the first and second half of the route and the presentation of attentional stimuli in Experiment 8....... 198

Appendix List

Appendix **Page**

Appendix 1:Scripts for scenario inductions. 220

Appendix 2: Playback factor calculation for Experiments 3, 5 and 7 222

Appendix 3: Details of the ratings for distance travelled, time, urgency and anxiety for

Experiments 2 , 3, 4 and 5 223

Appendix 4: Details of the ratings for PANAS, distance travelled and urgency estimations for

Experiment 6. 224

Appendix 5: Details of the ratings for distance travelled, time, urgency and anxiety for

Experiment 7 225

Acknowledgments

One of the main ingredients of having a good supervision team is to be able to recognise that you have one! I would therefore like to thank myself for having the ability recognise and appreciate the qualities of both Professor Kenny Coventry, my principle supervisor and my second supervisor, Dr Emine Mine Thompson. All I can say is that I certainly fell on my feet when I was appointed under their guidance. I would like to express my sincere thanks and gratitude for their help, which was always buoyed up with smatterings of good humour, during the process of this PhD.

I would especially like to thank Patrick Olivier, Culture Lab, Newcastle University, for coming to my aid by providing the materials and fighting for the space for my first series of studies. Without his help this thesis would read very differently. Many thanks also to Phil Jobson for his help in co-ordinating this too.

Thanks also to Graham Kimpton, Built Environment Visualisation Centre, for his visualisation skills and, more importantly, for emphasising the importance of cross disciplinarian communication.

Expressions of appreciation to my colleagues in CoCo, past and present, for their camaraderie and support and also, to Paul Agnew, who always has the right answer. Further thanks to all of my friends, who are all standing by waiting for the celebrations to commence.

I'd also like to thank Professor Christian Freksa and Professor Ruth Conroy Dalton for agreeing to assess this thesis. I hope they find it enjoyable.

Finally, I would not have been able to complete this journey without the patience and understanding of my three children; Charlie Cameron and Anna, and my mother, Anne. I am both grateful and indebted to her for the provision of a lifetime of unselfish support, thoughtfulness and encouragement.

Author’s declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the School of Life Sciences Ethics Committee at the University of Northumbria.

Name:

Signature:

Date:

SECTION I -COGNITIVE MAPS

CHAPTER 1.

Introduction

"..the whole notion of purpose and goal was excluded from motivational psychology simply because one could not ask a white rat about his purpose" (Maslow, 1943, pp 23).

Being able to navigate in one's environment is a fundamental aspect of human behaviour. The ability to understand the space around us is dependent on our understanding of distance and time and comprises one of the most important skills for human survival. Our everyday lives require navigation through a variety of structures and contexts; we need to know where we are and where we are heading in order to complete all manner of tasks and goals. In order to serve these functions, it has been proposed that individuals need to establish a relationship between the environment and their cognitive representation, commonly known as a 'cognitive map' (Downs & Stea, 1973, pp 79-86).

Research into the nature of cognitive maps has been extensive and the characteristics of cognitive maps are reasonably well understood. However, this thesis develops two lines of enquiry that have been somewhat neglected in spatial cognition research to date. First, what has been largely ignored in cognitive map research is that navigation in an environment rarely occurs without a purpose. These purposes can vary greatly, from positive experiences, such as delivering good news to a friend, to negative experiences, such as telling a person they have failed all their exams. The thesis will examine if such varying goals affect memory for distance and time experienced in both Real Space (RS) and Virtual Reality (VR). Second, following on from a series of experiments examining goals and associated mechanisms, the thesis will consider the role attention plays in distance and time estimation when captured in VR and during imagined traversal. Importing predictions from literature on time estimation, the second series of experiments shows that attention offers a powerful means to explain perception of distance and associated distance distortions.

The main objective of this chapter is to provide an overview of cognitive maps and their development, from a historical perspective. This will lead to a synopsis, important for the consideration of goals, of the distortions of distance and time people exhibit across a range of experimental paradigms. These distortions are important as they suggest that the metric assumptions of cognitive maps in our cognitive representations are violated. It is hoped that the investigation of goals and attention may offer a unified account of why these distortions occur.

1.1. Cognitive Maps and Spatial Representations of the Environment

The phrase ‘cognitive map’ was originally coined by Tolman (1948), famous for his experiments training rats in various maze structures (Figure 1.1). Tolman observed rats moving around mazes on several non rewarded trials, and found that they manifested high error scores, that is, they failed to navigate correctly to a food source.

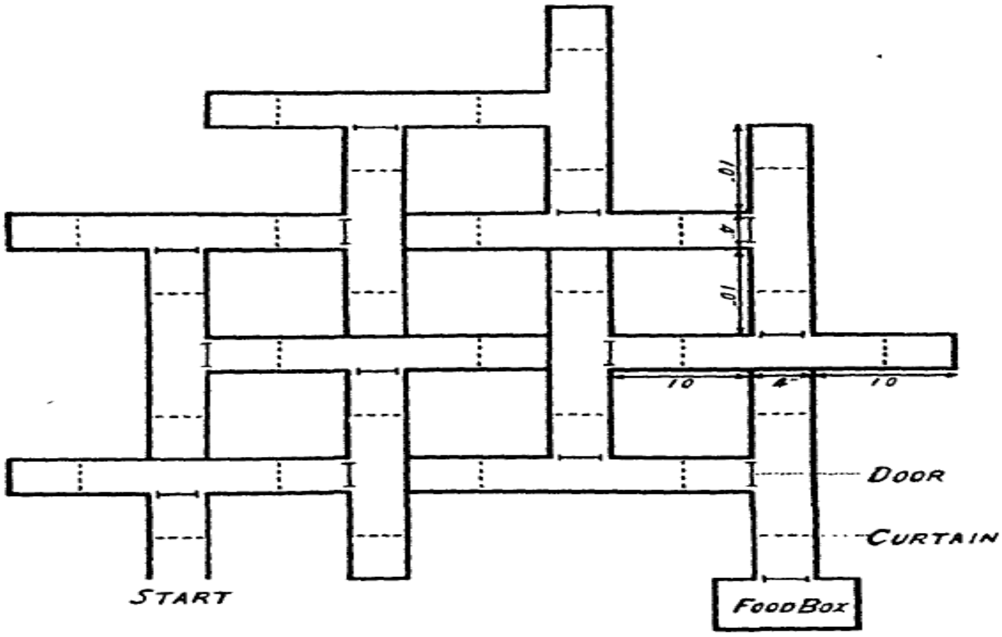

Figure 1.1: Illustration of 14 unit T-Alley Maze (Tolman, 1948)

For instance, three groups of rats were trained to run in a maze in order to investigate their ability to navigate correctly to a food source. The control group was fed immediately upon reaching the goal. he first experimental group was only rewarded from the seventh day of training and the second experimental group was rewarded after three days. Both of the experimental groups demonstrated fewer errors when running the maze the day after the transition from no reward to reward conditions and were able to retrieve the food immediately. That is, the rats were able to demonstrate latent learning via an ability to increase the speed of collecting the expected reward. In further studies, rats demonstrated greater knowledge by connecting trained routes with unknown paths and taking novel shortcuts. Tolman (1948) therefore assumed that navigational behaviour was holistic, purposeful and cognitive. He thus surmised that the rats must have developed internal representations of the environment that were topographical and could be interpreted, independent of the starting position or variations in the route.

Although Tolmans' (1948) methodology was adapted directly from the behaviourist approach which was firmly established at that time, his hypothesis appeared to be more supportive of Gestalt principles. Tolman rejected the simplistic Stimulus – Response behaviourist approach in exchange for the notion that the paths and connectors were not seen as separate routes but adjacent cues, to form one holistic representation. This suggested that exposure to spatial experiences led to complex mental representation of the environment going far beyond reproduction of familiar paths. This led Tolman to propose that rats form, not just egocentric representations from navigating in an environment, but also allocentric representations, a bird's eye view of the environment, which allows them to make shortcuts.

Following Tolmans' (1948) original work, the supposition that animals have cognitive maps or, alternatively, other forms of internal representations, was the subject of intense debate. It has since been established that some spatial processing in humans is accomplished through neural substrates shared with non-human animal species, emphasising the role of the hippocampus. Much of the original work implicating the hippocampus comes from studies utilising the Morris Water maze task (Morris, Garrud, Rawlins & O' Keefe, 1982). In the Morris water maze rats learn to escape from a pool half filled with cloudy water and their task is to swim to an escape platform that is hidden (submerged) a few millimetres under the surface. Training involves trial episodes with different starting points. Therefore, it is assumed that the animals rely on external/extra-maze cues as they cannot rely on scent to find the escape route (see Figure 1.2).

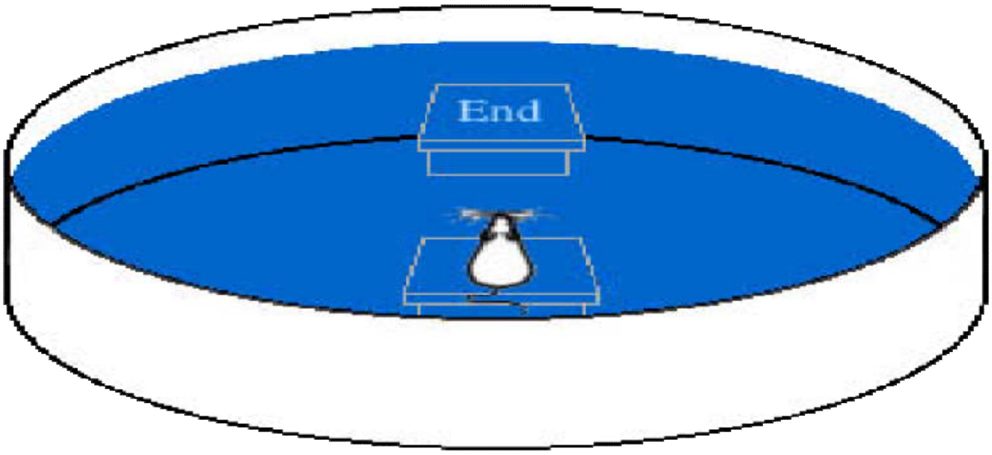

Figure 1.2: Illustration of Morris Water Maze – adapted from ratbehaviour.org

Theoretically, the ability to complete the water maze derives from place cells, that is, neurons in the hippocampus which identify or represent points in space in an environment (O'Keefe, 1976). The role of the hippocampus has been demonstrated across several studies, for instance, rats with hippocampal lesions are unable to learn the water maze task (Morris et al., 1982; Morris, Schenk, Tweedie, & Jarrard, 1990; McDonald & White, 1994).

Work on the hippocampus has produced a detailed model of cognitive maps. For instance, O'Keefe & Nadel (1978) proposed that place cells in the rat hippocampus respond selectively to the animal's current location irrespective of the direction they were facing, and similar findings have also been established in primates (Ono, Nakamura, Fukuda & Tamura, 1991). In addition, head direction cells are considered to enable rats to determine the position of their head within the environment providing orientation evidence independent of location (e.g. Taube, Muller & Ranck, 1990).

O'Keefe and Nadel (1978) therefore proposed that the hippocampus is a key factor in the production process of cognitive maps that encode a rat's environment in a two – dimensional representation, and the activation of each place cell represents the animal's presence at a particular set of co-ordinates within the representation. Cognitive map theory posits that entities are established by their spatial relationships to each other. The spatial relationships are identified in terms of three factors; places, directions and distances (O'Keefe, & Nadel, 1978, O'Keefe & Burgess, 1996). Figure 1.3 demonstrates a schematic example of the elements in cognitive maps. Cognitive maps are constructed from place representations and the distances and directions between them. Distances and directions can be represented by vectors drawn from one place to another in absolute coordinate systems. In a coordinate system, objects or places are encoded with respect to the three spatial axes so that relations between places are not explicitly represented but are implicit in the structure of the coordinate system and can be derived from it.

In addition, the locations of objects within allocentric frameworks are static and do not change, irrespective of the observer’s movements. This implies that the cognitive representation of the environment consists of fixed spatial representations of the environment and consequently preserves the notion of Euclidean properties from the environment.

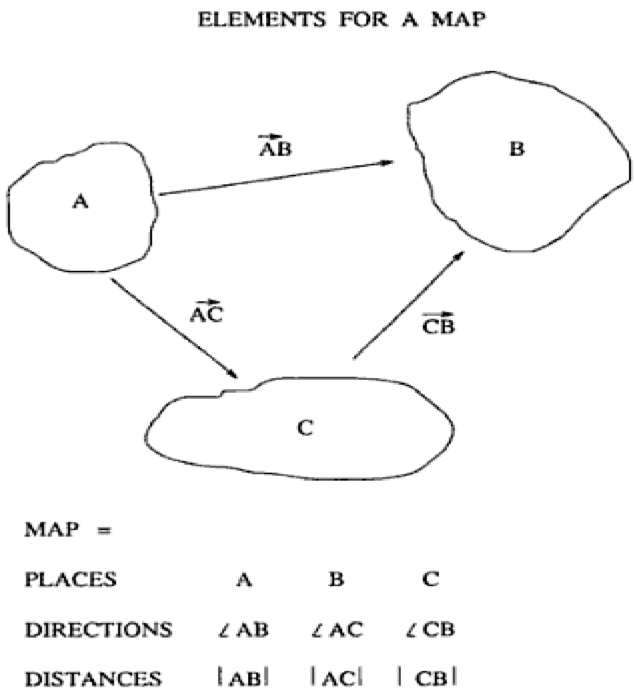

Figure 1.3: Elements in Cognitive Maps (O'Keefe & Burgess, 1996).

In humans, there is evidence for the existence of place (Ekstrom *et al.* 2003) and also the involvement of the hippocampus in spatial learning has been established (Bohbot, Iaria & Petrides, 2004; Iaria, Petrides Dagher, Pike & Bohbot, 2003). It is proposed that the similarities between non human animals and humans were not only structural but functional too as both species are guided by the shape of the environment (Cartwright & Collett, 1983; Gallistel & Cramer, 1996; Gouteux & Spelke, 2001; Hermer & Spelke 1994). However, the notion that the underlying processes for creating and retrieving spatial representations is similar in non human animals compared to humans, is still controversial (see Wang & Spelke 2002 for a discussion of this issue). Interestingly, O'Keefe & Nadel (1978) believe that humans have an awareness of linear time which rats do not possess.

There is also intriguing evidence that hippocampal volume in humans relates to spatial knowledge, as the posterior hippocampus is significantly larger in London taxi drivers compared to controls (Woollett, Spiers & McGuire, 2009). The relationship between the volume of the hippocampus and environmental knowledge maps onto both human and non human species. For instance, animals that have to hoard food have greater demands on spatial memory than animals that do not and, this is reflected in the hippocampal volume (Barnea & Nottebohm, 1994; Smulders, Sassoon & DeVoogd, 1995; Volman, Grubb & Schuett, 1997; Lee, Miyasato & Clayton, 1998; Biegler, McGregor, Krebs & Healy, 2001).

Neuropsychological evidence relates the volume of the hippocampus, in some non-human animals, as being varied and dependent on the function of the demands placed on spatial memory (Barnea & Nottebohm, 1994; Biegler, McGregor, Krebs, & Healy, 2001; Lee, Miyasato, & Clayton, 1998; Smulders, Sasson, & DeVoogd, 1995; Volman, Grubb, & Schuett, 1997). For instance hippocampal volume in birds can vary across species, sexes, and seasons according to nest-searching participation (Day, Guerra, Schlinger, Rothstein, 2008).

Evidence suggests London taxi drivers expertise is exceptional compared to that of other taxi drivers working in international cities, i.e. Paris (Pailhous, 1970; Peruch, Giraudo & Garling, 1989), Chicago (Chase, 1982) and Helsinki (Kalakosi & Saariluoma, 2001). This has been demonstrated through a series of studies (i.e. Macguire, Woolett & Spiers, 2006; Woollett and MacGuire, 2009; Woollett and MacGuire, 2010) through the measurement of performance on; sketching maps, direction pointing and giving route descriptions, superiority of memory for street names, spatially organised list recall for street names, whether they are presented by semantic organisation or listed alphabetically. An explanation of this superiority is attributed to the extensive training of 2- 4 years to acquire 'The Knowledge' is a test which all licensed taxi drivers need to pass before they can drive London's black cabs. The test involves learning the layout of 25,000 streets in the city of London and being tested on them. On completion, a driver must be able to decide routes immediately on request and adapt to traffic conditions without relying on a map, satellite navigation or controller via radio.

London bus drivers are considered to be a comparable control group for London taxi drivers as they spend a similar number of hours per day navigating in the city. Significant increased differences in hippocampal volume have been found in London taxi drivers compared to London bus drivers. This is claimed to be due to the bus drivers utilising restricted routes. Unsurprisingly, London taxi drivers performed significantly better than controls (London bus drivers) on tests assessing knowledge of London landmarks and their spatial relationships. However, it appears that the expertise of the taxi drivers is not necessarily transferable to other spatial tasks as the taxi drivers took longer to learn and performed worse than the bus drivers on a task that involved learning associations between sixteen objects and locations on a table-top array (Macguire, Woollett & Spiers, 2006; Woollett and MacGuire, 2009; Woollett and MacGuire, 2010).

Further, there was a positive relationship with the posterior hippocampal grey matter volume compared to the number of years spent as a taxi driver and a negative correlation with the anterior hippocampal grey matter (Maguire et al., 2000, 2006). This finding suggests that the greater volume of posterior hippocampal grey matter in taxi drivers may be related to the acquisition, storage and use of the ‘mental map’ within large complex environments (Maguire et al., 2000, 2006). Conversely, whilst the evidence appears to be robust (Woollett & Maguire, 2009), it is acknowledged that the findings as yet, are not easily explained and thus any theoretical implications drawn are still somewhat speculative. Nevertheless, we now appear to have a greater understanding of the neural mechanisms involved and the evidence suggests that humans and non humans do appear to share similar organic structures to represent their environments.

Despite evidence highlighting the similar neural mechanisms between humans and non human animals, there is no substantiation of the claim that allocentric representations are developed from immediate exposure to an environment. Evidence from the studies involving London taxi drivers suggests that individuals need to over-learn environments in order to form allocentric representations. This would imply that allocentric representations are built up over time from exposure to the environment and could lead one to assume that they are secondary to egocentric representations.

1.1.1. Egocentric versus Allocentric Spatial Representations

The notion of the cognitive mapping process is widely accepted as a means for spatial representation and memory due to the underlying principles: coding of location and goal direction occurs in a universal manner regardless of a person’s body centred orientation, which results in a flexible representation. This satisfies many problems such as memory capacity, competency in novel environments, short cuts, detours, and performance after viewpoint-change (Hartley, Maguire, Spiers & Burgess, 2003). Although the fundamental notion of some kind of map-like representation is shared by most researchers, the qualities, processes and nature of the representations are topics of debate, and the interaction of representations within the brain is poorly understood (Roche, Mangaoang, Commins, & O’Mara, 2005).

A frequent distinction in spatial navigation research differentiates between landmark, route, and survey knowledge of an environment; with landmarks being identified as unique objects at fixed locations. Route knowledge corresponds to fixed sequences of locations, as experienced whilst traversing a route, and survey knowledge abstracts from specific sequences and integrates knowledge from different experiences into a single model.

There is some evidence for how individuals represent their environment from verbal spatial descriptions (Taylor and Tversky, 1992). For instance, participants appear to construct maps following similar processes and utilising similar entities, irrespective of whether they were given directions from a survey (allocentric) or route (egocentric) perspective. That is, participants develop a hierarchy, based on scale, and they begin by drawing the larger, global features followed by the smaller, local features. They might start with the order of mountains and rivers, followed by main streets and highways and then buildings. This mental portrayal of spatial relations appears to be consistent irrespective of presentation, i.e. survey and route descriptions and maps.

However, Taylor and Tversky (1996) found that the types of cues used in verbal descriptions were dependent on the mode of acquisition. For instance, individuals in route perspective would produce locations of landmarks in relation to both the individual and the speaker in terms of their front/back/left/right. This results in the reader or listener being taken on a mental tour through the environment. Conversely, a survey perspective results in landmarks being described in relation to each other in terms of a cardinal system, for instance, North, South, East and West; therefore the survey description utilises a bird’s eye view. Table 1.1 demonstrates the properties of the description perspectives (Taylor & Tversky, 1996).

Table 1.1: Properties of Types of Description Perspectives (Taylor & Tversky, 1996).

Description perspectives	**Route**	**Survey**
Properties		
Viewpoint	Changing, internal	Fixed, external
Referent	Person	Object
Terms of reference	Left/Right/Front/Back	North/South/East/West
Frame of reference	Intrinsic	Extrinsic

In addition to how an environment has been experienced, it has also been shown that the characteristics of the environment influence the perspective taken. For instance, where there were single paths and landmarks of equal size, a route perspective was adopted (Taylor and Tversky, 1996). Generally though, perspective switching is associated with a cost, such as longer time to construct a mental model of the environment (Lee & Tversky, 2001). Although, eventually, after repeated exposure, those costs diminish and disappear and it has been demonstrated that repeated retrieval of environmental information results in perspective free representations (Lee & Tversky, 2005).

We can see that spatial locations can be defined as relative to the viewer or some external reference, which can be explained by allocentric and egocentric processes. The differentiation between allocentric and egocentric representations partly maps onto the one between a "Locale" and "Taxon" system (O'Keefe & Nadel, 1978). The "Taxon" system involves using a series of S-R-S (stimulus-response-stimulus) instruction and navigation involves moving from one landmark to the next by aligning oneself in relation to the landmarks. The "Locale" system is a highly flexible system, based on the development and use of internal maps. Therefore, internal, spatial, cognitive maps require constant updating through exploration. Cognitive maps are supposedly independent of the parts of the body, for instance the retina, trunk, head, etc, and are therefore allocentric as opposed to egocentric (O'Keefe & Nadel, 1978)

While many take the existence of cognitive maps as allocentric representations for granted, the notion that spatial representations in adults ever reach the stage of allocentric representations has been challenged (Wang & Spelke, 2002). Alternatively it has been proposed that humans represent egocentric distances and directions of objects and continuously update these representations as they move, rather than depending on an allocentric, map-like representation. Wang and Simons (1999) use as evidence for this theory the finding that disoriented participants lose representational coherence between objects of an array, but are nevertheless able to perform spatial tasking, using egocentric representations alone.

Burgess, along with many others, challenge Wang & Spelke's (2002) egocentric model, and argue for multiple representations of space. The presence of multiple representations raises the question of how they interact (Roche *et al.,* 2005). Burgess (2006) notes that:

> *Whereas egocentric systems can be used alone, the egocentric nature of perception and imagery require that input to and output from allocentric systems are mediated by transient egocentric representations. Conversely, action-oriented egocentric representations must be derived from enduring allocentric representations following long or complicated self-motion.*
>
> (Burgess, 2006, p. 555)

It is commonly accepted that there is a complementary relationship between allocentric and egocentric representations which results in a translation between the two systems. The process of translation between egocentric and allocentric representations is highlighted in the model of spatial encoding and retrieval shown in Figure 1.4. This model by Burgess, Becker, King and O'Keefe (2001) suggests this mediating role is supported by posterior parietal areas in mental representation.

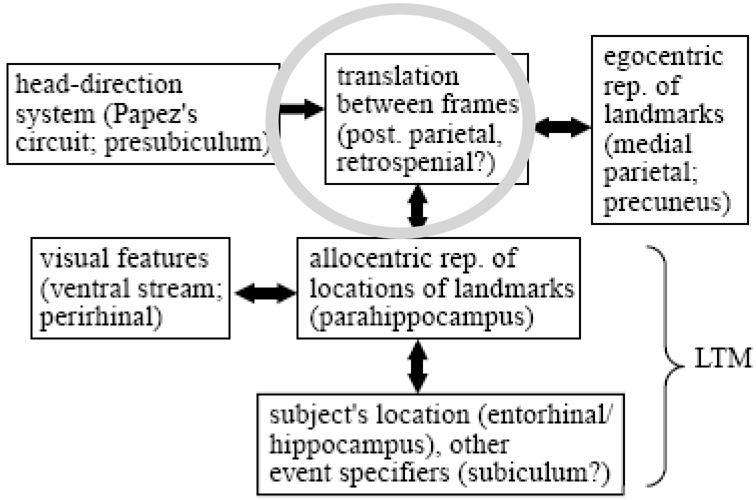

Figure 1.4: The functional architecture of the model of encoding and retrieval of the spatial context of an event (Burgess, Becker, King and O'Keefe, 2001).

The concept of translations between representations has received substantial interest in studies of spatial updating (Sholl and Nolin, 1997; Wang and Brockmole, 2003; Mou *et al.,* 2004; Waller and Hodgson, 2006; Byrne, Becker & Burgess, 2007). Egocentric movement- related spatial updating is considered to maintain the perception of an environment from moment to moment but reliance over long distances on such egocentric representations is shown to result in increased error (Etienne *et al.,* 1996; Waller *et al.,* 2003; Wang and Brockmole, 2003). Burgess (2006), suggests that, over time, individuals can navigate large-scale environments with high accuracy through the construction of an enduring allocentric representation (from temporary egocentric representations). This is supported by previous research which suggests that egocentric and allocentric relationship combine (Lee & Tversky, 2001).

1.1.2. How Representations Form

Research on the acquisition of spatial knowledge has been significantly influenced by sequential learning processes originally expressed by Piaget, Inhelder and Szeminska, (1960). They proposed that children progressively develop different cognitive representations of space as they age, advancing from initial landmark recognition to egocentric route learning and finally to metric representations of space in the allocentric frame. Studies of environmental learning in children have confirmed this developmental progression (e.g. Acredolo, 1977).

Siegel and White's (1975) theory also claims that spatial knowledge is attained sequentially, but their model differs slightly from Paiget et al. (1960). Their theory does not make any strict association between age and type of mental representation, although it has since been acknowledged that age can have an important influence on the accuracy and utilisation of mental representations (i.e. Herman & Siegel, 1979).

Siegel & White (1975) propose that knowledge of landmarks is acquired initially, with (points of high saliency such as buildings, junctions, signs) exclusive of specific information such as the spatial relations between them. The salience of the landmark is not just restricted to its physical features; they can also be encoded and recalled according to their relevance to the individual and the context of the environment. For example, on arrival at a college campus, students may identify buildings of most significance to them as the predominant features, for instance, halls of residence, the gym and the library (Evans, Marrero, & Butler, 198; Bruyné & Taylor, 2008).

Familiarity results in the development of a sequential ordering of these landmarks along a route. This leads to knowledge of the spatial relations among these landmarks and an understanding of the layout of the route. Route knowledge is initially *nonmetric*, developing into *minimaps* or clusters of connected by landmarks (Siegel & White, 1975).

The constant integration of different routes (or route schemata) results in the development of an allocentric and holistic (global) knowledge of the environment. Repeated exposure results in the greater flexibility of the mental representations. Quintessentially, it is a process of scaling and metricizing distances and directions between landmarks. These are later integrated into more complete and accurate construction so that that "routes or linear maps are superordinate to landmarks, and subordinate to configurations" (Siegel, 1981, p. 170). Configurational knowledge (or survey knowledge) is the most sophisticated stage, characterised by a Euclidean or metric understanding of relationships (both distance and direction).

Moreover, Siegel and White's (1975) theory emphasises the similarities between children's developmental stages and that of adults when learning a new environment. The fundamental feature of spatial knowledge is dependent on many factors, such as the level of experience or familiarity with the environment. In addition, delays in the acquisition of spatial knowledge depend to a large extent on the individual's ability to select and organize environmental information.

This progressive process has recently been challenged (Ishikawa and Montello 2006; Brunyé and Taylor 2008) through the demonstration that route knowledge does not necessarily precede survey knowledge, neither does it always lead to the formation of survey knowledge. Alternatively, both forms of knowledge may be acquired independent to each other at the beginning of the learning process (Istomin & Dwyer, 2009).

1.2. Distortions in Cognitive Maps

Given the importance of spatial knowledge for humans, it is perhaps surprising that there is much evidence demonstrating that mental representations of environments are fragmented, schematized and subject to systematic distortions (Golledge, 1987; Golledge

& Spector, 1978; Lynch, 1960; Stevens & Coupe, 1978). There are several theories that address the distortions, for instance hierarchical organisation of memory, the use of landmarks and the structure of the environment, modes of acquisition (navigation, virtual reality), and the contexts of learning (goals or action). These are each considered in the next sections.

1.2.1. Hierarchical Organisation

One source of distortions of distance comes from a wealth of evidence demonstrating that individuals group (chunk) elements together from geographic, environmental and vista space. This process is considered to arise from limitations at encoding which then influence spatial judgments, including perception of distance and the direction of the distance estimation. For instance, Jewish settlers perceive distances between Jewish buildings to be shorter than distances between Jewish and Arab buildings; the reverse bias is also prevalent with Arab settlers and distances between their buildings in comparison to Jewish settlements (Portugali, 1993). In addition, distance estimates to a landmark from an ordinary building are reliably smaller than distance estimates from a landmark to an ordinary building (McNamara and Diwadkar, 1997; Sadalla, Boroughs, and Staplin, 1980). Also, it appears that spatial relation judgements are influenced by geographical factors (Stevens & Coupe, 1978) and semantic information (Hirtle & Mascolo, 1986).

There are three major findings providing evidence for hierarchical organisation of environmental representation which suggest that space is divided into categories or regions by perceptual, conceptual, or physical boundaries (or barriers).

Firstly, Stevens and Coupe (1978) asked students to determine the spatial relationships between cities in different states. Participants were asked to indicate from memory the direction, by drawing a line utilising compass points, of one American city in relation to another, with 'North' noted at the top. Participants systematically reported Reno, Nevada to be north*east* of San Diego, California, even though Reno is actually north*west*. (a map depicting the true relation between San Diego, California and Reno, Nevada in Figure 1.5). In a following task, undertaken in the same series of experiments, participants were asked directly "Which is further east – Reno, Nevada or San Diego, California? Again, most participants chose Reno as the answer. In fact, this distortion is so robust that it is used frequently in general knowledge quizzes (Tversky, 1992). Similar effects were also found for the question "Which is farther north –Montreal, Canada or Seattle, Washington?" (a map showing the true relation between the landmark stimuli is illustrated in Figure 1.5)

Figure 1.5: Map illustrating the relationship between San Diego, California and Reno, Nevada (Pastorino and Doyle-Portillo, 2010)

McNamara (1986) explained the occurrence of this error because mental representations distinguish different regions as differing branches on a 'graph-theoretic tree.' They are organised so that the lower levels provide increasingly detailed spatial knowledge at lower and lower levels of the hierarchy. Regions, therefore can be defined by physical boundaries (e.g., walls between rooms); perceptual boundaries (e.g., lines on a map); or even subjective boundaries that individuals impose on undifferentiated spatial environments (e.g., Hirtle & Jonides, 1985).

Therefore, the error demonstrated with the Reno and San Diego example (Stevens and Coupe, 1978) could be explained in the following steps. It is largely accepted that most people will not have the spatial locations between Reno, Nevada and San Diego California stored in their cognitive map of the United States. Therefore, the judgement of Reno being east of San Diego could be based on their knowledge that Nevada is east of California. Judgements could then even further suggest that Reno was northeast of San Diego, if individuals knew that Reno and San Diego were in the northern and southern parts of Nevada and California respectively. However, Reno is northwest of San Diego.

McNamara (1986) encapsulated Stevens and Coupe's (1978) explanation in Figure 1.6; this illustrates a schematic representation of the spatial relations between Reno and San Diego in their respective regions. Basically, the figure identifies the regions as names in square brackets; spatial relations between regions are identified as labelled links.

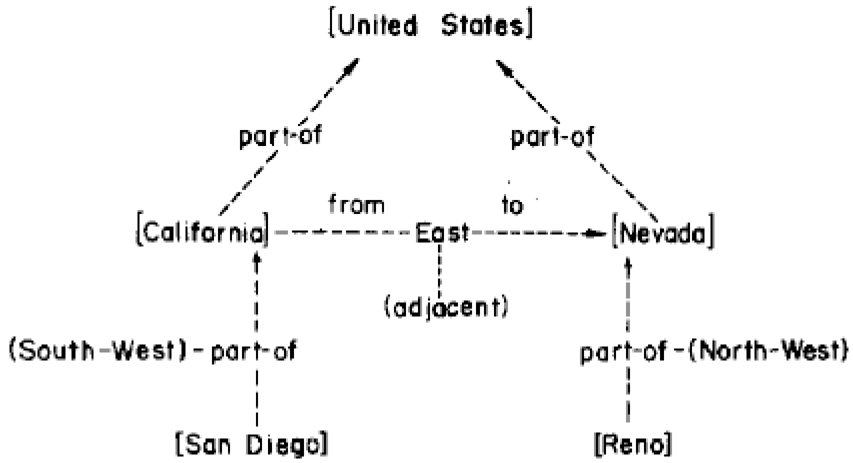

Figure 1.6: Hierarchical representation of states and cities in the Unites States (McNamara, 1986)

McNamara, Ratcliff, & McKoon (1984) presented participants with simple road maps and asked them to learn the locations of the cities which was followed by a recognition test. The dependent measure was the response time participants took to recognise a target city. Participants responded to a target city faster if, during the immediate previous trial, they had just recognised a city close to that target on the map. Thus priming between sequential items in the recognition test served as a function of distance on the map.

McNamara et al. (1984) found that participants responded to a target city when it was primed by a city close in route than when it was primed by a city at a greater distance. McNamara (1986) claims that it is the spatial arrangement and division of the regions that influences direction estimations. Strong hierarchical theories, proposed by Stevens and Coupe (1978) state that that locations in the same region should prime each other more than locations in different regions, but there should be no effects of distances whilst priming across region boundaries. McNamara (1986) proposed that a partial hierarchy is in operation which involves cross region relationships, especially when objects are in close proximity to a border. This bias was established in a small scale laboratory environment 20 x 24 feet, separated into four separate regions of equal size. McNamara (1986) arranged object names across the regions, created with string on the floor (see Fig 1.7).

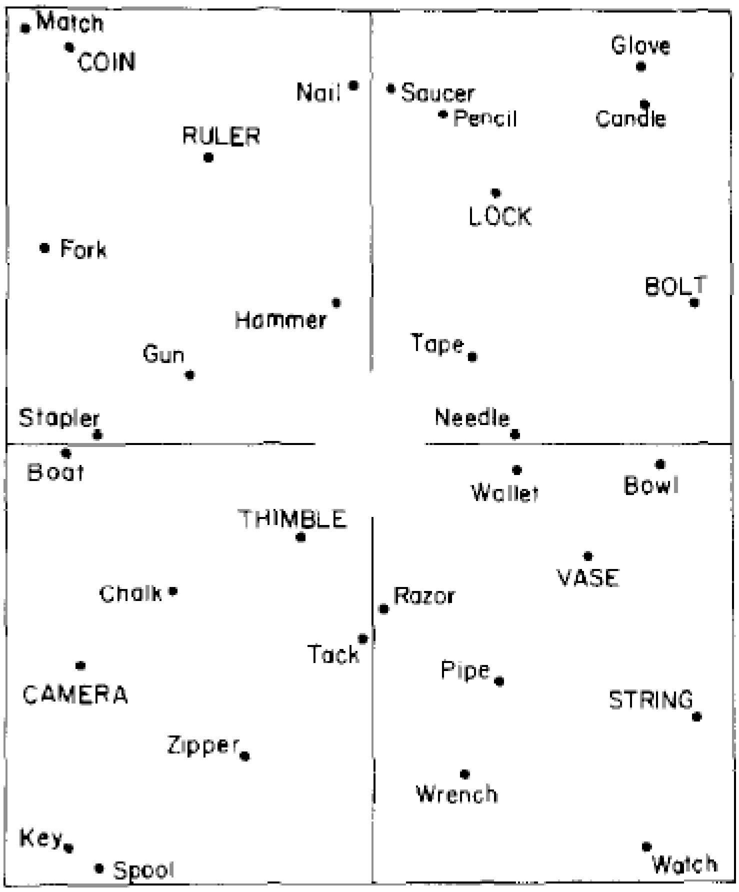

Figure 1.7: Arrangement of objects into regions (McNamara, 1986)

The rationale for using string was to examine the influence of transparent versus opaque boundaries, i.e. walls. At that time transparent boundaries which obstruct navigation had not been compared to transparent boundaries which do not obstruct navigation. This comparison enabled the effects of functional distance on the organization of spatial knowledge to be tested whilst holding the visual distance constant.

In a between groups design, participants learned the locations of objects through direct experience. One group was advised to move freely in the space across the navigational boundaries whilst learning the locations of objects, whereas the constrained group were prohibited from crossing region boundaries and treat the lines as if they were physical barriers.

Pairs of stimuli were arranged at equal distances both within and between the regions. Participants were asked to memorise the position of the stimuli and their memory was subsequently tested for object name recognition, direction estimation, and Euclidean distance estimation. The object name recognition utilised a priming task which presented the name of an object, followed by the name of a target and the participant had to indicate whether the target was one of the objects whose location they had memorised.

The results demonstrated that the organisation of the regions influenced the spatial estimations of the items. For instance, participants' reaction times were faster when the target had been primed by an object in the same 'region' compared to an object from a different region. A north-south axis bias was demonstrated when they were in regions with a north-south relationship. Therefore, McNamara (1986) proposed that spatial relations concerning items in differing regions are encoded and stored at differing levels in a hierarchical system.

The second example supporting hierarchical organisation comes from spatial memory retrieval. For example, when participants are asked to recall locations in a city, there is a tendency to recall places that belong to the same category, either determined by explicit borders (McNamara, 1986; Stevens & Coupe, 1978) or subjective boundaries that the individual has imposed (Hirtle & Jonides, 1985; McNamara, Hardy & Hirtle, 1989). In both instances, the categorisations were built on factors such as spatial arrangement, functional importance, size, and/or semantic similarity.

Evidence of hierarchical structuring is evident though objective boundaries are not present. Figure 1.8 demonstrates an example of an experimental array.

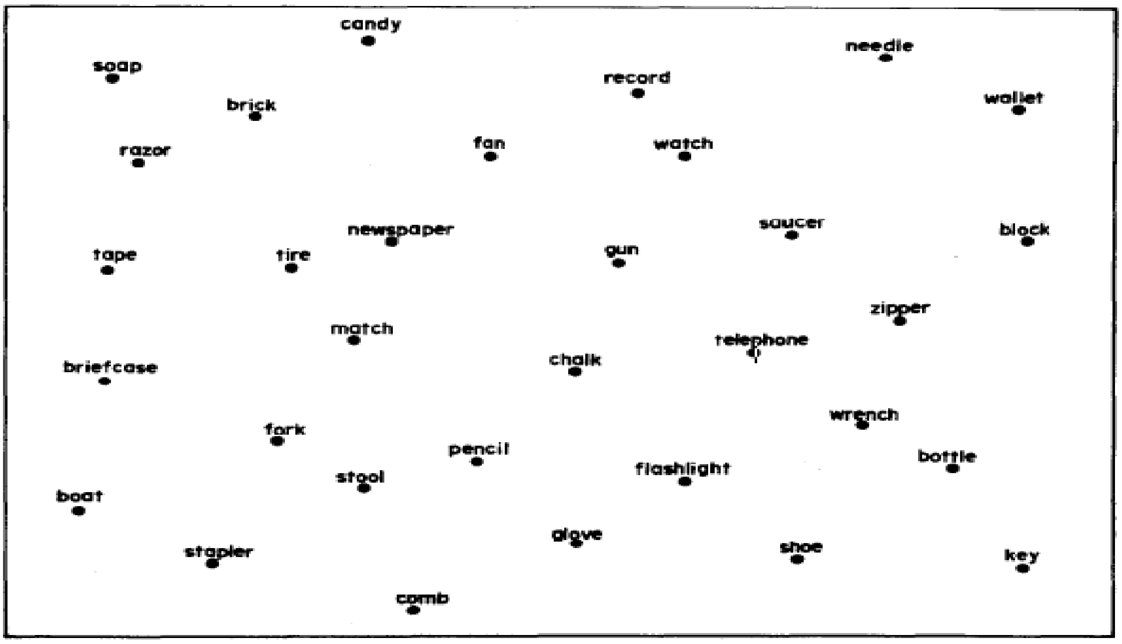

Figure 1.8: An example of one of the maps used in the studies of the subjective organization of spatial memory (McNamara, Hardy, and Hirtle, 1989).

Participants memorising spatial arrays with no physical or perceptual barriers responded to an object more quickly when it was preceded by the name of a neighbouring object than when it was primed by a distant object (McNamara, Hardy, and Hirtle, 1989). Following a free recall task, participants recalled the objects several times. The recall protocols resulted in the construction of ordered trees developed from the sequence in which the participants grouped the objects. Figure 1.9 shows an ordered tree for one of the participants after memorising items contained in Figure 1.8. (The tree is presented on its 'side,' with the root node on the right). The items are the leaves on the tree, and the internal nodes can be one of three kinds: uni-directional, bi-directional and non-directional. Uni-directional nodes indicate that the branches are always recalled in a single order, bidirectional nodes indicate that the branches are always recalled in a single order or its inverse, and non-directional nodes represent all other cases.

This tree specifies that ‘boat’ and ‘briefcase’ formed a cluster in the memory, and that these objects were a sub cluster of a larger cluster that also contained ‘tape, razor, soap, and brick.’ The hypothesis being that the hierarchical structure of a tree captured the internal organization of a given subject’s memory of that space.

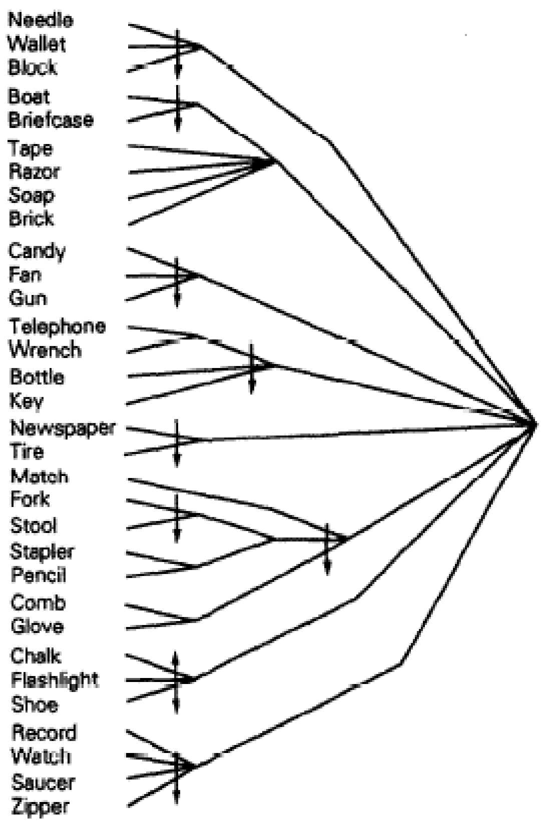

Figure 1.9: Ordered tree for the map in Figure 1.8. (McNamara, Hardy, and Hirtle, 1989).

For example, in the tree in Figure 1.9, "needle" and "wallet" are in the same subjective region, whereas "needle" and "boat" are in different subjective regions. Thus, "boat" and “briefcase" as well as "boat" and "tape" were classified as being in the same subjective region. Finally, participants had to estimate Euclidean distances between pairs of objects. Pairs of object names appeared on a computer screen, and participants had to type in an estimate using the computer keyboard. It was found the mean response time for target objects primed by an object in the same subjective region was 659 ms (e.g., needle-wallet), and the mean response time for target objects primed by an object in a different subjective region was 712 ms (e.g., boat- wallet). Pairs of objects were selected so that the actual inter-object distance was the same regardless of whether the objects were in the same subjective region or in different subjective region. It was found the mean distance estimates were 0.91 cm for same region pairs and 3.4 cm for different region pairs (the actual distance was 3.8 cm).

Hirtle and Jonides (1985) extend these results to real world locations, i.e., at the level of landmarks in Ann Arbor City, Michigan. They asked students to memorise landmarks in central Ann Arbor so that they would be able to recall the names and to draw maps locating each landmark (the map of central Ann Arbor indicating the relative locations of landmarks is shown in Figure 1.10). Participants then took part in several tasks, including multiple-trial recall, map drawing and distance estimation. Recall protocols from individual participants were submitted to the ordered-tree algorithms. There were two distance judgement tasks. In the first task, participants were shown the names of two locations, in sequence, and indicated whether the distance between the two locations was larger or smaller than a standard distance. The second task was a magnitude estimation task. Participants gave a distance estimate, from 1 to 100, for the distance between two locations.

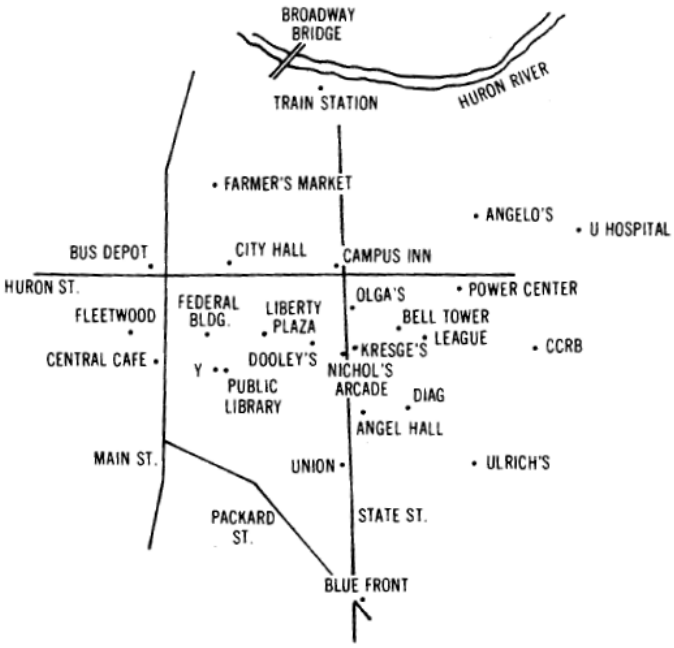

Figure 1.10: Map of Central Ann Arbor (Hirtle & Jonides, 1985)

Hirtle and Jonides (1985) were able to isolate subjective regions of the campus by examining which landmarks were clustered together in hierarchical trees. There was similarity in recall strings across participants, which suggests there is similarity in memory representation of the campus and town (see Figure 1.11).

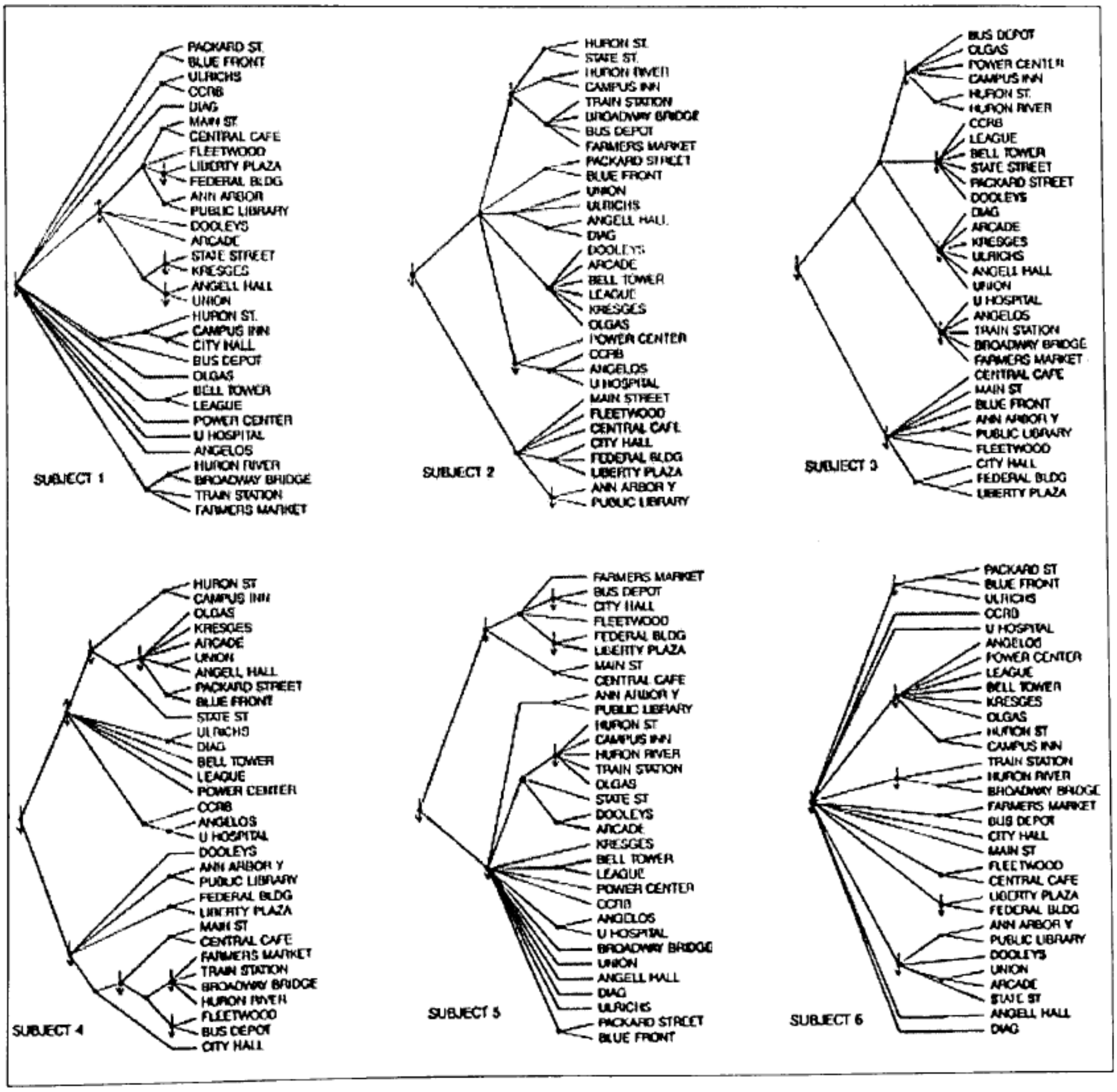

Figure 1.11: Individual ordered trees derived from the recall data of each subject (Hirtle & Jonides, 1985).

For example, four landmarks - Huron River, the train station, the Broadway bridge and the Farmer's Market - frequently appear in the same cluster. The similarity arises because different individuals tend to interact with and perceive an environment somewhat similarly (at least if they have a good deal in common, as students do). The definition of pairs as being within versus across cluster was made individually for each subject. For example, in participant 1’s structured tree, Huron St. - Campus Inn was considered an across-cluster pair relative to Campus Inn - City Hall; whereas it is a within-cluster pair relative to Huron St. - Bus Depot. The pairs League-CCRB and League-Campus Inn were classified, respectively as within and across cluster for Subject 3, and as across and within for Subject 6. The most important result was that distances that are roughly equal on the Euclidean map are consistently judged to be shorter if they lie within regions defined by clusters of landmarks than if they lie across such regions.

The categorisation of space can be easily extrapolated to the case of route knowledge organisation. Previous studies (i.e. Allen, 1981; Hirtle & Hudson, 1991) have shown that during the acquisition of route knowledge individuals tend to organise their experience into distinct segments and that these segments influence subsequent judgements of distances.

In Allen's (1981) study, participants viewed a series of 60 colour slides depicting a 1km walk that extended through several different types of scenery including a wooded park, a university campus, and several residential areas. Slides portrayed viewpoints separated by 20 m. At turns, the view provided 50% overlap of visual fields in successive slides. Slides were projected at a rate of 5 sec. each. After participants had viewed the slide presentation twice their knowledge was tested using distance judgements. For instance, a typical question was:-

> *"If you were standing along the walk where you could see this scene (pointing to the reference scene), would you be closer to where you could see this scene (pointing to the comparison scene on the left) or closer to where you could see this scene (pointing to the comparison scene on the right)?"*

The most important result was that participants were able to make accurate decisions regarding which of two comparison scenes was nearer a reference scene when all three scenes were within a common route segment. However, they grossly distorted their estimates of proximity when the nearer comparison scene was in a route segment adjacent to the one in which the reference scene and more distant comparison scene were located. In such cases, the comparison scene within the same segment was reliably judged to be closer to the reference point, even though it was up to three times the distance from the reference point to the comparison scene in the adjacent route segment.

The results from the research reviewed in this section suggest that space is divided into categories or regions by perceptual, conceptual, or physical boundaries (or barriers) providing strong evidence that cognitive maps have a hierarchical structure. Spatially proximate objects or landmarks are likely to form clusters; landmarks or objects separated by physical barriers are likely to be in separate clusters. Therefore, the spatial relation between landmarks in separate clusters is inferred from their respective locations within a cluster and the relation of the two clusters to each other. Distances between objects within a cluster are likely to be underestimated whereas between cluster distances are likely to be overestimated. The cognitive categorisation of space that underlies spatial judgments extends even to route knowledge.

1.2.2. Reference Points

It is claimed that our spatial knowledge develops sequentially, from relative locations of landmarks, the routes between them, and finally the survey information is acquired (Siegal & White, 1975). When giving directions, individuals will generally utilise the landmarks around which to formulate a detailed route (Tversky, 1992). However, it is well established that some landmarks apparently distort the space surrounding them (Holding, 1992; Sadalla, Burroughs, & Staplin, 1980). Tversky explains that it is partly because of the way that landmarks are used. For example, main features, either implicitly or explicitly, influence the way that the space around them is distorted. In addition, it has been demonstrated that some types of inter-landmark distance judgements are not symmetrical (McNamara & Diwadkar, 1997; Moar & Bower, 1983; Sadalla, Burroughs, & Staplin, 1980).

Sadalla et al. (1980) initially asked students on the Arizona State campus to rate nearby places across a range of factors including historical and cultural importance, familiarity, and visibility from a distance. The sum total of the ratings provided each location with a scale of salience. Reference points were identified as locations on and around the Arizona State campus that were visited often, were well known, and were of historical and cultural importance. For example, within the Arizona State campus the students' union was considered to be more salient compared to the architecture building. Participants were then asked to estimate distances between pairs of campus locations, using either a reference point or a relatively unknown location as referent object. Participants were given response sheets consisting of a semi-circular grid, with a location name printed at the origin, and were asked to place a second name on the grid at the point that best represented the distance between the two locations. The results demonstrated that participants systematically placed the ordinary landmark closer to the salient landmark when the latter was fixed at the origin of the grid than when the ordinary landmark was fixed at the origin. That is, distance estimates were significantly smaller, on average, when the more salient landmark (e.g., the students union) was fixed at the origin than when the more ordinary landmark (e.g., the architecture building) was fixed at the origin. Sadalla et al. concluded that, "... the cognitive distance between reference points and non reference points is asymmetrical" (p. 475). They claimed that the asymmetries in estimated distances were due to the organisation of spatial memories.

In general, judgements, including non spatial judgements are not always optimal. For instance, Tversky (1977) found participants claimed that Cuba is more similar to the Soviet Union than the Soviet Union is to Cuba. Similarly, when people make judgments about spatial distance, their estimations often vary depending upon the origin, the location from where the judgement is to be made from and the destination location (Holyoak &

Mah, 1983;McNamara & Diwadkar, 1997). It is suggested that these asymmetries in judgments are the products of heuristics (Hogarth, 1981; Kleinmurtz & Kleinmuntz, 1981; Newcombe, Huttenlocher, Sandberg & Lie & Johnson, 1999). Heuristics are often useful, as they allow individuals to make reasonably accurate judgments, based on relatively little information and with little cognitive effort. In sum, it appears that they occur either from the way in which information is represented mentally or from limitations in the way that people make distance judgments.

McNamara & Diwadkar (1997) developed the implicit scaling model to account for the asymmetries in proximity judgements. The model claims that asymmetries can be regarded as a collection of psychological principles which are influenced by context which then influence the magnitude estimates. To date, theoretical explanations of asymmetric distance judgments are still in dispute, although the empirical evidence is convincing (Newcombe, Huttenlocher, Sandberg, Lie, & Johnson, 1999). The existence of the asymmetry effect is an obvious violation of metric properties of cognitive maps but has yet to be fully explained in terms of actual cognitive processing.

1.2.3. Influence of Structure of the Environment

Another source of distortions involves the structure of the environment. For instance, the influence of route segmentation, where increased turns in an environment results in an increase of distance estimation, is quite robust and appears to be applicable to distance distortion independent of the magnitude of the environment studied. These segmentation effects have also been found across a range of environment setting, including laboratory settings (Sadalla & Magel, 1980), real world settings (Byrne, 1979; Sadalla & Staplin, 1980a), and map settings (Thorndyke, 1981).

Byrne (1979) asked participants to give estimations of route lengths for routes in urban or rural settings of 300m, 500m, or 750m across routes that were straight paths or had 2-4 turns. Significant effects were found for all three path lengths. Rural routes were judged to be longer than urban routes, straight routes were judged shorter than cornered or angled routes, and shorter routes were overestimated more relative to longer routes.

For actual traversed routes, the perception of route length is influenced by the number of turns that are distributed along the routes. Sadalla and Magel (1980) assigned participants to three paths in Real Space, laid out with masking tape along two floors in a building. Two were 200 feet long, path A had two turns and path B had seven turns, whilst the third path (C) had no turns and was 100 feet in length. Exposure to the paths was counterbalanced and all participants were assigned path C last, with all participants being exposed to all three paths twice. (see Figure 1.12). .

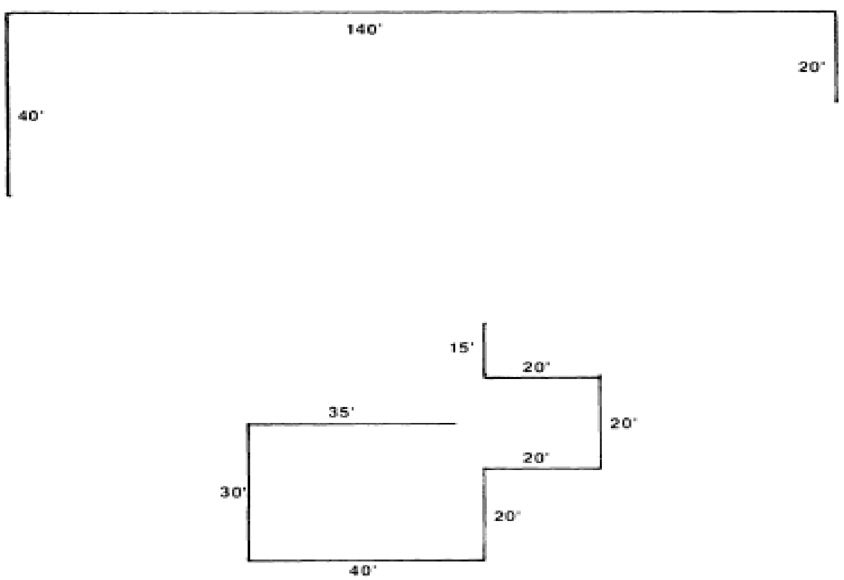

Figure 1.12: Allocentric view of paths – not to scale. (Sadalla & Magel, 1980)

Immediately upon completion of the paths, participants provided with a line and were asked to estimate the distance of each path by marking them on the line. The line informed participants that point X to Y represented the final path (C) length that they walked. They were then asked to mark paths A and B on the line, in relation to Path C. (see Figure 1.13).

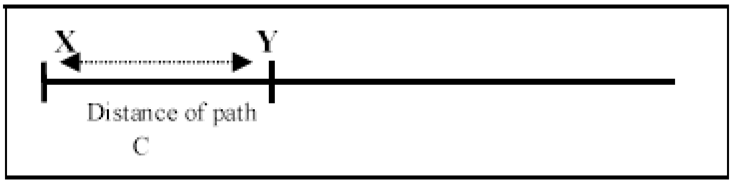

Figure 1.13: An example of the distance estimation judgement of paths A and B. (Sadalla & Magel, 1980).

The results illustrated that the path with 7 turns was systematically estimated and drawn as being longer than the path with 2 turns.

Thorndyke (1981) demonstrated similar results from map settings. Participants were asked to learn maps containing city names (the spatial layout of map is shown in Figure 1.4). The routes between the points contained varying numbers of intervening cities (0, 1, 2, or 3). The cities in each pair lay along a straight route with no turns and the inter-city distances were 100, 200, 300, 400 miles. Participants were asked to study the maps until they had memorised the positions of the cities in it. They were then asked to estimate the distance between pairs of cities.

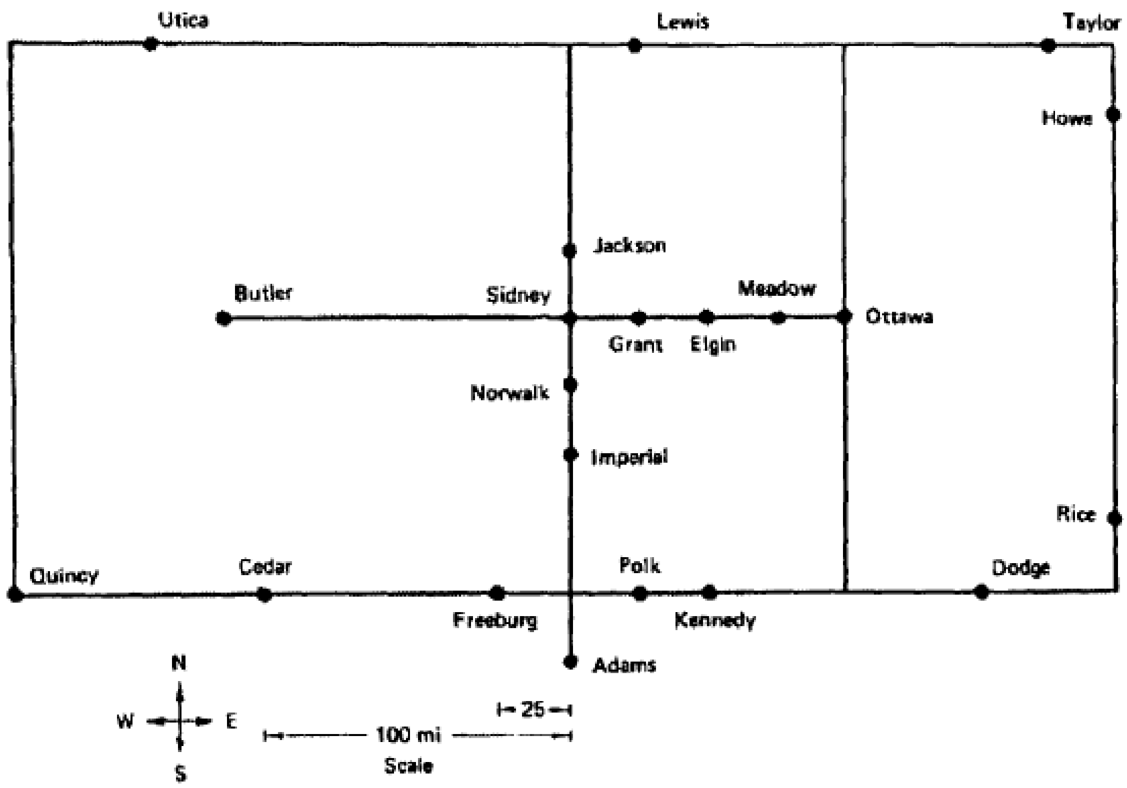

Figure 1.14: Map of the environment used from Thorndyke (1981).

The results indicated that distance estimates were larger when the number of intervening cities between two given cities increased. For example for an equivalent actual distance of 300 miles, the estimates of that distance were 290 miles for no intervening cities and 320 miles for 3 intervening cities.

To date, the explanation for the influence of turns in environmental structure is still unclear. Sadalla & Magel (1980) offered three possible explanations for the effect of turns: the storage hypothesis, the scaling/segmentation hypothesis and the effort hypothesis. The storage hypothesis, supported by the information storage model suggested by Milgram (1973), states that strongly segmented routes contain more information which result in greater processing activity and leads to a greater accumulation of information. Therefore, complex routes are estimated as being longer because they have more information which impacts on the storage capacity of that information. Sadalla, Staplin, and Burroughs (1979) examined the storage hypothesis in more detail by asking participants to walk pathways containing intersections with either high-frequency or low-frequency proper names. The pathway with high-frequency names was estimated as longer than the pathway with low-frequency names. Subsequent tests of memory for names indicated that high- and low-frequency names were recognized equally well, but that the former were recalled more easily. In addition, prompting participants with intersection names eliminated the difference in distance estimation between high and low-frequency name conditions. Their second study demonstrated that category prompts increased information recall and also increased estimated distance. The results were interpreted as highlighting the significance of the role of information retrieval in distance cognition.

The scaling or segmentation, hypothesis supposes that turns divide the route into segments, and that the perceived lengths of each segment are mentally added to create the estimate of the whole route. If there are two routes of the same physical length, the one with more turns has shorter segments. Larger distances tend to be psychologically compressed in relation to their physical length and smaller distances tend to be overestimated (Dainoff, Miskie, Wilson, & Crane, 1974). Therefore, the longer segments of the route with fewer turns are underestimated relative to the shorter segments of the route with more turns. When these “condensed” segments are added to estimate the length of the whole route, the route with fewer turns is thus underestimated relative to the route with more turns.

The third hypothesis, the effort hypothesis, is more simplistic as it assumes that participants base the distance they have traversed on the time taken to walk a route. Therefore, walking complex routes takes longer as it will involve slowing down prior to turning corners and additional steps are required to turn the corners.

Whilst the effect of turns has been replicated (Jansen-Osmann & Berendt, 2002; Bugmann & Coventry, 2008), it is noted that some studies have failed to find an effect (Herman, Norton & Klein, 1986; Jansen-Osmann & Wiedenbauer, 2004). Jansen-Osmann et al. (2004) suggest that the effect of turns is influenced by the experimental design used with effects appearing in within participant designs but not in between participant designs. They offered two explanations of why the within-participants design would show the route angularity effect but the between-participants design would not. First, they argued that the comparison of routes in the within-participants design may result in a relative judgment process, whereas the lack of such comparisons in the between-participants design forces the participant to make an absolute judgment. Second, they argued that the within-participants design required participants to maintain more information in memory, which may have led them to rely on a turn-based heuristic in order to estimate distance.

To summarise we can see that there are a variety of circumstances which result in distance distortions, from hierarchical organisation (McNamara, 1986), grouping (McNamara, Hardy & Hirtle, 1989), context (McNamara & Diwadkar, 1989), size and salience of objects (Sadalla, Burroughs & Staplin, 1980), the structure of the environment (Sadalla & Magel, 1980) and also the reference objects chosen (e.g. McNamara & Diwadkar, 1997;Moar & Bower, 1983 etc). Yet, these multiple distortions are largely dealt with in isolation.

In the second section of the thesis, we consider another possible source of distortions in distance; goals. As discussed above, Tolman (1955) argued that goals are important in a spatial context and stated that the performance and behaviour of rats navigating in space was directly influenced by their drives (physiological and psychological states). The contribution goals play in distance perception has never been developed and this thesis will demonstrate that goals may contribute to distance estimation distortions. Section III in the thesis will further address the role of attention as a fundamental contributory factor towards an explanation of the effect of goals in distance estimation. Moreover, in the later sections of this thesis, it is proposed that attention may provide a unified means with which to understand why these distance distortions occur as a whole.

Before tackling these issues in the body of the thesis, it remains in this chapter to turn to a final possible means of distortion, that is, the medium through which an environment is learnt. This provides a motivation for testing distance distortions in a range of media in the rest of this thesis.

1.3. Modes of Learning

It is thought that humans have additional mechanisms, compared to non human animals, affecting the development of symbolic representations (Gattis, 2001; Gauvain, 2001; Taylor & Tversky, 1992, Uttal, 2000). These mechanisms allow humans to gather spatial representations from indirect sources, such as maps, verbal descriptions, diagrams and, more recently, Virtual Reality (VR). However, the equivalence of learning through different media has not been established consistently. The next section will therefore address the development of spatial knowledge via these media and VR in comparison with spatial knowledge acquired in ‘real’ environments.

1.3.1. Maps

The relation between maps and the development of spatial cognition is reciprocal in nature (Liben & Downs, 1989, 1991; Gauvain, 1993; 1995; Liben, 1999). As children develop new and more sophisticated ways of mentally representing and using spatial information, their understanding of maps improves. Furthermore, children’s developing conception of maps influences how they understand and conceive spatial information.

Generally, research focuses on the differences between the specific media from which information is extracted and real space. Thorndyke & Hayes-Roth (1982) demonstrated that knowledge acquired from maps is different from knowledge acquired from navigation by comparing participants (employees) who had navigational experience in a building but had never seen a map of that building, to those who had seen a map of the building but had never been in it. The participants with navigational experience were separated into three groups, depending on their time of exposure to the building (1-2 months, 6-12 months, and 13-24 months). The participants with no navigational experience but studied the map were psychology students. The psychology students were also divided into three groups. All of the map learners were asked to study the map of the building until they could recreate the map without error. The first group, from the map learning condition, ceased to be exposed to the map at this point, the second group received 30 more minutes to study the map and the third group an additional 60 minutes. Participants were then required to perform five judgements:

1) Euclidean distance, i.e., the straight-line distance from the start point to the destination
2) Route distance, i.e., the distance from the start point and the destination along the hallways,
3) Orientation, i.e., pointing to the destination from the start point,
4) Simulated orientation, i.e., while in a closed office, pointing to the destination from an imagined position at the start point,
5) Location, i.e., indicating the location of the destination on a piece of paper containing the start point and another reference point.

The results demonstrated that route distance estimates made from spatial knowledge acquired from free exploration are more accurate than Euclidean judgements, with the reverse being true for spatial knowledge acquired from maps. Secondly, although route estimates were more accurate than Euclidean estimates initially, for those with navigation experience, this difference diminished with increased exploration experience. No such improvement was observed in the map learning groups.

These findings indicate that the knowledge acquired by studying a map of an environment is both qualitatively and quantitatively limited in comparison to that acquired by navigating in an actual environment. Thorndyke and Hayes-Roth (1982) suggest that map learners acquire a bird's eye view of the environment that encodes survey knowledge. When knowledge is used to perform spatial judgements, individuals have direct access to the knowledge required to estimate Euclidean distances and judge object locations. However, information in maps has to be transferred from survey perspective into route perspective which is associated with switching costs (Lee & Tversky, 2001; Shelton & McNamara, 2004).

1.3.2. Virtual Reality (VR)

Whilst it is largely acknowledged that survey knowledge acquired from allocentric views such as maps or figures are a poor substitute for the real experience, some researchers claim that knowledge acquired from navigating through VR models is similar to real world experience (i.e. Jansen-Osmann & Berendt, 2002; Ruddle, Payne & Jones, 1997).

A key requirement of VR is to simulate or facilitate behaviour that would occur in the real world. Failure to meet this prerequisite will naturally limit the conclusions drawn from this mode of presentation. The goal of any system utilising VR is to provide environments that give the user the sense of being present in the simulated world (Steuer, 1992). Although VR technology offers an alluring basis for a rich sensory experience, and, more importantly, an opportunity to experience navigation in real time, research into the effectiveness of VR is mixed.

It has been argued that the availability of proprioceptive information may give little advantage when navigating a complex virtual maze (Ruddle & Peruch, 2004), that optic flow alone is sufficient to enable efficient navigation (Riecke, van Veen & Bulthoff, 2002) and that learning through rotational movements is unaffected by the lack of vestibular feedback (Tlauka, 2007). Furthermore, several studies have found that learning transfers efficiently between real world and virtual equivalents (Bliss, Tidwell & Guest, 1997; Ruddle & Peruch, 1997;Wilson, Foreman & Tlauka, 1996, 1997) suggesting that similar cognitive mechanisms are involved in both domains (Richardson, Montello & Hegarty, 1999).

In contrast, a number of studies have called into question the equivalence of VR to real space in the acquisition of spatial knowledge. A potential limiting factor of using passive VR environments is that they typically fail to provide the proprioceptive and vestibular feedback that would be encountered in a real world environment (i.e. Campos, Nusseck, Wallraven, Mohler, & Bülthoff, 2009). Ruddle and Lessels (2006) found information to be acquired more efficiently when using proprioceptive and vestibular feedback as opposed to simulated optic flow.

From an egocentric viewpoint, users' ability to judge directions and relative distances in a virtual building model is similar to that in the real building, improving with increased exploration (Ruddle, Payne & Jones, 1997). However, there is much evidence stating that judgements of absolute distances in VR are compressed by as much as 50% (Witmer and Kline, 1998; Knapp and Loomis; 2004; Thompson, et al., 2004). This has been attributed to the quality of the graphics and the blinkered nature of the field of view, which is typically 60-100 degrees in desk top virtual environments (Ruddle, et al., 1997). Sizes appear smaller in both horizontal and vertical dimensions (Henry, 1992) and increased exploration yields no improvement (Turner & Turner, 1997). Campos et al., (2008) state this is highly unlikely to result from one contributory factor, but a combined effect of different factors. In addition to this, there are problems with 'perceptual- motor' coupling contributing to reported differences for speed perception (Witmer & Sadowski, 1998; Banton et al., 2005).

The impact of visual flow on distance estimation was highlighted by Riesser, Pick, Ashmead, & Garing (1995), who asked participants to walk on a treadmill, which was on a trailer and pulled by a tractor. The treadmill and tractor were then set to different speeds, and participants were then asked to walk the equivalent length. In the fast condition the treadmill was set at 8 kph and the trailer at 5 kph and in the slow condition, the treadmill operated at 7 kph and the trailer at 17 kph. The results found that participants walked too far after the faster condition, but not far enough following the slower condition. These results suggest a relationship between memories for distance travelled, visual flow, distance traversed, speed of travel, and degree of biomechanical effort. In addition, the results suggest that visual and mechanical signals generated by the gait are continually calibrated against each other so that the speed of optic flow together with mechanical receptors, provide an anticipated optic flow. When the relationships change suddenly, just as when we step off a walkway at an airport, the walking speed is misjudged until recalibration takes place. Even in natural situations relationships between optic flow and mechanical feedback can vary, as changes to physiological states, effort or slope.

The importance of motor input has also been raised by Ruddle and Lessels (2006), who found the presence of proprioceptive and vestibular feedback in a complex small scale VR environment was more effective for learning than when information acquired was reliant solely on simulated optic flow. Ruddle et al. followed on to claim that only motor input is required to successfully navigate in one's environment with minimal visual information and that physical rotations alone were insufficient. Conversely, it has also been found that learning through rotational movements can be as effective as free walking (Riecke et al, 2010). This makes the issue of utilising the appropriate VR system to interface with the task a key priority, especially given that individuals, most often, will change some of the features of their pace in accordance with the environmental features and the purpose of their journey.

In summary, we can see that the various ways in which space is processed impacts on spatial judgements. Spatial knowledge gained through navigation results in procedural knowledge that is more efficient particularly in route distance estimations, whereas knowledge acquired by studying maps of the environment results in survey knowledge that is more efficient particularly in Euclidean distance estimations. The utilisation of VR requires consideration of a variety of factors but, generally its use yields shorter distance and reduced speed judgements.

Nonetheless, there is much work to be done to establish just how spatial knowledge acquired through VR relates to knowledge in real space. One of the subsidiary goals of this thesis is to contribute to this understanding.

1.4. Summary and Précis of the Thesis

In this chapter we have reviewed the literature concerning what form of representations people construct from their experience of environments and how egocentric and allocentric representations combine. Furthermore, it has been shown that our representations of the environment violate the metric properties which are often attributed to cognitive maps. How the type of learning and media in which learning takes place impinges on our spatial representation construction has also been considered.

Yet, the underlying contributory mechanisms in the distance distortion literature have still to be identified as there is little evidence pinning down why the distortions are there. This thesis aims to consider that the distortions occur for other reasons than those proposed and intends to identify the contributory mechanisms involved.

The first aim of this thesis is to explore the possible role goals may play in distortion of distance estimations. The organisation of the thesis is as follows. In Section II of this thesis the focus is on the work conducted on goals. In Chapter 2 we review how goals might influence distance estimation in real space and VR. Chapter 3 reports Experiment 1 which develops the materials and identifies two goal scenarios for use in later experiments. Experiments 2 and 3 investigate the role of goals on distance estimation, in a straight path in both real and virtual space. In addition, Experiments 4 and 5 investigate the role of goals in a more complex environment, again in both real and virtual space. The results of these four experiments will identify that investigations into goals are necessary to understand how individuals comprehend the space around them, for both distance and time perception across real and virtual space and that the aspects of the goals will directly influence representations. Chapter 4 presents Experiment 6, which aims to tease apart the contributory mechanisms into the effect of goals and it will become clear that goals may play a role in moderating of attention for distance and time during navigation. The results of this experiment provide the impetus to examine the role of attention in greater detail as an explanatory mechanism in Section III.

In Section III, Chapter 5 reviews the importance of attention in theories of time estimation and examines whether manipulation of attention might account for distortions in distance estimation. Chapter 6 reports two experiments which manipulate attention in two ways. Firstly, Experiment 7 shows that by drawing attention to the environment in VR, we can demonstrate how distance estimation increases. This experiment investigates within and between modality interference through the use of visual flashes or tones. Secondly, Experiment 8 uses a blindfold methodology, adapted from Bugmann & Coventry (2008), which restricts visual information and allows attention to be directly taken away from the environment through auditory distracters. This experiment involved participants being taken on an imaginary walk in a town whilst visiting various landmarks along the way. Attention was taken away from the environment through the inclusion of naturalistic attentional stimuli, i.e. "Look, a bird in the sky!" This allowed the influence of attentional distracters to be examined in a no goal condition and also make a direct comparison with the goal scenarios, which were adopted from the first set of experiments. The control condition exhibited the opposite effect to that in Experiment 7 by demonstrating that distance estimations are reduced when attention is grabbed outside of the environment. The goal scenarios were resistant to the extraneous stimuli. The findings from Experiment 7 and the control condition in Experiment 8 are consistent with the literature on time and attention. The effects of goals on attention are supported by literature on attention.

Finally, Chapter 7 discusses the findings of this research in the context of theoretical and practical implications. The limitations of the research will also be discussed, together with suggestions for future research. In particular, the role of attention as an explanation for a range of distortions demonstrated in the spatial cognition literature will be reviewed and developed.

SECTION II-GOALS

CHAPTER 2.

Introduction

The previous chapter reviewed the development of cognitive maps and also a range of distortions which highlight that the metric assumptions of cognitive maps are violated across a variety of conditions. It also reviewed the media from which we learn about our environments, with a specific focus on VR, where the research investigating the usefulness of VR has reported mixed results. One of the main conclusions was that goals are a necessary part of human behaviour and play a fundamental role in why individuals navigate in their environment. However, they have, so far, eluded investigation within real space and VR. This section of the thesis aims to explore whether goals influence memory for distance across a range of environments.

Before presenting a series of studies showing the effects of goals on distance and time estimation, the present chapter will briefly review the importance of goals in higher level cognition.

2.1 Historical Context

Documentation of the meaning of goals in human behaviour traces back to Taylor (1911) where goal setting was identified as a way of improving human resource management and maximizing industrial profit. This was developed further in Maslow's (1943) Hierarchy of Needs, see Figure 2.1, which identified the importance of goals to humans. Maslow acknowledged the limitations of the behaviourist approach, especially concerning the mapping of the behaviour from rats onto humans, stating that rats have "few motivations other than physiological ones" (p. 374). Maslow's (1943) hierarchical approach to human nature, whilst not without its critics, is now one of the most widely cited and most influential models used in the field of psychology (Kenrick, Griskevicius, Neuberg & Schaller, 2010).

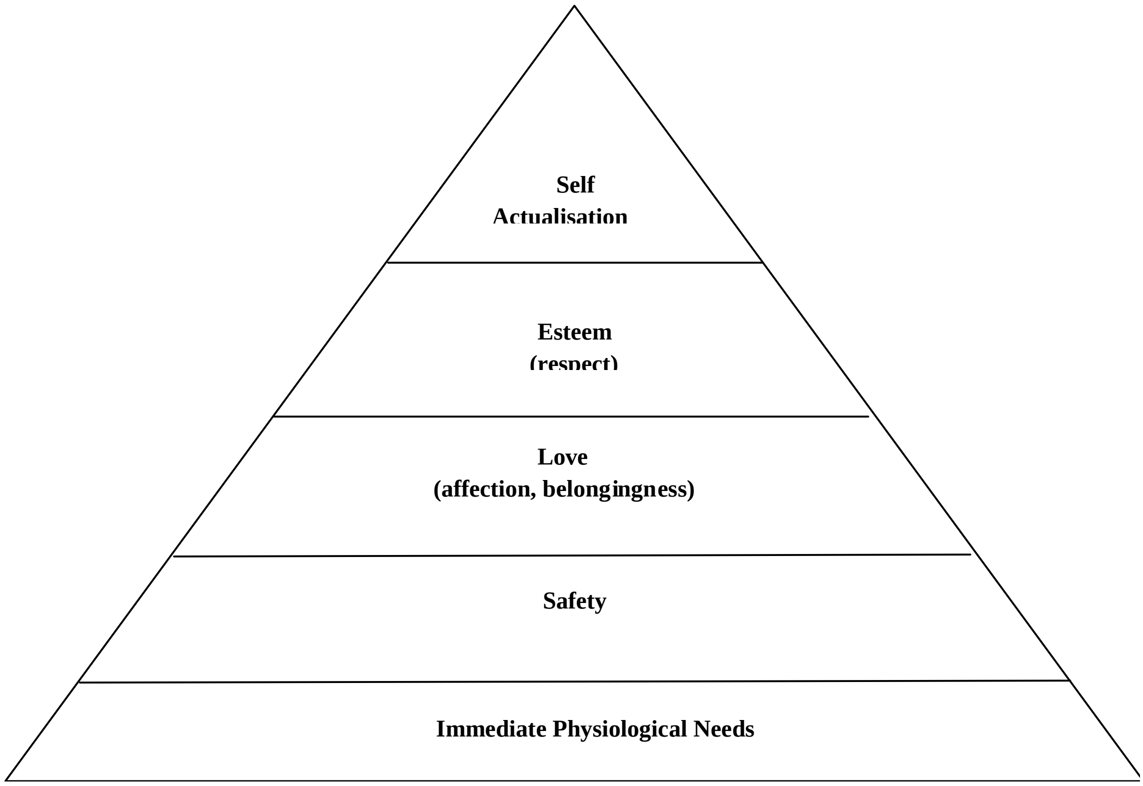

Figure 2.1: Maslow's (1943) Hierarchy of Needs (Kenrick, Griskevicius, Neuberg & Schaller (2010)

There are two ideas at the core of Maslow's motivation theory:

a) There are multiple and independent motivational/goal systems

b) These motives form a hierarchy in which some goals have priority over others.

Maslow acknowledged that goals were an integral part of human nature, employed to aid survival and fulfil various purposes. Goals were also seen to be multi faceted, varying across many dimensions, such as, basic needs for survival, individual desire for achievement and consciousness. Moreover, Maslow did not regard goals as universal, as culture and gender played a role in their importance. For instance, one might assume the immediate physiological need of hunger to be considerably more desirable and urgent if the individual is living in an environment where food supply is scarce as opposed to an individual living in a modern industrialized society, where food is abundant.

A criticism of Maslow's (1943) theory is that it was developed from merely manipulating environments and observing behaviour, which provides limited insight into why people behave as they do. Nevertheless, the theory is considered pertinent within industrial and applied settings of human resource management, where the main focus is on utilising goals in order to motivate and increase productivity.

Goals continue to be seen as a fundamental part of human nature and have been highlighted from an evolutionary perspective (e.g. Meston & Buss, 2007) through to a modern day context (e.g. Ackerman & Kenrick, 2009; Kameda & Tindale, 2006; Keltner, Haidt & Shiota, 2006; Van Vugt & Ver Lange, 2006). Humans devote a great deal of effort fulfilling their own goals. This can be merely for self gratification, such as increasing social status and social privileges, survival reasons or just for increased self esteem.

Stereotypical goals are represented as behaviours that are rewarding or desirable to engage in or to aspire to (Dijksterhuis & Aarts, 2010) and they can be consciously strived towards or unconsciously activated, for instance, by environmental features (Aarts & Dijkdsterhuis, 2000). However, the outcome or end state of a goal (often called the goal state), can be either positive, which the individual would want to approach or negative, which they would prefer to avoid (Higgins, 1997).

There is evidence that individuals repeatedly engage in behaviours guided by the anticipated realisation of goals and that individuals can hold multiple and sometimes, opposing goals (Bandura, 1982). The notion of opposing negative and positive goals lead to a direct connection between cognition and goals by recognising that the setting and achievement of goals impacted on future cognitive states, whereby goals influenced self efficacy, which was directly affected by cognition in relation to those active goals (Olsen, 1979).

There is now a growing body of literature within the social cognition domain demonstrating that goals can influence higher cognitive processes and overt behaviour, without conscious awareness of the goal. For example, participants discreetly exposed to motivational words such as “strive” and “succeed” prior to being given a set of anagrams outperformed those who were not primed with the motivational goal words (Bargh, Gollwitzer, Lee-Chai, Barndollar & Trotschel, 2001). The influence of unconscious goals has also demonstrated that such goal priming leads to qualities associated with motivational states or “goal-directedness,” such as persistence and increased effort (e.g., Aarts, Custers & Veltkamp , 2008; Bargh et al., 2001; Fitzsimons & Bargh, 2003; Lakin & Chartrand, 2003; Shah, Friedman & Kruglanski, 2002).

From a cognitive perspective, human observers are better at detecting an object in a visual scene when they know in advance something about its features, such as its location, motion or colour (Eriksen, & Hoffman, 1973; Posner, Snyder & Davidson, 1980; Ball & Sekuler, 1980; Egeth, Virzi, & Garbart, 1984; Dosher & Lu, 2000). In addition, factors such as novelty and unexpectedness, influence attention and subsequent representations thus reflecting the interaction between cognitive and sensory influences. (Corbetta & Shulman, 2002).

Furthermore, the influence of goals on how we process and remember information is already well established and documented in several areas, such as text comprehension (Graesser, Singer, & Trabasso, 1994; van den Broek, Lorch, Linderholm, & Gustafson, 2001) and event understanding (Zacks, Tversky, & Iyer, 2001). Goals also play a fundamental role in autobiographical memory (Conway, 2005; Holland & Kensinger, 2010) as they motivate memory processes to act partially in the interest of the individual to maintain a coherent sense of self. It is postulated that this occurs by self relevant goals being continually active at memory encoding and retrieval. However, when it comes to spatial cognition the evidence for the influence of goals on how we represent our environment is scant.

2.2. Goals in Spatial Cognition

Despite the salience of goals in psychology generally, there are very few studies that examine goals in spatial cognition. Rossano and Reardon (1999) identified goal specificity as an inhibitory factor in the development of survey knowledge, claiming goals sacrifice schematic development, possibly by diverting attention from the environment and focusing more resources towards the goals. The Rossano and Reardon study is typical of experiments that do investigate goals through focussing primarily on way finding. A number of studies have shown that how participants learn about an unfamiliar environment and what they are asked to learn about that environment affects memory for that environment (Curiel & Radvansky, 1997; Gauvain & Rogoff, 1986; Magliano, Cohen, Allen, & Rodrigue, 1995; Taylor, Naylor, & Chechile, 1999; Taylor & Naylor, 2002).

Actually guiding the individuals' attention also has illustrated differences in memory for environments according to the learnt perspective. Thorndyke & Hayes Roth (1982), as described in Chapter 1, demonstrated how a different perspective during learning influenced participants' memory for their environment. Taylor et al. (1999) manipulated this further by varying perspective at learning. They asked participants to learn about a university campus building by moving around the building or by examining a map of it. Additionally, they were instructed to either learn the spatial layout of the environment or the shortest routes between locations across both the route and map conditions. After learning, Taylor et al. found that participants were more accurate for Euclidean distance estimates (straight line distances between places) when they had learned the environment through a map or were given the goal to learn the shortest routes than when they learned through traversing the environment or had the goal to learn the spatial layout. Conversely participants were more accurate for route distance estimates when they learned the environment through traversing it or when they had the goal to learn routes from a survey perspective. This demonstrates that maps, which are presented as an external survey perspective can be cognitively transformed to represent route perspectives.

Although learning does affect performance at retrieval, it is also the case that performance at retrieval is nevertheless flexible. That is, the representations are not solely influenced or maintained by the mode of learning (e.g., Denis, 2008; Lee & Tversky, 2001; Taylor & Tversky, 1992). For instance, participants performing recognition/priming and Euclidian distance estimation tasks after learning from survey or route descriptions demonstrated a high degree of flexibility, suggesting that the representations originated from either description type contained information abstracted from the learned perspective.

Moreover, these representations were fluid to the extent that they could be applied quickly and accurately towards multiple tasks (Noordzij & Postma, 2005).

This would suggest that individuals are not passive recipients to the mode of acquisition at the learning perspective and can demonstrate flexibility between perspectives. In addition there is much evidence of robust top down influences which indicate that learners' intentions and strategies shape their spatial memories (i.e. Bruynè, Rapp and Taylor, 2008; Bruynè & Taylor, 2008a, 2008b; Taylor & Tversky, 1992; Tversky, 1993). There are two possible explanations for this effect. Firstly, goals may guide attention and actively gather relevant information during learning. A second explanation is that the information is automatically organized into a goal-congruent spatial model that guides retrieval.

Bruynè and Taylor (2009) highlighted the role of attention through the measurement of eye movements. Participants were assigned to one of three goal groups; survey, route and none, and studied two adapted maps of different college campuses, depicting 14 landmarks and 6 street names. Map presentations were counterbalanced and participants were instructed to study each map for 5 minutes whilst eye tracking devices recorded their fixations. Participants in the survey goal were instructed to learn the overall layout of the environment, in particular, where the buildings were to one another in canonical co-ordinates i.e. east, west, etc. The route goal participants were instructed to learn the routes around the environment paying attention how to get from one place to another and remembering the things that they would pass on the way. The no goal/no perspective control group were advised to learn everything they could about the environment. All conditions were presented with the maps on a computer monitor.

Participants were then given 10 minutes to reconstruct and draw the maps which were scored for landmark and street name recall, relative landmark and street positioning and quadrant accuracy. The map drawing exercise was then followed with a self paced statement verification test, such as “the administration building is south-east of Cleves Hall” or “standing with Moy Hall to your left, you reach physical education by walking straight ahead and turning right.”

The eye movement fixations were divided into six regions of interest (ROI) for each map (see Figure 2.2). The regions were; peripheral versus central (controlling for the amount of objects populating the area), buildings, streets, street names and the compass rose which was pointing north.

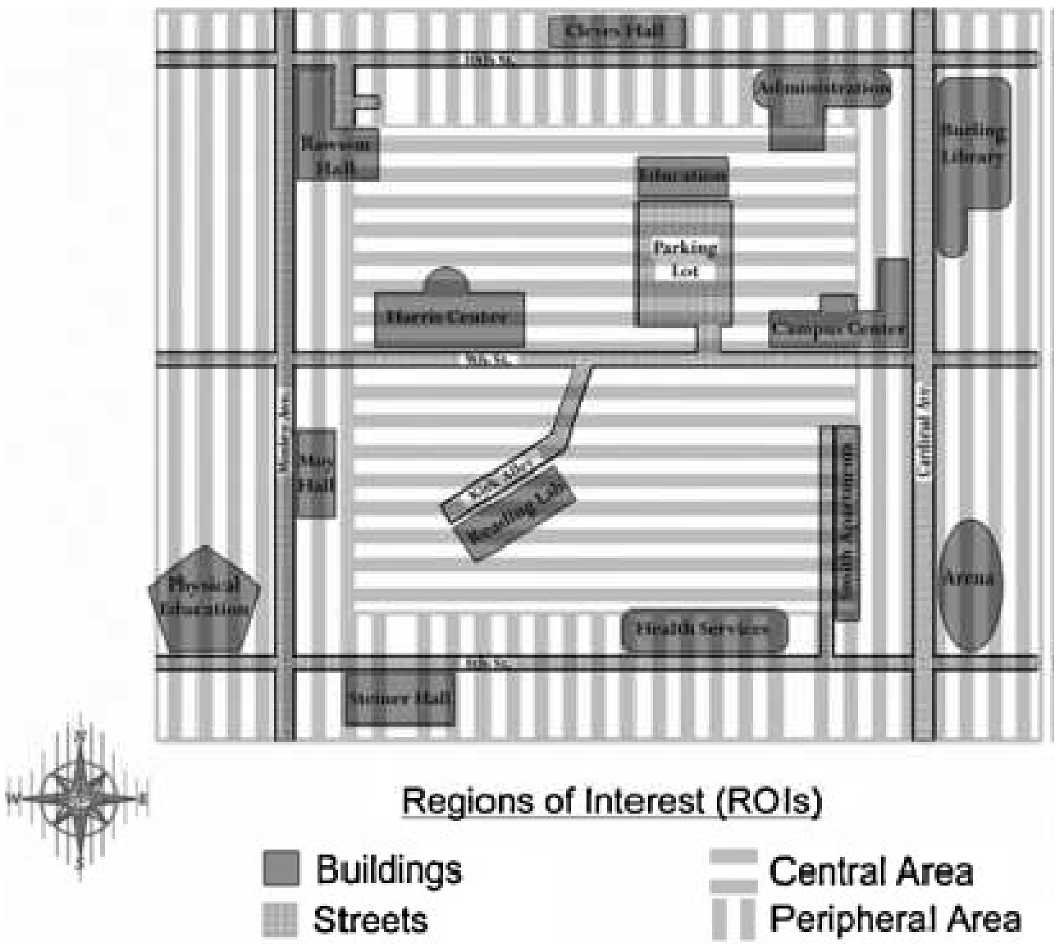

Figure 2.2: Map of Grinnell College campus, with the six analysed regions of interest (ROIs) depicted: buildings, streets, street names, peripheral and central areas and compass rose (Bruyné, & Taylor, 2009)

The study found eye fixations were allocated from the central to the peripheral areas, which confirms previous research stating that map studying progresses from central to global features of the environment (Golledge & Spector, 1978) although this bias was not evident when the environment was learned. During the first 2 minutes of learning participants focused on goal congruent elements of the map learning, that is in the survey goal condition participants had longer fixations on buildings and the compass rose whereas the route goal perspective resulted in longer fixations on streets and street names. The study demonstrated that the perspective goal influenced visual attention directly, but only early on in the study. Bruyné and Taylor (2009) explain this behaviour as being consistent with the development of early memory schemas where eye movements are guided during learning. This performance is also consistent with the investigation of goals during advertisement viewing (Rayner, Miller & Rotello, 2008).

The Bruyné and Taylor (2009) study highlights the importance of acknowledging the role of goals on encoding as it clearly demonstrates the influence of visual attention towards pertinent environmental elements. For instance, in the survey condition participants' eye movements were focused on aspects crucial to gaining knowledge about the overall layout of the environment; buildings and compass coordinates. However, in contrast, the route goal condition biased attention towards streets and street names. In addition, the subsequent memory task also highlighted the switching costs involved when transferring between survey and route perspectives, supporting earlier work (Taylor et al., 1999; van Asselen, Fritschy & Postma, 2006). Another interesting aspect to the study was that the participants in the no goal condition performed equally as well across both perspectives and were able to demonstrate perspective flexibility without compromising accuracy. Overall, goal contextualization provides perspective testing advantages and supports a growing body of research that demonstrates the malleability of spatial memories which can clearly be influenced by a multitude of factors (Brunyé, Rapp & Taylor, 2008; Bruyné & Taylor, 2008 a, 2008b; Chabanne, Péruch, Denis & Thinus-Blance, 2004; De Beni, Pazzaglia, Gyselinck, & Meneghetti, 2005; Denis, 2008; Lee & Tversky, 2005; Noordzij & Postma, 2005; Noordzij, Zuidhoek & Postma, 2006, Péruch, Chabanne, Nese, Thinus-Blanc & Denis, 2006; Shelton & McNamara, 2004).

These studies highlight that goals are important and demonstrate that goals influence what people attend to in the environment. Whilst this is true, people can be reasonably flexible. However, the studies only demonstrate the effects of goals through the measurement of way finding accuracies and associated subsequent costs. Way finding is not just about recalling elements and their relation to each other, as metric distance also plays a role in our spatial memories. It is to this issue that we will now turn to.

2.3. Goals and Metric Properties

Much of the work referred to in spatial cognition refers to actual way finding accuracies. However, the aim of this thesis is to investigate the everyday influences on navigation and how these affect the metric qualities that cognitive maps are meant to possess. Whilst much of the area of spatial cognition refers to bottom up processes of environmental features distorting distance estimations, there is very little research identifying the top down processes utilized in the attainment of goals. In order to understand the possible influence, it is necessary to review goals and its influence on metric properties from a wider perspective in cognitive science.

In everyday life, individuals pursue an assortment of goals, differing across a range of dimensions in importance, urgency and desirability, which influence our cognitive processes. Goals are representational structures that guide the individual in his/her pursuit of an end state or a reference state. When the goal has a desirable end state, it is classed as an ‘approach’ goal, which results in the individual reducing the psychological distance to the end state. However, when the goal has an undesirable end state, it is termed as an ‘avoidance’ goal, which results in the individual wanting to increase the distance between themselves and the end state (Carver & Scheier, 1990; 1998; Carver, 2006). These processes are explained as utilising feedback loops, which are governed by two bipolar dimensions of the affective experience. One is generated by affect loops linked to approach behaviour; the other is generated by those linked to avoidance. For instance, this is demonstrated neatly by identifying how goals can influence objects by identifying individuals’ who vary in the values they assign to physical objects.

A classic study demonstrated that children from affluent backgrounds judge the size of coins to be smaller than children from less privileged backgrounds, thus exhibiting the influence of value relations between goals and the mental representations of the size of physical objects (Bruner & Goodman, 1947). More recently, Balcetis & Dunning (2010) demonstrated that financially strapped college students viewed $100 as being physically closer when they were advised that they had an opportunity to win the sum of money through drawing a card from a deck as opposed to when the $100 was to be directly pocketed by the experimenter, thus establishing the effect of desirability on metric distances.

Brendl, Markman & Messner (2003) manipulated goals states, or desire, in cigarette smokers by depriving or not depriving them of smoking and asking them to judge the length of a cigarette. Findings demonstrated that the deprived smokers (i.e., smokers with an active goal to smoke) judged the length of a cigarette to be longer than did non-deprived smokers. This also identifies the influence of the degree of a need or goal on the perception of relevant objects, similar to Bruner and Goodman’s study.

Most recently, there has been a considerable body of work which demonstrates that estimations of physical dimensions, including distance, size and slope, are affected by a range of variables going beyond approach and avoidance effects. More importantly, the research highlights the anticipatory role of perception. Individuals see the world in terms of what they plan to do, not what they are doing at that precise moment. For instance, action-specific perceptual effects have been identified as perceivers report a target as being closer when they intend to reach a target beyond arms reach with a tool than when they intend to reach it without the tool (Witt Proffitt & Epstein, 2005; Witt & Proffitt, 2008). The role of effort and physical demands in perception have been shown to affect participants' estimates of how distal a visible landmark is, or how long it would take them to get there, in line with the view that perceptual judgments are mediated by the perceiver's capacity to act within that given space, at a given time (e.g. Proffitt, 2006a, 2006b; Proffitt, Stefanucci, Banton & Epstein, 2003; Witt, Proffitt & Epstein, 2004). For example, Proffitt et al. (2003) found that stationary participants with a distal landmark in view (a cone) estimated the distance to that landmark as being further away when wearing a heavy backpack than when not wearing the backpack. The role of effort was also demonstrated by asking participants to judge a distance; this estimation was preceded by squeezing a heavy ball versus a light ball with the intention of throwing the ball at a target (Proffitt *et al.* 2003; Witt *et al.* 2004).

Unsurprisingly, physical states also influence perception, for instance, hills are reported to be harder to climb for elderly or fatigued individuals and after having exercised heavily, people perceive hills as steeper than when they are not fatigued (Bhalla & Proffitt, 1999; Proffitt, Bhalla, Gossweiler & Midgett, 1995). In addition, there is also evidence of bio energetic costs influencing the perception of geometric properties of our environment. For instance glucose levels have been shown to influence perception as individuals reported a hill as being less steep following the consumption of a glucose-containing drink than did participants who had consumed a drink containing non-caloric sweetener (Schnall, Zadra, Proffitt, 2010). Furthermore, individual difference measures in factors related to bioenergetic state, such as fatigue, sleep quality, fitness, mood, and stress, also correlated with perception, with poorer energetic states being associated with steeper perceptions of hill slant.

There are also examples demonstrating this in the area of experts and novices or successful athletes, with a mixed direction of distance distortions. For instance, expert urban climbers (parkours) will report walls to be smaller and take a shorter run in an attempt to jump over a wall as opposed to novices (Taylor, Witt & Sugovic, 2010). Similarly, judgments of the size of a softball are correlated with batting performance (Witt and Proffitt, 2005), and judgments of golf hole size correlate with golf performance (Witt et al 2008). This suggests that an athlete's performance influences perception, that is, the more successful they are, influences the perception of the size of the target. However, there is additional evidence to show that these distortions can be transient, depending on moment to moment experiences. For instance, Witt & Dorsch (2009) demonstrated that individuals with the most successful kicks in American football perceived the field goal posts to be farther apart and perceived the crossbar to be closer to the ground compared to participants who made fewer kicks. The perceptual effects related to performance only after kicking the football but not before kicking, indicating a performance related effect. More interestingly, the types of performance errors influenced specific aspects of perception. For instance, when kicks were missed, players reported a narrowing of the goal posts or a heightening of the crossbar, i.e. the more kicks that were missed left or right of the target, the narrower the field goal posts looked. In addition, the more kicks that were missed short of the target, the taller the field goal crossbar looked, demonstrating the importance of performance and overall success rate as a factor in size perception.

In the studies just described, the distal cue is constant, with the exception of Witt and Proffitt (2005) and Witt et al. (2008) where the judgements were made from memory. However, the distortions do appear to be systematic. Nevertheless, there is very little evidence of distance judgements being influenced during or following the performance of an action. The role of distortions from estimates given directly following a walked path is an area that needs to be addressed.

2.4. Distortions from a different perspective

The previous studies provide evidence of distortions utilizing perspective estimates. Studies demonstrating distance distortions during traversal are scarce. However, Balcetis & Dunning (2007) demonstrated the effect of cognitive dissonance on perception of a path after an actual walked distance in the natural environment, through high choice, no choice and control conditions. Participants in the high choice condition were given the option to either walk across a quadrangle wearing a Carmen Miranda outfit consisting of a coconut brassiere, a fruit laden head dress and a grass skirt, or take part in another unpleasant task, the details of which were never disclosed. In the no choice condition, participants were told to wear the outfit. Finally, there was a control condition which did not involve dressing up. All participants were informed that the experimenter was interested in emotional reactions to an embarrassing experience and they were then asked to walk across a university quadrangle either wearing the outfit or not, depending on the condition they were assigned to. Participants were then asked to estimate the distance of the path walked and the high-choice condition participants, to resolve dissonance, perceived the environment to be shorter than did the participants in the low-choice and control conditions. Moreover, participants in the no choice condition reported the distances to be longer than both the control and the two choice condition. Furthermore, the participants who chose to wear the outfit walked at the same pace as the control group, who did not have to wear the Carmen Miranda outfit. This suggests that perception of distance walked is mediated by individual variables – in this case, cognitive dissonance.

A second experiment by Balcetis & Dunning (2007) also aimed to replicate the finding of the Carmen Miranda study, in that motivation to resolve cognitive dissonance influences perception of environments, in this case examining perceptions of a hill's slope. This study was modelled on the Bhalla & Proffit (1999) findings which suggest that visual perception functions in order to regulate physical behaviours. For instance, when people are required to use greater effort to complete a task action, the perceptual system portrays the environment as more challenging so as to guide them toward what actions to take (or to avoid), as well as how to execute those actions successfully. Hence, distances to walk seem longer after one straps on a heavy backpack (Proffitt, Stefanucci, Banton, & Epstein, 2003), and hills appear steeper when one wears a backpack, is fatigued after a long run, is out of shape, or is not in good health (Bhalla & Proffitt, 1999). Balcetis and Dunning's (2010) second experiment asked participants to estimate the slope of the hill while looking at it before they performed the task. Instead of asking participants to write down a number representing how steep they perceived the hill to be, they were asked to directly indicate their perception of slope by drawing it, as well as by matching the incline using a movable arm on a protractor (two visual angle-matching tasks modelled after those used by Bhalla & Proffitt, 1999; see Figure 2.3).

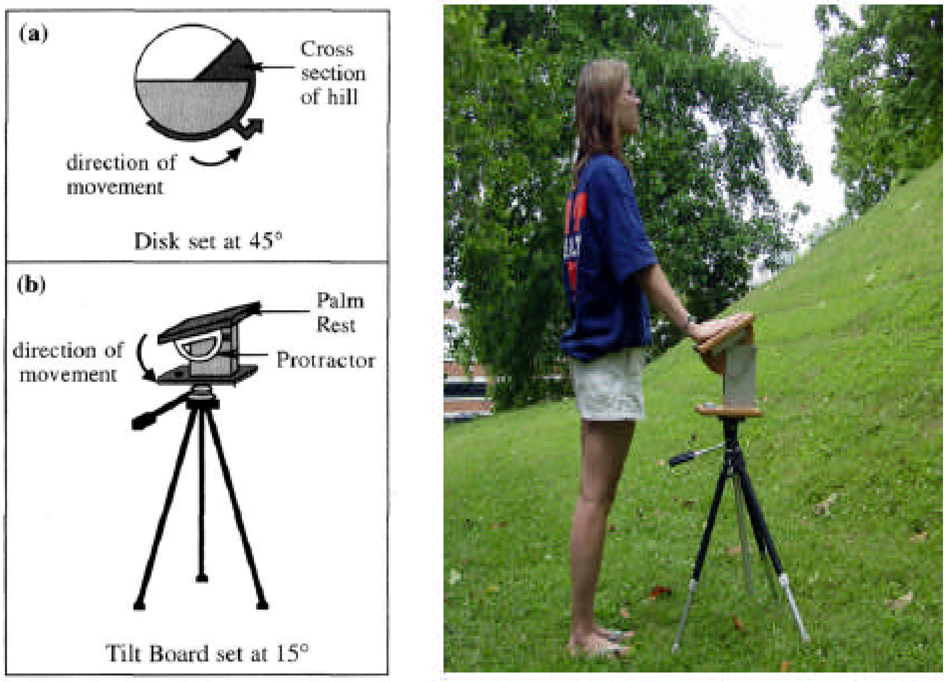

Figure 2.3 a: visual measure; b: haptic measure (adapted from Bhalla & Proffitt, 1999)

In this study participants were individually accompanied by the experimenter to the foot of a hill and an identical method to the first experiment was used. Again participants were randomly allocated to a high choice, no choice and control condition, manipulated in the same manner as the Carmen Miranda Study (CM). The results followed the same pattern to the CM study, with participants in the high-choice condition estimating the slope of the hill as being shallower than the no choice participants and control participants (who were given no cover story).

These two studies provide strong evidence that motivational pressure, including higher-order, intrapsychic motivations such as cognitive dissonance reduction, can influence perceptual processes. T his therefore demonstrates that internal states influence perception. When experiencing dissonance, perceivers may take advantage of an opportunity to ‘‘push’’ around perceptual experiences to return to a preferred baseline of cognitive dissonance. These results explore how other higher-order goals, beyond the binding of effort and energy (Proffitt et al., 2003), influence how individuals represent the environment.

2.5. Summary

We have seen in this section that there are both external and internal influences that contribute to the distortion of our representations of everyday objects and space. Proffitt and colleagues propose that perception of distance is directly influenced by one's current physiological potential (perceived anticipated effort) to perform an intended action (Proffitt, 2006a, 2006b; Proffitt, Stefanucci, Banton, & Epstein, 2003; Witt, Proffitt, & Epstein, 2004; see also Fajen, 2005; Land, 2006; Yarbus, 1967). This assumes a direct relationship which predicts that, as effort associated with acting on a target (e.g., walking or throwing) increases, then the perceived target distance also increases. If this is the case then a plethora of unrecognized effort-related factors might influence perception (e.g., sleep deprivation, emotional state, fatigue, age, injury, and so on). Proffitt claims that there are many reciprocal interconnections, functionally and neurally, linking incoming visual information, the control of behaviour, and non visual (cognitive) factors (Proffitt, 2006b); and he therefore posits that that the mechanisms underlying distance perception should not be conceived as a series of encapsulated, sequential processing stages.

To date, several studies have produced results consistent with an effect of perceived anticipated effort on perception (e.g. Bhalla & Proffitt, 1999; Creem-Regehr, Willemsen, Gooch, & Thompson, 2005; Proffitt et al., 2003; Witt et al., 2004). However, it has also been suggested that many of the results obtained are the result of demand characteristics (Durgin et al., 2009; Woods, Philbeck & Danoff, 2009). The term *demand characteristics* refers to conditions in which the experimental predictions are transparent to participants, either because the experimenter or design somehow communicates the predictions to the participants or because participants' independent hypotheses about the predicted outcomes happen to match those of the experimenter. In either case, participants could respond in a way that supports these predictions without there being any change in perceived distance per se, especially in within participant designs.

Furthermore, failed replications of Proffitt et al.'s (2003) study found anomalies in the underestimations compared to the replications (Durgin et al., 2009). For instance, Proffitt et al.'s no-backpack group tended to underestimate target distances by approximately 26%, considerably less accurate than is typical for verbal estimates obtained under similar viewing conditions (which average about 17% undershooting; Da Silva, 1985; Woods et al. 2009).

Witt et al. (2004) found that verbal distance estimates were larger after participants tossed a heavy ball than after they tossed a lighter ball. However, there are possible methodological flaws raised with this as the experimenter threw the ball directly back to the participant after each successive throw by the participant. Because experimenters must exert effort to throw a ball, just as participants do, seeing the experimenter exert effort might draw participants' attention to the ball weight and influence response calibration, thus providing visual cues. Woods et al. (2009) claim that it could result from participants' frustration at throwing inaccurately with the heavier ball, they also postulate that the experimenters' inaccuracy was not reported and therefore could have influenced the participants' judgements. Overall, the critique highlights the importance of internal states as an explanatory factor on the manipulation of distance estimation as highlighted earlier by Balcetis and Dunning (2007). From this we can postulate that goals could be an important contributory factor on distance estimation and, moreover, we can see that the desirability of a goal state can both vary and influence our representations.

Finally, the influence of goals for learning new environments has also been demonstrated (e.g. Taylor & Naylor, 1999; van Asselen et al, 2006; Bruyné et al. 2009).

For instance, map like configurations improve our knowledge for environments in congruent allocentric survey knowledge conditions and direct experience aides route recall, whilst specific goals to learn survey or route knowledge also improves performance for recall in those domains. In addition, it has been demonstrated that individuals have the ability to attend to environmental features according to the active goal at learning and that, in everyday life, perceptual cues and immediate memory for size and distance can be distorted by many non perceptual factors.

Given these effects, we consider the possibility that goals will influence immediate memory for distance. In the next chapter we test whether the variation in desirability and urgency of a goal influences our immediate memory for distance and time.

CHAPTER 3.

The Effect of Goals in Real and Virtual Space

We have seen from Chapters 1 and 2 that perception and memory for distance is subject to distortions. There is also some evidence that the individuals' experience during navigation clearly influences distance estimations within that space (Balcetis & Dunning, 2007). Combined with the myriad of influences of goals on higher level cognition considered in Chapter 2, this chapter considers directly whether goals affect distance estimation following traversal of a straight line path in real and virtual environments (Experiments 2 and 3) and environments with several turns (Experiments 4 and 5).

Given the mixed reports to the fidelity of VR mention in Chapter 1 (i.e. Campos et al., 2007; Ruddle & Lessels, 2006), a secondary aim of these experiments was to test the fidelity of a large screen stereo projection VR system. A fundamental requirement of the usefulness of VR is that it simulates or captures behaviour that would occur in the real world. Failure to meet these factors will naturally limit the conclusions drawn from this as a valid media for measuring the experience of space.

The present series of experiments in this chapter were based on the following hypothesis. Given that we often go places associated with goals varying in urgency and desirability, one can envisage that these differences in urgency may influence the perception of how far (and for how long) one has walked, even though the distances are the same. Evaluating the influence of goals of varying urgency on distance and time estimation is the main goal of this chapter is that predicting the influence of goals on preferences requires determining the scope of the participants' goals across the scale of desirability and urgency.

Later in the chapter, five experiments are reported whose participants were given goals to perform by delivering various objects/information to the end of a route. These studies were designed to examine the effect of varying goals on immediate memory for distance. However, prior to conducting these studies, it was necessary to select the goal scenarios to be used in a systematic way and it is to this selection that we now turn.

3.1. Experiment 1.

Selection of Goal Scenarios

The first study in this series of experiments was designed to enable the identification of appropriate goal scenarios to be used during the main body of experiments. Parameters for goals were obtained from the review of goals in the previous chapter. In particular, approach and avoidance goals (i.e. Higgins, 1997) and desirability have been identified as playing a key role in the execution of tasks (e.g., Einstein et al., 2005; Kliegel et al., 2001). In addition, importance was also considered to be another factor that might influence a task being acted upon (i.e. Penningroth & Scott, 2011). A constraint in the selection of goal scenarios was the nature of the experiments to be later conducted. Taking those factors together, desirability and urgency were considered to be key parameters with which to select the goals for later use.

In order to avoid the possibility of demand characteristics as mentioned earlier in the chapter, it was important to use a between participants design. This meant that using lots of goal scenarios would not be possible, and recognising that, the scenarios were therefore selected carefully & systematically. It was decided that realistic scenarios would therefore need to be both maximally different from one another. Twelve scenarios were generated, which were thought to vary across the parameters of urgency and desirability, with a mixture of positive, negative and neutral tasks. Participants were given questionnaires containing the twelve scenarios which they had to rate in terms of desirability or urgency.

3.1.1. Method

In order to select appropriate goal scenarios for use in the later experiments, a questionnaire method was used. Naturalistic scenarios, thought to vary in urgency and desirability (with some negative, positive and neutral scenarios) were presented. Participants were asked to rate each scenario in terms of urgency and desirability, both from their own perspective (as the person responsible for completing the task), and from the perspective at the end of the task (i.e. the recipient of the object/information), in order to maintain participant naivety and avoid demand characteristics. All participants completed all questions.

3.1.1.1. Experimental Design

A 12 scenario, motivation (desirability vs. urgency) repeated measures design was used.

3.1.1.2. Participants

Twenty undergraduate students, 10 male and 10 female, age ranged between 18 and 30 years (mean age = 20.6, SD = 3.9) completed the questionnaire for course credits.

3.1.1.3. Materials

The scenarios were as follows:-

1. Your friend has emailed you to print out an essay for a course they are studying as their printer has broken. The deadline is in a few hours. Your task is to get to the computer shop to buy an ink-cartridge for your printer which has run out of ink.
2. You have been working as part of a pair and have your final working meeting today. You have all of your input on your pen drive – but you are on the bus and have left it at home. Your task is to retrieve it before you meet your friend.
3. Your friend is critically ill in hospital. Your task is to deliver essential drugs to the hospital to save your friend's life.
4. It is your friend's birthday & you are meeting them in a pub. Your task is to buy them a gift before the shops close.
5. You and your friend have won a raffle – an all expenses paid holiday. Your task is to pick up the tickets for your friend and yourself.
6. You are about to be interviewed for a well-paid job (an interview your partner has organised for you). Your task is to get to the office building where you will be interviewed for the job without being late.
7. You wake up following a 'Work's Night Out.' The sweater you borrowed from your friend is ruined. Your job is to visit your friend to tell them what you have done.
8. You had agreed to buy tickets for your favourite band for you and a friend. The agent site was closed and you missed out on the tickets. Your task is to tell your friend that you won't be going.
9. You have to tell a lover that you don't love them anymore (you have found someone else). Your task is to go to their house and break the news to them.
10. You have just taken part in a psychology experiment –it was really tiring and boring. You are about to tell your friend that you have signed them up for it.
11. The final degree results have just been published. You have promised to deliver the results to your friend. The envelope containing the results isn't sealed, and you see that they have failed every single exam. Your task is to deliver the results to them.
12. You have borrowed a very expensive text book from your friend. Your dog has chewed the edges. Your task is to deliver the book to your friend.

3.1.1.4. Procedure

Participants were presented with the scenarios (in written form) and presented with a set of four questions per scenario, with the following instructions:-

"The following questionnaire presents various scenarios in which you have to collect/deliver an item to a recipient. For each scenario, please rate the following:-

- *How keen would you be to complete the task for the recipient?*

- *How urgent is it from your point of view that you complete the task?*

You must then consider how the recipient of the item/information would feel and identify:-

- *How keen do you think the recipient would be to receive the item/information?*
- *How urgent is it from the recipient's point of view that the item/information is delivered? "*

The questions were presented in the order of deliverer and recipient perspective under each scenario. The participants were then asked to give ratings for desirability and urgency using a 7 point Likert scale, where 1 represents "not at all" and 7 represents "extremely." The order of the scenarios was randomised and the latter two questions from the perspective of the recipient were included merely to maintain naivety and avoid demand characteristics. These questions were

3.1.2. Results

Mean ratings were collapsed across desirability and urgency and are displayed in Table 3.1.

Table 3.1: Descriptive Statistics for Combined Desirability and Urgency According to Scenario from the Questionnaire

Scenario (numbers refer to key on page 78)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Mean	4.58	5.6	6.85	5.6	6.58	6.85	3.15	4.08	3.75	4.73	3.13	3.65
(σ)	0.36	0.27	0.07	0.2	0.14	0.11	0.26	0.25	0.25	0.21	0.25	0.28

The goal of the analysis was to afford selection of two goal scenarios in the first instance that varied both in terms of desirability and urgency (for use in later experiments).

In order to do so, a repeated measures ANOVA was conducted; 12 Scenario x 2 Measure (desirability versus urgency). (Table 3.2.)

Table 3.2: Results of Three-Way Repeated Measures ANOVA for Scenario Identification

Source	df and F value	MS	Significance
Scenario (S)	$F_{(11,209)} = 37.18$	77.45	*
Measure (M) (desirability/urgency)	$F_{(1, 19)} = 22.91$	99.92	*
S x M	$F_{(11, 209)} = 11.53$	14.27	*

Note. *: $p < 0.001$

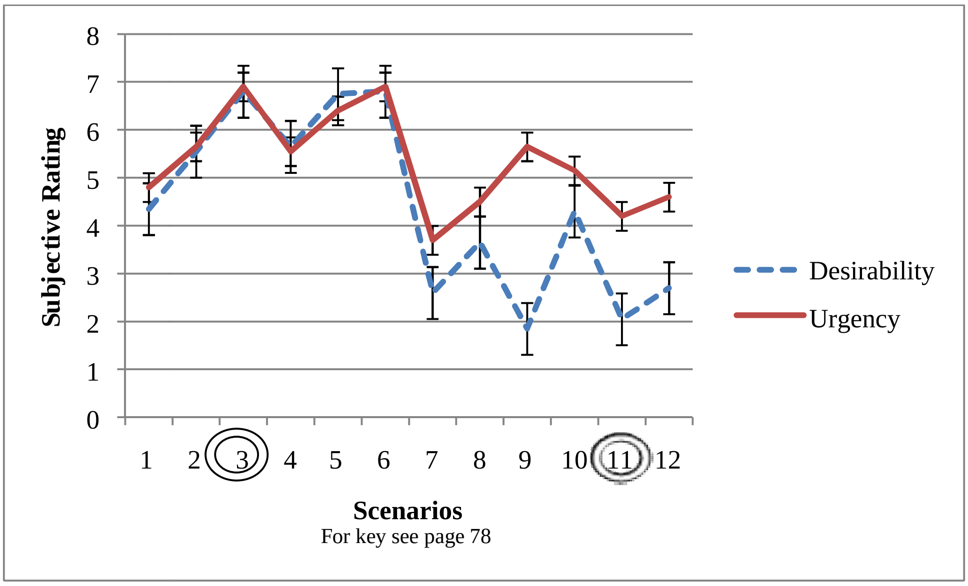

Figure 3.1: Main Effect of Urgency and Desirability on Scenario

As can be seen from Table 3.2, there was a significant main effect of Scenario, with some scenarios being rated higher in desirability and urgency than others. There was also a main effect of measure: overall ratings for urgency were higher (M = 64) than ratings for desirability (M = 53). There was also a significant interaction between scenario and measure (desirability versus urgency) (Figure 3.1). For our purpose it was important to select two scenarios, one significantly higher than the other, on both dimensions (urgency and desirability). These would represent a high urgency/desirability and low urgency/desirability scenario.

The analysis identified two possible scenarios for each of the criteria, Scenarios 3 and 6 were the highest scoring and scenarios 7 and 11 were the lowest scoring for urgency and desirability combined. At this stage scenario 6, attending a job interview, was discounted as it was realised that the task could have been interpreted as being conducted for the protagonist as opposed to on behalf of another individual and therefore was potentially confounded. Bonferonni pairwise comparisons, identified that there were greatest differences for desirability and urgency ratings for two specific scenarios: Scenario 3; delivering medicine to a sick friend (desirability M= 6.8; urgency M = 6.9) and Scenario 11; (desirability M= 2.1; urgency M = 4.2) MSe = 0.412, $p < 0.00001$. These scenarios, representing high urgency/high desirability and low urgency/low desirability, served as the goal scenarios for the next series of experiments.

3.1.3. Discussion

These results enabled us to identify the most and least desirable scenarios according to desirability and urgency. Scenario 3; "*Your friend is critically ill in hospital. Your task is to deliver essential drugs to the hospital to save your friend's life,*" (mean = 6.85) was consistently reported as being most urgent and desirable task to conduct across all of the scenarios and was therefore identified as the high urgency/desirability scenario to be used in the future experiments. Using the same criteria, Scenario 11; "*The final degree results have just been published. You have promised to deliver the results to your friend. The envelope containing the results isn't sealed, and you see that they have failed every single* *exam. Your task is to deliver the results to them,"* (mean = 3.13) was also the lowest scoring for combined ratings in desirability and urgency. (Table 3.1).

These scenarios, representing high urgency/high desirability and low urgency/low desirability respectively, served as the goal scenarios for the following Experiments in the remaining section of this chapter.

3.2. Experiments 2 and 3.

The Effects of Goals on Immediate Memory for Distance and Time in Real and Virtual Environments; Straight Path

The aim of this chapter is to test whether goals varying in urgency and desirability affect memory for distance. As reviewed previously, in spite of the vast literature relating to cognitive maps, there is a distinct paucity of research examining the effect of goals whilst travelling through an environment on distance perception. There is some evidence for enhanced recall of learned environments if the goal type and recall methods are congruent, for instance if participants are asked to learn an environment from a survey perspective they will be more accurate and faster when recalling from a survey perspective as opposed to a route perspective (e.g. Taylor and Naylor, 1999; Rossano and Reardon, 1999). However, this research does not examine the more basic function that goals serve. Individuals very rarely walk through an environment without a purpose; usually one travels somewhere for a reason. Using the goal scenarios identified in Experiment 1; delivering medication to a sick friend in hospital and delivering an envelope containing failed exam results to a friend by hand - this experiment set out to examine the effects of these goals on immediate memory for distance following a walk along a route.

To achieve this, participants were informed that they were taking part in an experiment examining role play in the environment. Whilst blindfolded they would be told to imagine a scenario and, when they fully understood the task, the blindfold would be removed and they would then have to conduct the task, whilst imagining themselves as the main protagonist in the scenario.

The present studies are based on the following hypothesis. As goals have been demonstrated to directly influence both current and future cognitive states (e.g. Bandura, 1982; Higgins, 1997; Olsen, 1979), then one can expect the role of goals to influence our behaviour in an environment and subsequent representations of that environment.

It was hypothesised that the high urgency/high desirability goal and low urgency/low desirability will differ in comparison to the control (no goal) condition. Given the goal scenarios chosen from Experiment 1, it was expected that the introduction of the goal states when walking a fixed distance and at a set speed will affect perception of distance and therefore perception of that distance in both real and virtual space.

3.2.1. Method Outline

3.2.1.1. Measurement

According to Montello (2009), quantitative information about distances is required to understand human behaviour as sequences of landmarks provide an insufficient basis from which to navigate or plan. Montello even claims that some kind of distance knowledge was required by our ancient ancestors in order to navigate successfully. There are a variety of methods available for collecting estimations of distance (Montello, 1991) which can involve marking distances on representational lines to indicate relative distances between paths (Sadalla & Magel, 1980; Jansen Osmann & Berendt, 2002; Jansen Osmann & Wiedenbauer, 2006), numerical estimates of distance (e.g. McNamara, 1986; Bugmann, Coventry & Newstead, 2007), throwing distances (Sahm, Creem-Regehr, Thompson & Willemsen, 2005) and blind rewalked distances (Witmer and Sadowski 1998).

Importantly, there is much evidence that individuals make metrically accurate distance estimates, and can perform shortcut and detour tasks with some accuracy, which supports the psychological reality of distance knowledge (Montello, 1997; Ishikawa & Montello, 2006). In order to maintain the ecological validity of the study, all remaining experiments in this section use numerical estimates. The use of numerical estimates ensured that the studies were as naturalistic and real as possible as they are most likely to be used in everyday settings. For instance, if a stranger to an area were to as a local how long they would have to travel to get to a location, numerical estimates of time and distance would be provided – as opposed to marking relative distances on paper.

3.2.2. Methodology

Participants took part in a 'role play' Experiment 1 in real space - a human environment constructed out of large polystyrene blocks (Experiments 2 and 4) and, identical virtual analogues of these environments (Experiments 3 and 5). The methodology was designed to control for potential confounding variables such as visual cues, walking pace, and time spent within the environment. This was achieved by ensuring participants could walk comfortably and unconsciously to the sound of a metronome, preset to their natural walking pace (following Bugmann & Coventry, 2008). The environment was covered in clear tarpaulin to reduce visual cues, while allowing light to still filter through.

The 'role play' scenarios used were those identified in Experiment 1, where participants were asked to rate various scenarios in terms of urgency. The two scenarios were selected based on high and low values on desirability and urgency [1] as follows:

- High Urgency – delivering medication to a friend critically ill in hospital.

[1] From herein the scenarios will be referred to as High Urgency and Low Urgency and Control

- Low Urgency – delivering exam results to a friend, and opening the envelope so that you know that they have failed.
- Control condition – no scenario

The paths were marked with tape on the floor to identify the start and end of the task. The requirement that participants walk in time with a metronome eliminated the possibility that participants would simply walk more quickly (or run) through the environment in the more urgent scenarios. The experimenter discretely timed the participants' duration in the environment to ensure that participants adhered to the metronome beats.

3.2.2.1. Procedure

i) Real Space

Participants' were tested individually in a session lasting about 30 minutes. Initially, participants were met in an area separate from the environment; they were then instructed to walk along a pre-designated reference path at their natural walking pace to establish step length & speed of walk. The speed of walk was calculated as follows:

[number of steps to walk the reference path / time taken to walk the reference path] * 60 seconds

For example, a participant who walked the reference path in 12 steps in 6.8 seconds would have the metronome set at 106 beats per minute (12 steps / 6.8 secs * 60 secs).

The speed of the metronome was then set to the speed of walk, and participants were again asked to walk along the path three times to the sound of the metronome. This ensured that the calculations were correct and they could walk with ease to the sound of the metronome.

Next, participants were advised that they were going to be blindfolded and transported to the 'Polystyrene Block World'. Once participants were blindfolded they were guided to the end of the 8 metre reference path, spun around, clockwise and anticlockwise, three times and then guided to the beginning of the real or virtual environment.

At the beginning of the environment the experimenter then reminded the participants that they were to take part in a ‘role play task’. They were also informed that they would be asked a series of questions at the end of the experiment about their role play experiences, thus encouraging participants to immerse themselves in the task. The participants were not aware that they were being tested for their memory for distance or time during the task.

When confirmation was received that they were ready to take part, the experimenter then instructed the participant to visualise the assigned scenario (Appendix 1). Participants, after putting on the blindfold, were asked to close their eyes and listen, i.e.

> *“As I mentioned earlier, the purpose of this task involves role play. I would like you to concentrate completely on what I am about to say”.*
>
> *“Your closest friend is seriously ill in hospital. The medics are around the bed as we speak and state their condition is critical. Your friend is wired up to a life support machine. They need medication as soon as possible. Only you have the medication that is going to save your friends life. If you don’t get there in time there is a chance that this could be fatal. The only person that can save them is you.*
>
> *Do you understand the seriousness of the task?*
>
> *You must keep in step with the metronome; you are not allowed to walk any quicker or slower than the sound of the metronome. The metronome has been purposefully set to replicate your natural walking pace. Do you understand? Do you also understand the seriousness of the task?*
>
> *Here is the medicine, you must deliver the medicine but keep your steps to the sound of the metronome. OK – are you ready to have your blindfold removed? Remove your blind fold & you will start your task when you are ready.”*

Following the visualisation the experimenter gave the participant a medicine bottle or a folded failed exam result manuscript to deliver at the end of the task. Participants in the control condition did not receive an object. When participants reported visualising the task and were confident of the importance of task, they were then asked to remove their blindfold and commence their journey. The path used was a straight 15.4 metre path, displayed in Figure 3.3 (see section 3.2.2.2. for more details of path construction). Participants were timed, discretely, during their duration in the environment and, on completion, were then asked a series of questions concerning distance estimation, time estimation, and levels of anxiety and urgency experienced.

Immediately after crossing the end line for the route, participants were asked a range of questions including how long (in metres) they thought the route was, how long they thought they had spent in the environment (in time), and how urgent they perceived the task to be. Subjective reports of changes in anxiety levels were taken from the beginning of the task, prior to the scenario induction and also during and following the completion of the task.

ii) Virtual Reality

The procedure for Virtual Reality was the same as for the real space, with the exception that participants also walked the reference path in the virtual environment prior to taking part in the role play so that they could get used to being in VR. The participants were blindfolded and seated in front of the screen during the period of transition from exposure to the practice path and the main environment.

3.2.2.2. Materials

i) Experiment 2: Real Space Straight Path

The environment was erected in Space 4 and 5, Culture Lab, Newcastle University; dimensions (metres) 15 width x 6 height x 20 length. The human maze consisted of 26 polystyrene blocks, dimensions (metres) 1.2 width x 2.1 height x 0.3 depth. 11 polystyrene blocks were set up side by side, creating one wall 2.1 metres in height. A further 13 blocks were placed 1 metre opposite, creating a path 1 metre wide with additional blocks perpendicular to the longest wall at either end to ensure that the entrance to and exit from the environment were not visible to the participants. Finally, the environment was covered with clear tarpaulin. The total distance, using the central route of the environment, was 15.4 metres. Figures 3.2 and 3.3 provide an allocentric and egocentric view of the path. The beginning and end of the paths were distinguished with tape on the floor to provide the experimenter with the cue for timing the journey.

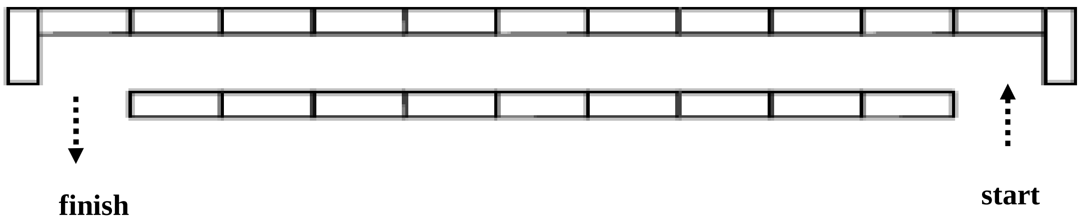

Figure 3.2: an allocentric view of the real space straight path

ii) Experiment 3: Virtual Reality Straight Path

The computer model depicted an exact replica of the real space environment and was created using 3DStudioMax software (see Figure 3.4b). The model was then transferred to VR4Max to establish immersion and navigation capability. The model was extremely realistic, replicating light and textures that gave the strong impression of the original environment. The Virtual Environment used for the Virtual Human Environment condition consisted of Intel Xeon X5450 CPU 2 x Quad (8 cores running at 3.00Ghz) GPU: Nvidia Quadro FX 5600, and StereoWorks DLP Passive Stereo Projection System that was based on a rigid rear projection screen with dimensions: 244x183cm, with images projected by two Christie Digital DS+25 high resolution projectors. Figures 3.3b and 3.4 provide an egocentric and allocentric view of the path.

a b

Figures 3.3a: and 3.3b: provide an egocentric view of the real space path and the identical VR path.

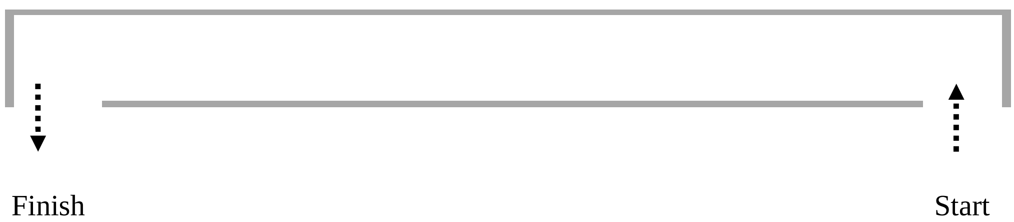

Figure 3.4: Allocentric view – Experiments 2 and 3 straight environment (15.4 metres)

3.2.2.3. Walking Pace and Speed in VR

The VR condition was passive and the pace was pre-programmed according to the individual's natural walking speed. The baseline speed of the VR was set at 1.25 metres per second and participants pace of walk was calculated according to the natural walking pace whilst walking the reference path. The visual flow was calculated from the number and length of steps taken to complete the 8 metre reference path walk. Five step lengths identified from the experimental population of the real space experiment and the speed of flow was calculated exactly to that of the individual's pace. (Table 3.3.)

Table 3.3: Identification of step lengths from real space experiment for use in VR experiments

Step number	1	2	3	4	5
Step length (metres per step)	0.57	0.62	0.67	0.73	0.8

The 'head bob' is commonly used in passive projection systems as a solution to overcoming a static field of view as it simulates natural walking by moving the peripheral field of view slightly whilst giving the impression of a stable point of fixation. A 'head bob' of 1.5cm was used to enhance the perception of natural walking (Masaad, Lejeune & Detrembleur, 2007). The sound of the metronome was synchronized to a 'head bob' and step length, which also corresponded to the visual flow. (Appendix 2 demonstrates how the pace of the visual flow was calculated).

3.2.2.4. Presentation

The study was presented to participants as a role play task. They were told that they were going to be transported to the experimenter's Polystyrene Block World (Environment), and that a scenario was going to be described to them where they would have to deliver an object whilst imagining themselves in that scenario. The importance of the role play scenario was emphasized so that participants would take the scenario seriously to make it as real as possible.

3.2.2.5. Experimental Design

To examine the influence of goals on distance and time estimation, the experiment employed a 2 Environment (Real Space (Experiment 2) vs. Virtual Space (Experiment 3) x 3 Scenario (High Urgency vs. Low Urgency vs. Control) between-participants design. Each participant gave 1 distance estimate, 1 time estimate, 1 urgency estimate and 3 anxiety estimates (Table 3.4 & Appendix 3)

Table 3.4: Illustration of 2 x 3 between participants design for Experiments 2 and 3, according to Environment Type and Scenario

	Environment Type	
Scenario	***Real Space***	***Virtual Reality***
Control	**Dependent Variables;** • Distance Estimate • Time Estimate • Urgency Estimate • 3 x Anxiety Estimates	
High Urgency		
Low Urgency		

3.2.2.6. Participants

One hundred and five individuals were recruited to take part from Newcastle city centre; forty five took part in the real space condition and sixty in the VR condition. They were paid a nominal fee for participation (or given course credit if they were students). Participants were aged between 18 and 54 years old (mean age = 25.98, SD= 8.1). Participants were randomly allocated and evenly distributed for age and gender across all conditions. No participant had any previous experience of the building in which the real space maze was constructed or of the Virtual Environment.

3.2.3. Results

Experiments 2 and 3

Real Space (RS) Straight Path versus VR Straight Path

An alpha level of 0.05 was adopted for all the analyses reported in this thesis. Also, outliers were removed according to the criterion of 2 standard deviations above or below the mean of the condition, in accordance with Field (2009, p. 153). Outliers were evenly distributed amongst all three scenario conditions in the following reported experiments.

Responses from 3 participants (6.7%) in the RS and 4 (8.9%) from the VR were excluded, as their distance estimations were extreme (i.e. they exceeded the criterion of 2 standard deviations from the mean). Responses from 42 participants in the RS and 56 from the VR were included in the following analyses.

3.2.3.1. Preliminary Analyses

A series of between participants one-way ANOVA[2]s were conducted to ensure that participants did not differ in their walking speeds across the scenarios and also to make sure that the time spent in the environments was controlled across all conditions. It was thought that participants in the high urgency condition may feel tempted to run, instead of keeping to their natural walking pace, which would have confounded the results. The results are displayed in Table 3.5.

[2] For the present ANOVAs, as for all subsequent ANOVAs presented in this thesis, should the assumption of equal variances be violated the significant Levene's test will be reported along with the Games-Howell corrections (Field, 2009, p. 374)

Table 3.5: Results of the 1 – Way ANOVA for pace of walk and time spent in the environments in Experiments 2 and 3.

Environment	Source	df and F value	MS	Significance
RS (Experiment 2)	Pace of walk	$F_{(2,39)} = 0.04$	0.001	ns
RS (Experiment 2)	Duration of task	$F_{(2,39)} = 0.22$	1.25	ns
VR (Experiment 3)	Pace of walk	$F_{(2,53)} = 1.45$	1.45	ns
VR (Experiment 3)	Duration of task	$F_{(2,53)} = 2.40$	8.05	ns

Note. ns: $p > 0.05$

No significant differences were found for the pace of walk for the Real Space (RS), $F_{(2,39)} = 0.05$, $p > 0.05$ or VR, $F_{(2,53)} = 1.45$, $p > 0.05$ between scenarios. There were also no significant differences in the times spent in the environment between scenarios for the RS, $F_{(2,39)} = 0.22$, $p > 0.05$ or the VR, $F_{(2, 53)} = 2.4$, $p > 0.05$.

3.2.3.2. Main Analyses

In order to account for methodological adaptations in the later experiments, that is shorter distances being covered, data for distance and time estimation was converted to ratio estimations (estimated distance or time / actual distance or time). This approach ensures consistency and comparability across all experiments (Montello, 1997).

i) <u>Distance</u>

To examine the influence of goals in both RS and VR environments, a 2 Environment (Experiment 2; RS vs. Experiment 3; VR) x 3 Scenario (High Urgency vs. Low Urgency vs. Control), between participants ANOVA was performed on distance estimations. The ANOVA results are displayed in Table 3.6.

Table 3.6: Between Participants ANOVA for Distance Estimation on Experiments 2 and 3.

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2,92)} = 4.22$	2.74	***	0.08
RS vs. VR	$F_{(1,92)} = 2.00$	1.3	ns	0.021
Environment x Scenario	$F_{(2,92)} = 0.88$	0.57	ns	0.019

Note. ns: $p > 0.05$; ***: $p < 0.005$

There was no significant main effect of environmental condition $F_{(1,92)} = 2.0$, $p > 0.05$, and no reliable interaction between condition and scenario, $F_{(2,92)} = 0.88$, $p > 0.05$. However there was a main effect of scenario, $F_{(2,92)} = 4.22$, $p = 0.018$, partial $\eta^2 = 0.08$ (see Figure 3.5). Tukey post hoc tests confirmed that the high urgency condition (M = 1.242) was associated with significantly larger distance ratio estimates than the low urgency condition (M = 0.08), p = 0.03, and near significantly larger distance ratio estimates than the control condition (M= 0.07), p = 0.06.[3] There were no significant differences between the low urgency and the control condition *MSe* = 0.203, p > 0.05.

[3] Trends will be considered to be evident if $p \leq 0.09$ following Zindani, Streetman & Nasr (2006).

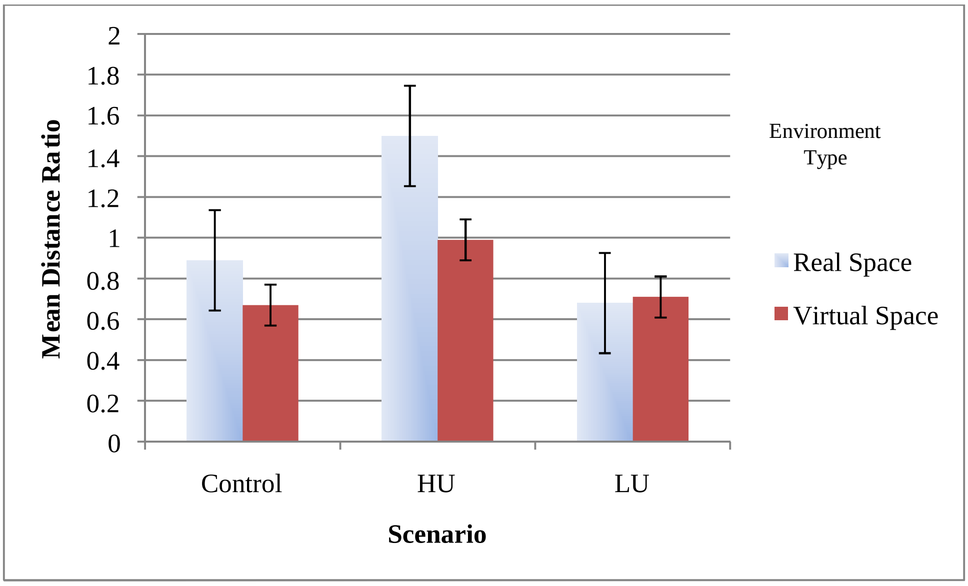

Figure 3.5: Main Effect of Scenario on Distance Estimation, in Experiments 2 and 3, with standard error bars (+/- 1 SE).

ii) <u>Time</u>

A 2 Environment (Experiment 2; RS vs. Experiment 3; VR) x 3 Scenario (HU vs. LU vs. Control) between participants ANOVA was also performed on time estimations to examine the influence of goals in both RS and VR environments. The ANOVA results are displayed in Table 3.7.

Table 3.7: Between Participants ANOVA for Time Estimation on Experiments 2 and 3.

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2,92)} = 2.6$	15.351	0.08	0.053
RS vs. VR	$F_{(1,92)} = 2.49$	14.72	**	0.026
Environment vs. Scenario	$F_{(2,92)} = 2.19$	12.962	**	0.046

Note. ns: $p > 0.05$; **: $p < 0.01$

There was a trend approaching significance for time estimation on scenario, $F_{(2,92)} = 2.58$, $p = 0.08$, partial $\eta^2 = 0.053$. However, there was no significant main effect of environment type on time estimation, and there was no significant interaction between environmental condition and scenario. Although there was no main effect of scenario for time, the following trends can be observed (see Figure 3.2.). Tukey post-hoc tests confirm that the high urgency condition (M = 2.48) yielded larger estimations of time approaching significance, than those of the low urgency (M = 1.29), p = 0.058, and control condition (M = 0.042), p = 0.09. There were no reliable differences between the low urgency and control condition, MSe = 0.061, $p > 0.05$. (Figure 3.6).

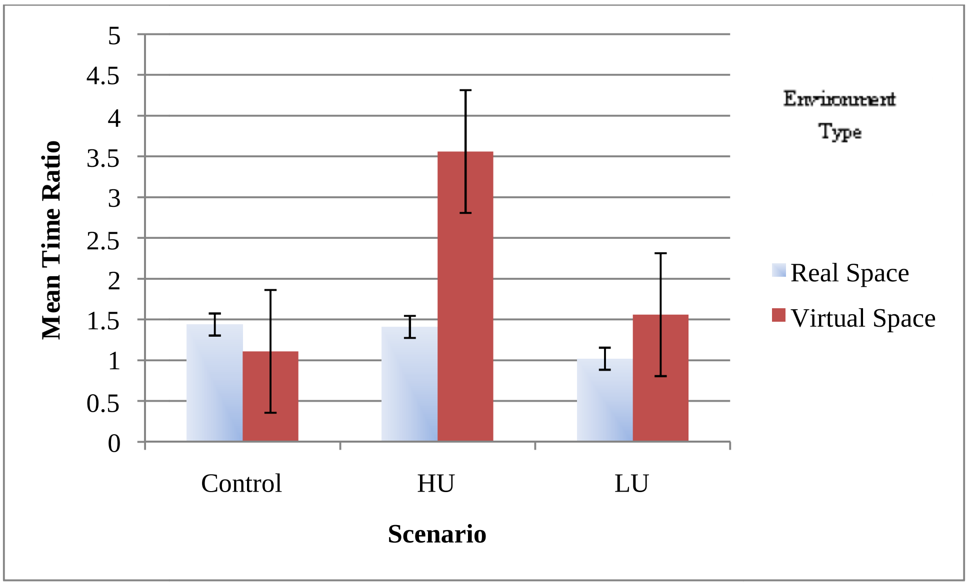

Figure 3.6: Trend of Effect of Scenario on Time Estimation, in Experiments 2 and 3, with standard error bars (+/- 1 SE).

Urgency

Subjective measures of urgency reports, that is, how urgent the participant perceived the task to be provided additional information to examine whether the participant immersed themselves in the scenario appropriately. The urgency reports were significant according to scenario $F_{(2, 92)} = 32.519$, $p < 0.001$, but not for environment type, $F_{(1, 92)} = 0.175$, $p > 0.05$, and there was no interaction between environment type and scenario, $F_{(2, 92)} = 0.219$, $p > 0.05$. This suggests that participants immersed themselves in the scenarios equally across both the real space and VR conditions. In addition a significant correlation was found between the level of urgency reported and the scenario, $r = 0.404$, $p < 0.01$, the higher the level of urgency reported, the greater the distance recalled for the path travelled. Reported levels of urgency also yielded significant results in relation to distance estimation, $r = 0.226$, $p < 0.05$ and also time estimation, $r = 0.264$, $p < 0.01$.

Anxiety

Subjective reports of changes in anxiety levels prior to the scenario induction and also during the task also provide further evidence to substantiate that participants were immersing themselves in the scenarios appropriately. Changes in self reported anxiety measurements were significant according to scenario $F_{(2, 92)} = 14.652$, $p < 0.0001$, but not environmental condition, $F_{(1, 92)} = 0.328$, $p < 0.05$. There was also no reliable interaction between path structure and scenario $F_{(2, 92)} = 0.108$, $p > 0.05$. This highlights that subjective anxiety levels were reported according to the scenario and that neither the real space nor VR affected these reports.

3.2.4. Discussion

The results from Experiments 2 and 3 confirmed the expectation that goals distort memory for distance following straight line movement through both a real space and in virtual space. The High Urgency (medication) Scenario resulted in greater distance and time ratio estimates than either the Low Urgency (failed exam result) Scenario and control condition (no scenario). This pattern of results is consistent with work (reviewed in Chapter 2) showing the influence of goals on distance estimation. For instance, if greater effort is perceived to be required then individuals will report the path as being longer (Proffitt et al., 2003). In this study, effects of goals were found immediately after participants moved through an environment. Although the environment was not real (in the sense of being naturalistic), the subjective urgency and anxiety reports suggest that the participants were able to engage with the task and act the scenarios out as if they were real.

It is also worth noting that effects of goals were found for the VR environment, and were no different to those found in the real environment. This supports much of the evidence that states VR as being a valid methodological tool for the investigation into the mechanisms of spatial cognition, despite the lack of proprioceptive information; (Bliss, Tidwell & Guest, 1997; Jansen-Osmann and Berendt, 2002; Riecke, van Veen & Bulthoff, 2000; Ruddle & Peruch, 2004; Wilson, Foreman & Tlauka, 1996; 1997). Self-report urgency ratings after the experiment suggested that participants immersed themselves in the role-play appropriately and additional subjective anxiety level reports also support this view.

Overall, the results provide evidence that goals affect the immediate memory for distance in both real and virtual space. However, these data pertain only to a single environment path type; a straight line path. Experiments 4 and 5 examine the effect of scenario on distance estimates for a path with many turns in real space.

3.3 Experiments 4 and 5.

It is clear from the distance distortion literature that changing environment type affects distance judgements. A prominent example of this is the manipulation of turns in the environment. Recall, Sadalla & Magel (1980) who demonstrated that participants reported paths with seven turns as being significantly longer than paths with two turns. This has also been demonstrated in VR (Jansen-Osmann & Berendt, 2002). Therefore, it is important to investigate if goals differ across environmental structures. The next two experiments propose to investigate the role of goals in a real space path with eight turns and an identical VR analogue of those paths.

If goals clearly do influence distance, then this should be apparent in Experiments 4 and 5, which employ different spatial structures to Experiments 2 and 3.

3.3.1. Methodology

The method used was exactly the same as in Experiment 2 and 3.

3.3.1.1. Materials

i) Experiment 1V; Real Space Complex Path

The environment was built from the same material as in Experiment 2 and consisted of 28 polystyrene blocks, dimensions 1.2 x 2.1 x 0.3 metres – more blocks were required to accommodate the variance in width at the right-angled turns. The environment consisted of 8 turns; 4 x right and 4 x left angled (Figure 3.7). The environment was designed so that it exited directly into a lobby where the experimenter was waiting, out of the field of view of the participant. Again, the total distance, using the central route of the environment was 15.4 metres (the same distance as Experiment 2) and floor markers provided the experimenter with the cue for timing the journey. (Figure 3.8).

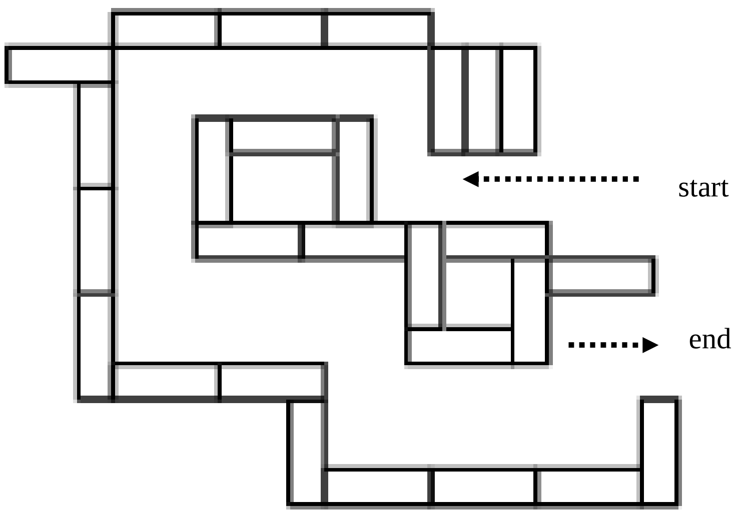

Figure 3.7: – an egocentric view of Experiment 4; real space complex path (15.4 metres)

Figure 3.8: An egocentric view of the entrance to the real space complex path; Experiment 4

ii) Experiment 5; Virtual Space Complex Path

The virtual model was an exact replication of the real space environment (Experiment 1V) and utilised the same software as Experiment 3. Again, paths were marked with tape on the floor, to emphasize the start and end of the task.

iii) Distance and Time Discrepancies

During the real space experiment, several participants claimed that they found it difficult to keep in step with the metronome whilst turning corners, resulting in participants spending less time in the real space maze with turns (Mean = 11.8 seconds) than in the real space straight line maze (Mean = 13.8 seconds), $p < 0.001$. Also, on development of the VR model a further possible discrepancy was identified. The navigated route in the VR path with several turns, that is, the actual path that participants walked in the environment, had to be 'smoothed' at the corners in order to create a more naturalistic experience. This resulted in the participants walking a slightly shorter distance in order to avoid 90° turns, which consequently shortened the actual traversed route for both distance and time. Therefore distance and time estimations were converted to ratios: estimated distance/actual distance, and estimated time/actual time, in order to provide comparable reports across conditions/experiments. Figures 3.9 and 3.10 illustrate the allocentric and egocentric viewpoints of the virtual path.

3.3.1.2. Walking Pace and Speed

Walking pace and speed was calculated exactly the same as in Experiment 2. However, prior to the experiment being performed, a preliminary pilot study in VR established that the pace in the paths with several turns was too fast at 1.25m per second. There is evidence to suggest that individuals vary their pace and step length in complex environments, such as taking shorter paces and slowing down at corners (i.e. Kim, Park & Oh, 2007; Hu, Gangfeng & Zhiyun, 2010). It was therefore decided that the pace should be decreased by 20%. Therefore, the default speed was reduced to 1 metre per second.

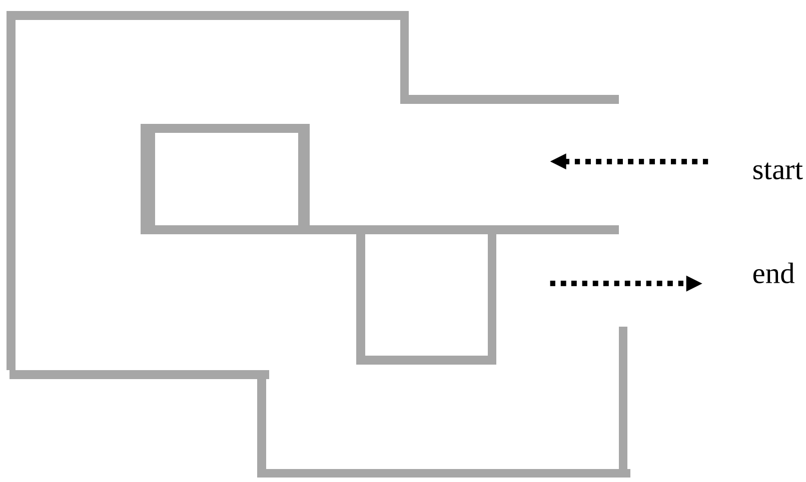

Figure 3.9: Egocentric view of the VR complex path; Experiment 5

Figure 3.10: Allocentric view of the entrance to the VR complex environment; Experiment 5

3.3.1.3. Participants

One Hundred and Twenty individuals, sixty in real space and sixty in VR; aged between 15 and 53 years (mean age = 25.4, SD = 8.6) were recruited from the University of Northumbria and were paid a nominal fee or given a course credit (if they were students) for their participation. All participants were randomly allocated and evenly distributed for age and gender across all of the conditions. No participant had any previous experience of the building in which the real space maze was constructed or of the Virtual Environment.

3.3.1.4. Experimental Design

To examine the influence of goals on distance and time estimation, the experiment employed a 2 (Environment: Real Space (Experiment 4) versus Virtual Space (Experiment 5) x 3 (scenario: High Urgency vs. Low Urgency vs. Control) between-participants design.

Each Participant gave 1 distance estimate, 1 time estimate, 1 urgency estimate and 3 Urgency estimates, identical to Experiments 2 and 3.

3.3.2. Results

Experiments 4 and 5;

Real Space Complex Path versus VR Complex Path

Using the same criteria as Experiments 2 and 3, responses from 4 participants (7%) were excluded in Experiment 4 (RS) and 5 (8%) from Experiment 5 (VR). Data from the remaining 111 participants were included in the following analysis.

3.3.2.1. Preliminary Analysis

A series of one-way ANOVAs were conducted to ensure that participants did not differ in their walking speeds across the scenarios and also to make sure that the time spent in the environments were controlled across all conditions. The results are displayed in Table 3.8.

Table 3.8: Results of the 1-Way ANOVA for pace of walk and time spent in the environments in Experiment 4 and 5.

Environment	Source	df and F value	MS	Significance
RS	Pace of walk	$F_{(2,53)} = 0.471$	0.294	ns
RS	Duration of task	$F_{(2,53)} = 0.569$	5.62	ns
VR	Pace of Walk	$F_{(2,52)} = 1.54$	0.641	ns
VR	Duration of task	$F_{(2,52)} = 1.53$	2.38	ns

Note. ns: $p > 0.05$

No significant differences were found for the pace of walk for the Real Space or VR space between scenarios. There were also no significant differences in the time spent in the environments across the scenarios.

3.3.2.2. Main Analysis

<u>Distance</u>

To examine the role of goals on distance estimation in RS and VR complex environment, a 2 Environment (Real Space vs. VR) x 3 Scenario (HU vs. LU vs. Control) between participants ANOVA was performed on distance estimations. The ANOVA results are displayed in Table 3.9.

Table 3.9: Between Participants ANOVA for Distance Estimation on Experiments 4 and 5.

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2,105)} = 1.142$	0.321	ns	0.021
Environment (RS vs VR)	$F_{(1,105)} = 0.938$	0.263	ns	0.009
Environment x Scenario	$F_{(2,105)} = 4.651$	1.301	***	0.081

Note. ns: p > 0.05; ***: p < 0.005

There was no significant main effect of scenario or environmental condition, $p > 0.05$. However, there was a significant interaction between scenario and the environment, $F_{(2,105)} = 4.651$, $p = 0.0018$, partial $\eta^2 = 0.08$ (See Figure 3.12). Additional separate one way ANOVAs on the real space and VR conditions identified that there was no significant effect of scenario in the real space, $F_{(2,53)} = 2.14$, $p > 0.05$. However, there was a significant effect of scenario in VR, $F_{(2,52)} = 3.4$, $p < 0.05$, partial $\eta^2 = 0.08$, with the high urgency and low urgency scenarios yielding larger distance estimations than the control condition. Tukey post hoc tests revealed that the low urgency scenario (M = 1.13) resulted in significantly larger distance estimations than the control condition (M = 0.64), $p < 0.05$, MSe = 0.487, $p < 0.05$. There were no significant differences between the low urgency condition and the high urgency (M = 1.0), $p > 0.05$, or the high urgency and the control condition, $p > 0.05$.

It was also of interest to examine whether there were any differences in estimation comparing VR to real space. To do so further follow up analysis on the interaction, consisting of a series separate one-way ANOVAs was conducted for each scenario. The results are displayed in Table 3.10.

Table 3.10: Results of the one-way ANOVA on ratio distance estimation (metres) for complex path in Real Space and VR, in Experiments 4 and 5.

Source	df and F value	MS (error)	Significance
Control	$F_{(1,33)} = 16.16$	2.526	****
High Urgency	$F_{(1,35)} = 0.602$	0.193	ns
Low Urgency	$F_{(1,37)} = 0.277$	0.098	ns

Note. ns: $p > 0.05$; ****: $p < 0.001$

The results of the separate one way ANOVAs for each scenario across the complex real space and VR path yielded a significant result for the control condition, $F_{(1,33)} = 16.16$, $p < 0.001$ with the VR (M = 0.64) distance estimations being reliably compressed compared to that of real space (M = 1.18). There were no reliable differences for the high urgency scenario or the low urgency between real space and VR, both $p > 0.05$, (Figure 3.11). The control condition reported shorter distance estimations for VR than for real space, this is consistent with the literature in this area (i.e. Witmer and Kline, 1998; Jansen-Osmann et al., 2002; Knapp and Loomis; 2004; Thompson, et al., 2004)

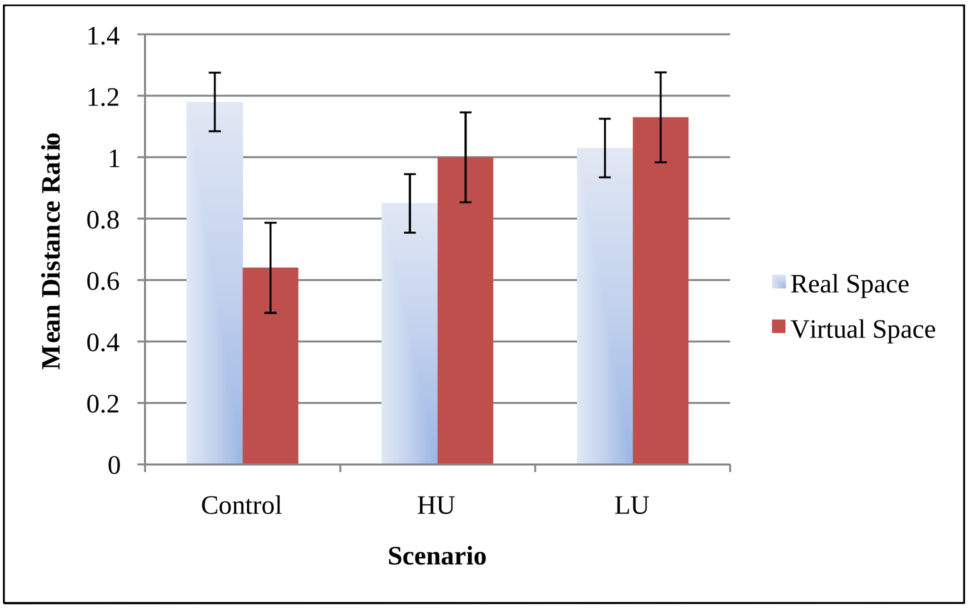

Figure 3.11: Interaction between Scenario and Environmental Condition on Distance Estimation Ratio, in Experiments 4 and 5 – path with turns, with standard error bars (+/- 1 SE).

Time

To examine the role of goals on time estimation in RS and VR complex environment, a 2 condition (RS vs. VR) x 3 Scenario (HU vs. LU vs. Control) between participants ANOVA was performed on distance estimations. The ANOVA results are displayed in Table 3.11.

Table: 3.11: Between Participants ANOVA for Time Estimation on Experiments 4 and 5.

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2,105)} = 1.56$	14.43	ns	0.029
RS vs. VR	$F_{(1,105)} = 0.51$	4.72	ns	0.005
Environment x Scenario	$F_{(2,105)} = 2.523$	23.34	0.085	0.046

Note. ns: $p > 0.05$

There was no significant main effect of scenario or of environment type. There was however a trend approaching significance on the interaction between goals and environmental condition (see Figure 3.12). Again, separate one way ANOVAs on the real space and VR condition identified that there was no significant effect of scenario in the real space, $F_{(2,53)} = 2.44$, $p > 0.05$. However, there was a trend approaching significance on scenario in VR, $F_{(2,52)} = 2.77$, $p < 0.07$. Tukey post hoc tests reveal that the high urgency scenario (M = 4.1) resulted in near significant larger distance estimations than the control condition (M = 1.44), MSe = 1.81, p = 0.07. There were no significant differences between the high urgency and the low urgency conditions (M = 2.05), MSe = 1.17, p > 0.05, or the low urgency and the control conditions, MSe = 1.17, p > 0.05. (Figure 3.12).

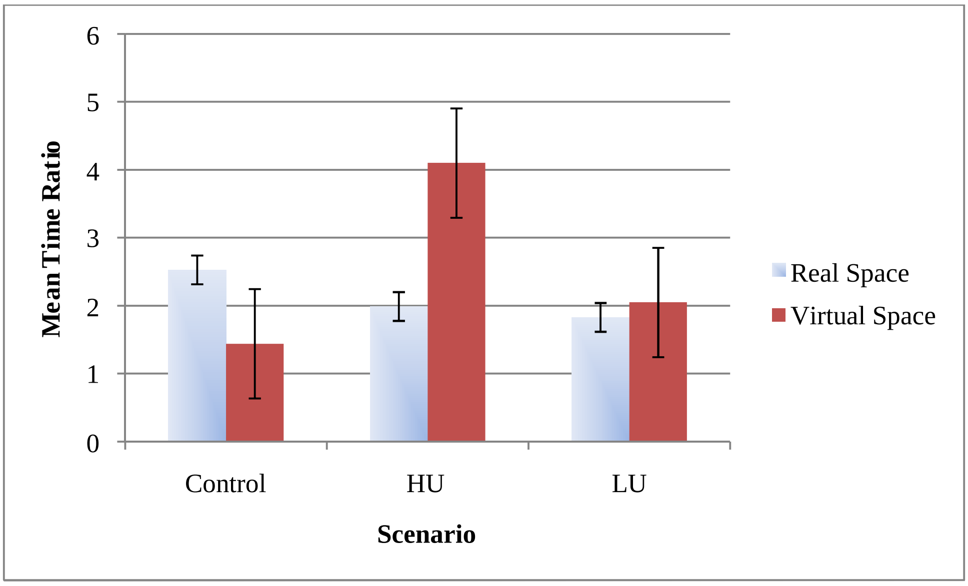

Figure 3.12: Interaction between Scenario and Environmental Condition on Time Estimation Ratio, in Experiments 4 and 5 – path with several turns, with standard error bars (+/- 1 SE).

Urgency

To establish if participants immersed themselves in the scenario appropriately a 2 Environment (RS vs. VR) x 3 Scenario (HY vs. LU vs. Control) between participants ANOVA was conducted on Urgency reports.

Table 3.12:. Between Participants ANOVA for Urgency Reports on Experiments 4 and 5.

Source	df and F value	MS	Significance
Scenario	$F_{(2,105)} = 18.26$	149.41	***
RS vs. VR	$F_{(1,105)} = 3.214$	26.3	0.07
Environment VR Scenario	$F_{(2,105)} = 0.751$	6.15	ns

Note. ns: $p > 0.05$; *** $p < 0.001$

The urgency reports were significant according to scenario, $F_{(2,105)} = 18.26$, $p < 0.001$, partial $\eta^2 = 0.03$. Tukey posthoc comparisons confirmed that the high urgency condition ($M = 7.7$) was reported as being significantly more urgent than both the control ($M = 3.66$), $Mse = 0.675$, $p < 0.001$ and the low urgency scenario condition ($M = 5.46$), $MSe = 0.657$, $p < 0.005$. In addition, the low urgency condition was reported to be significantly higher for urgency than the control condition, $MSe = 0.67$, $p > 0.05$.

There was also a trend for environment type, $F_{(1,105)} = 3.214$, $p = 0.076$, partial $\eta^2 = 0.03$, with the VR ($M = 6.11$) environment eliciting greater subjective urgency reports than the real space ($M = 5.13$). However, there was no significant interaction between environment type and scenario, $F_{(2,105)} = 0.751$, $p > 0.05$. In addition, there was a significant correlation between the level of urgency reported and the scenario, $r = 0.21$, $p < 0.05$, with higher levels of urgency being reported with the high urgency condition. In addition, reported levels of urgency also yielded significant results in relation to time estimation, $r = 0.226$, $p < 0.05$, that is, higher reported levels of urgency correlated with higher time ratio estimations. There was no significant relationship between urgency reports and distance estimation ratios, $r = 0.16$, $p < 0.05$ (see Table 3.12).

Anxiety

A 2 Environment (RS vs. VR) x 3 Scenario (HU vs. LU vs. Control) between participants ANOVA was conducted on changes in self reported anxiety measurements were also significant according to scenario $F_{(2,105)} = 10.86$, $p < 0.001$, but not environmental condition, $F_{(1,105)} = 0.424$, $p > 0.05$. There was also no reliable interaction between path structure and scenario $F_{(2, 105)} = 0.214$, $p > 0.05$.

3.3.3. Discussion

The more complex environmental structure with multiple turns did not produce the same findings with regard to scenario as the straight-line path. However, this difference cannot be explained as a function of differences in perception of urgency across conditions;

urgency ratings were reliably different between scenarios for the path with many turns, just as they were for the straight-line path. Rather, effects of scenario were found for the complex path in VR, but not in the complex path in real space. The VR complex path demonstrated that goals do matter, in VR. However, a follow up identified that

There are several reasons why the effect of scenario was not demonstrated in the real space path. Firstly, it may well be that environment structure does mediate the effect of goals in real space, but not in VR.

Alternatively, the absence of the distortion of distance estimation for the role-play task in the real space complex environment could have been due to methodological issues. On debrief, several participants in real space reported difficulty in keeping to the sound of the metronome clicks on turns, distracting them from the task at hand and they also walked significantly faster in the real space complex task than the straight path. The shorter period of time spent in the real space complex path could be for several reasons. Firstly, participants stated that they experienced difficulty keeping to the sound of the metronome whilst negotiating the corners and many claimed to have just ignored the metronome. This could have resulted in them walking at a faster walking pace or could have distracted their attention away from the task. Furthermore, the measurement of the traversed distance was directly down the centre of the paths, with 90° angles, which, in retrospect, does not reflect naturalistic walking. Participants could have just walked a shorter route, taking shortcuts at the corners. The experiment did not use overhead tracking devices and therefore it is difficult to ascertain the actual issue here.

Overall, there were significant differences in the length of time spent in the real space environment with turns ($M = 11.77$ secs, $SD= 3.12$) compared to the real space straight path ($M = 13.81$secs, $SD = 2.34$), (this will be discussed further in the later combined analysis, Section 3.3.2.).

The development of the VR replication of the real environment did not have these problems. Whilst the passive VR system was unable to replicate natural walking pace in complex environments, such as change of stride lengths and changes in walking speed (i.e. Hu, Gangfeng & Zhiyun, 2010), the VR environment was more controlled in that participants all walked the same distance in a controlled time frame. This may well be why individuals were more able to engage with the role play than those in the real space condition, and thus why scenario effects were found in the VR complex path.

3.4. Further Combined Analysis

The experiments have demonstrated that goals do appear to influence distance estimation in some conditions, in both real space and VR. The paths with turns yielded no effect of goals across real space and VR combined, but they did demonstrate a trend towards significance for an interaction between environment types, i.e. RS versus VR.

To further investigate these effects, and to examine the possible effect of turns in VR and real space, two further analyses were undertaken.

The first analysis will investigate the real space straight path versus the real space complex path. This will then be followed by combined analyses for the VR straight versus the VR complex path.

3.4.1. Experiments 2 and 4.

Real Space Straight Path versus Real Space Path with Turns

3.4.1.2. Design

A 2 Path Structure (straight vs. turns) x 3 Scenario (HU vs.LU vs. Control) independent ANOVA was conducted utilising the data from Experiments 2 and 4.

3.4.2.2. Results

Preliminary analysis

A series of one-way ANOVAs were run to investigate walking speeds across the conditions. No significant differences were found for pace of walk prior to the main experiment, across the path structures, $F(1,92) = 0.002$, $p > 0.05$; or scenarios $F(2, 92) = 0.071$, $p > 0.05$. There was however, a significant difference in the times spent in the environments $F(1, 96) = 12.723$, $p < 0.01$, with the participants in the complex path ($M = 11.77$) spending significantly less time in the environment than participants in the straight path ($M = 13.82$).

Main Analysis

Distance

Table 3.13: Between Participants ANOVA for Distance Estimation Ratio according to Scenario and Path Structure in Real Space (Experiments 2 and 4).

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2, 92)} = 0.183$	0.158	ns	0.004
Path Type (Straight vs. Turns)	$F_{(1, 92)} = 20.9$	17.99	****	0.185
Path Type vs. Scenario	$F_{(2, 92)} = 4.76$	4.1	**	0.09

ns: $p > 0.05$; **: $p < 0.01$; ****: $p < 0.001$;

We can see that a combined analysis across the real space environmental structures yielded no significant main effect of scenario F (1, 92) = 0.183, $p > 0.05$. There was however a significant main effect of path type, $F_{(1, 92)} = 20.9$, $p < 0.001$, with the path with several turns (M = 1.89) being reported as being longer than the straight path (M = 1.03). Furthermore, there was a reliable interaction between path type and scenario, $F_{(2,92)} = 4.76$, p = 0.01. Separate one way ANOVAs on the real space straight path and the path with several turns identified a trend approaching significance for scenario $F_{(2,39)} = 2.55$, p = 0.09, with the Tukey post hoc tests confirming that the high urgency scenario (M = 1.5) in the real space path was reported as being longer than the low urgency condition, but was not reliably significant (M = 0.68), MSe = 0.41, p = 0.15. There were no significant differences between the high urgency and the control condition (M = 0.91), MSe = 0.43, $p > 0.05$ or between the low urgency and the control condition, MSe = 0.37, $p > 0.05$. The path with several turns did not yield a significant result of scenario, F (2, 53) = 2.1, $p > 0.05$, and as can be seen in Figure 3.13, the means are in opposite directions for the control and the low urgency condition.

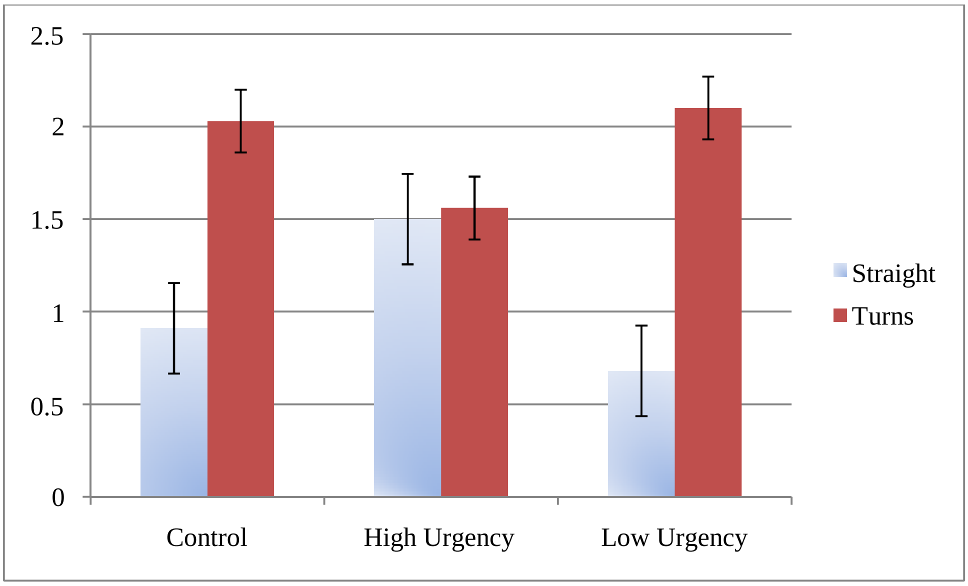

Figure 3.13: Main effect of Path Type and Interaction in Real Space on Ratio Distance Estimation in Experiments 2and 4.

Additional follow up analyses were conducted on the interaction, consisting of a series separate one-way ANOVAs by scenario. The results are displayed in Table 3.14.

Table 3.14: Results of the one-way ANOVA on ratio distance estimation (metres) for path structure in real space according to scenario, in Experiments 2 and 4.

Source	df and F value	MS (error)	Significance
Control	$F_{(1,30)} = 19.07$	10.05	****
High Urgency	$F_{(1,31)} = 0.026$	0.028	ns
Low Urgency	$F_{(1,31)} = 16.54$	15.9	****

ns: p > 0.05; **: p < 0.01; ****: p < 0.001;

Distance estimations for the straight real space versus complex real space path with several turns, yielded a significant effect of turns for the control condition, $F_{(1,30)} = 19.07$, $p < 0.001$ with the complex path being reported as being a longer distance ($M = 2.03$) than the straight path ($M = 0.91$). The effect of turns in the low urgency scenario also was also reliably significant, $F_{(1,31)} = 16.54$, $p < 0.001$ with the complex path being reported as longer ($M = 2.1$) than the straight path ($M = 0.68$). There was no significant effect of path structure for the high urgency condition, $F_{(1,31)} = 0.026$, $p > 0.05$.

Time

Table 3.15: Between Participants ANOVA for Time Estimation Ratio according to Scenario and Path Structure in Real Space (Experiments 2 and 4).

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2,92)} = 0.769$	2.921	ns	0.016
Path Type (Straight vs. Turns)	$F_{(1,92)} = 4.218$	16.03	*	0.185
Path Type vs. Scenario	$F_{(2,92)} = 0.106$	4.05	ns	0.002

ns: $p > 0.05$; *: $p < 0.05$

The real space path produced no significant main effect of scenario on ratio time estimation, $F_{(2, 92)} = 0.769$, $p > 0.05$ but did produce a significant main effect of time on path type $F_{(1,92)} = 4.218$, $p < 0.05$, partial $\eta^2 = 0.185$, with the complex path (M= 2.1) being reported as taking a longer time to traverse than the straight path (M = 1.31). There was no significant interaction for time ratio estimation between scenario and path structure,

$F_{(2,92)} = 0.106$, $p > 0.05$. (see Figure 3.14)

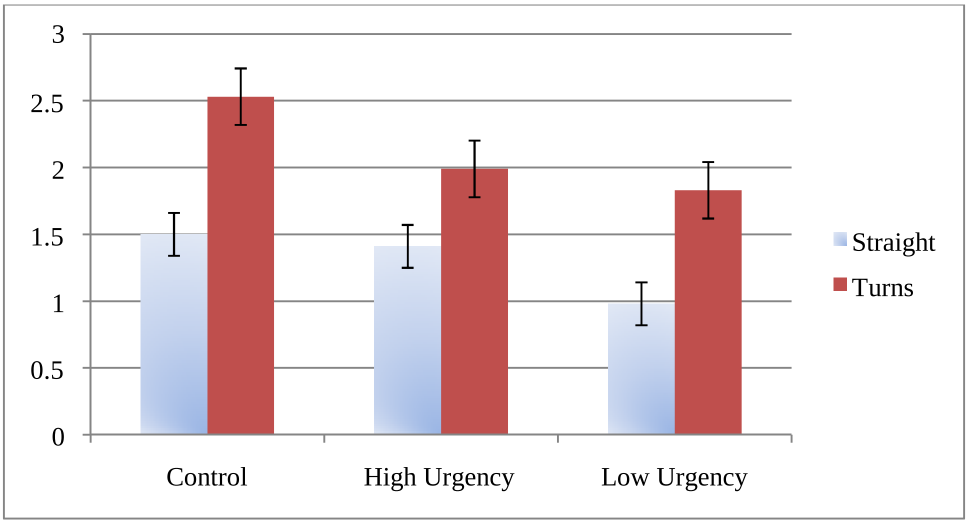

Figure 3.14: Main effect of Path Type and Interaction in Real Space on Ratio Time Estimation in Experiments 2 and 4.

3.4.2.3. Discussion

The outcome of the combined analyses into the effect of goals in real space was interesting. The results replicated the robust effect of turns; consistent with previous studies (i.e. Sadalla & Magel, 1980) with both greater time and distance estimations being reported for the path with several turns but there was no reliable effect of scenario for either distance or time.

The interaction for distance estimation between the real space environments and scenarios, on further investigation, highlighted a trend approaching significance. This demonstrated that the high urgency condition resulted in significantly higher distance estimations in the straight path compared to than the low urgency scenario yet this effect was not reliable in the complex path. Most interesting was that the ratio distance estimation for the high urgency was consistent for both the straight path (M = 1.5) and the complex path (M = 1.56).

The following combined analysis aims to identify if there is an angularity effect in VR and whether goals are mediated by environment structure in VR.

3.4.3. Experiments 3 and 5.

VR Straight vs. VR Complex Path – Combined Analysis

3.4.3.1. Design

A 2 Path Structure (straight versus turns) x 3 Scenario (HU vs. LU vs. Control) independent groups design was conducted, utilising the data from experiment 3 and 5.

3.4.3.2. Results

Preliminary analysis

A series of between participants one-way ANOVAs were run to ensure that the participants across conditions did not differ in their walking speeds or time spent in the VR environments. No significant differences were found for the pace of walk for the straight path, $F_{(2, 52)} = 1.81$, $p > 0.05$ or the path with several turns, $F_{(2, 52)} = 1.54$, $p > 0.05$ between scenarios. There were also no significant differences in the times spent in the VR environments between scenarios for the straight path $F_{(2,52)} = 0.11$, $p > 0.05$ or the path with turns $F_{(2,52)} = 1.53$, $p > 0.05$.

Main Analysis

A 2 Path Structure (straight path vs. path with 8 right-angled turns) x 3 Scenario (HU vs. LU vs. Control) between participants ANOVA was performed on distance and time ratio estimations.

Distance

Table 3.16: Between Participants ANOVA for Distance Estimation Ratio according to Scenario and Path Structure (Experiments 3 and 5).

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2,105)} = 3.32$	1.736	*	0.06
Straight VR Turns	$F_{(1,105)} = 10.99$	5.738	***	0.095
Path Type vs. Scenario	$F_{(2,105)} = 0.751$	1.81	ns	

Note. ns: $p > 0.05$; * $p < 0.05$; ** $p \leq 0.001$

There was a significant main effect of path structure $F_{(1, 110)} = 10.99$, $p \leq 0.001$, partial $\eta^2 = 0.095$, with the path with turns being reported as significantly longer (M = 1.25) than the straight path (M = 0.79). There was also a main effect of scenario $F_{(2,110)}$ =

3.33, $p < 0.05$, partial η^2=0.06 with urgency influencing distance estimation. Tukey posthoc tests of the three conditions indicate that the high urgency condition (M = 1.16) demonstrated a trend approaching significance for longer distance estimations compared to the control condition (M = 0.67), MSe=0.17, p = 0.054. The low urgency condition (M = 1.12) also produced longer distance estimations compared to the control condition, MSe = 0.17, p = 0.098. There were no significant differences in ratio distance estimations between the high urgency and low urgency conditions, MSe = 0.17, p > 0.05. There was no reliable interaction between path structure and scenario. $F_{(2,110)} = 1.81$, $p > 0.05$. (see Figure 3.15).

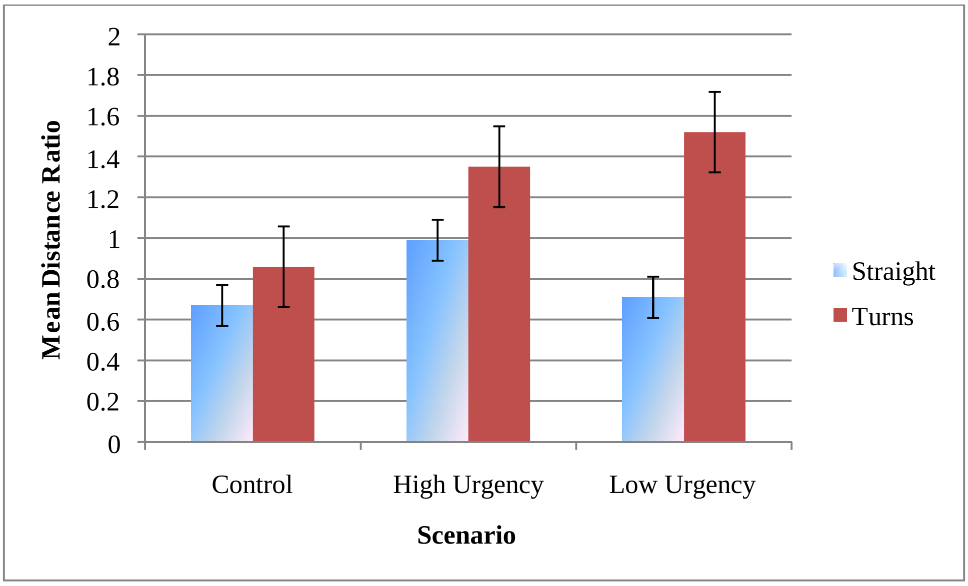

Figure 3.15: Main Effect of Goals and Structure in VR on Distance Estimation Ratio, in Experiments 3 and 5.

<u>Time</u>

Table 3.17: Between Participants ANOVA for Time Estimation Ratio according to Scenario and Path Structure (Experiments 3 and 5).

Source	df and F value	MS	Significance	partial η^2
Scenario	$F_{(2,105)} = 6.01$	66.64	*	
Straight VR Turns	$F_{(1,105)} = 0.512$	0.476	ns	
Path Type VR Scenario	$F_{(2,105)} = 0.01$	.012	ns	

Note. ns: $p > 0.05$; * $p < 0.005$;

There was a significant effect of scenario on ratio time estimation, $F_{(2,105)} = 6.01$, $p < 0.05$. Tukey posthoc tests of the three conditions indicate that the high urgency condition (M = 3.83) produced significantly larger time estimations than the Control condition (M = 1.28), MSe =0.78, p = 0.001 and also the Low Urgency condition (M = 1.81), MSe = 0.77, p = 0.01. There was no significant difference between the Low Urgency condition and the Control condition, $p > 0.05$. There was also no significant interaction between the scenario and path structure F (2,105) = 0.01, $p < 0.05$ (see Figure 3.16).

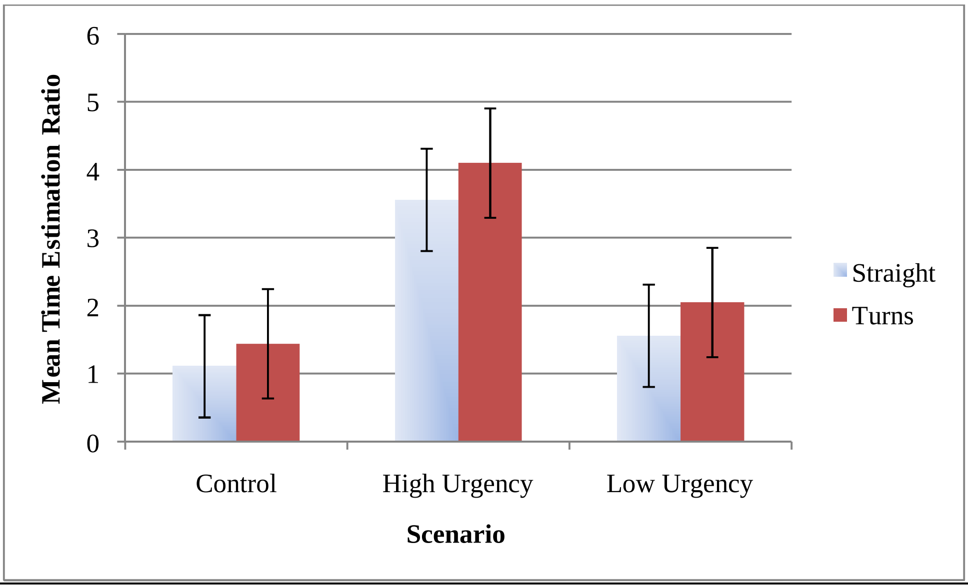

Figure 3.16: Main Effect of Goals and Structure in VR on Time Estimation Ratio, in Experiments 3 and 5.

3.4.3.3. Discussion

The outcome of the combined analysis of the VR experiments demonstrated a robust effect of goals across environmental structures. In addition, there was a striking effect of turns (Sadalla & Magel, 1980), which is in line with previous VR research (i.e. Jansen Osmann & Berendt, 2002). VR, in this instance, is able to provide a more controlled methodology compared to real space and provides robust evidence for the importance of goals across environmental structures.

3.5. General Discussion

People usually go somewhere for a reason – from visiting the dentist to going to see a movie. It is therefore important in terms of ecological validity when studying cognitive maps to include tasks that involve meaningful goals. Four experiments tested whether urgency and desirability of goals influence distance and time estimations for environments varying in structure (straight line path versus path with turns) and media (real versus virtual environments).

The results for the straight line path (Experiments 2 and 3) and the complex VR path (Experiment 5) demonstrate a reliable influence of goals on immediate memory for distance travelled. Greater urgency was associated with greater distance and moreover, these experiments demonstrated a reliable correlation between urgency ratings and distance estimates, suggesting that individual differences in perceptions of urgency may also play a role in perception of distance (consistent with Golledge, 1987; 1999). This effect cannot be explained by the amount of time spent traversing the path for between the goal scenarios as time and speed of walk were strictly controlled across all of the scenarios. In addition the absence of differences in scenario effects as a function of media supports the robustness of VR as a methodology despite acknowledged limitations with regard to simulating real life experience (Campos et al., 2007).

Theoretically, one can ask why urgency of goals influences distance estimation. Bugmann and Coventry (2008) suggest that the extent to which attention is engaged during a task affects memory for distance. So urgency may lead participants to consciously engage with the task more, consistent with Bugmann and Coventry's 'attentional shift' hypothesis. However, there are other alternative explanations that also need to be considered. In the next chapter, we begin to unpack why goals affect distance estimation.

CHAPTER 4.

The Influence of Arousal on Distance Estimation; Experiment 6

This section aims to consider why we have an effect of goals. The experiments so far have established, not only an effect of goals on distance recalls but also significant changes in self reported anxiety measurements and levels of urgency according to goal scenario. In this chapter the aim is to begin to tease apart the underlying mechanisms which may have contributed to the effect of goals in the last chapter. In particular the next experiment aimed to establish whether the experience of walking with a goal in mind affects distance and time perception, perhaps by mediating attention during navigation. Alternatively, the state induced by goal scenarios may affect the estimation process without performing the task (Figure 4.1). If the distance and time estimation effects are due to the affect of arousal/anxiety increases on the estimation process generally, an effect of scenario should be present even for a route walked prior to the scenario induction. Similarly, if the effects are due to a change in mood, induced from the goal scenario, we would also anticipate a relationship between reported change in mood between the scenarios and also differences across scenarios in memory for the length of a path travelled earlier.

States Induced by Goals		
Arousal	?	
Anxiety	?	
Mood	?	
States Affect General Estimation Process? ?	**States Affect Experiemce During Navigation ?** ?	
	Attention? ?	**Mood Congruence?** ?

Figure 4.1: Why the effect of goals? An overview of the contributory mechanisms

What states do Goals Induce?

There is a possibility that goals may influence distance estimation from three emotional states; anxiety, arousal and mood. Artificial induction of emotion in laboratory settings is stated to be comparable to naturally occurring situations as it results in similar physiological conditions that heighten memory retention by exciting neuro-chemical activity affecting areas of the brain responsible for encoding and recalling memory (Christianson & Loftus, 1990; Schacter, 1996). Triggering an emotional response may be an important indicator for information to be encoded and retained as it is well established that memory is enhanced for emotional information (e.g., Cahill & McGaugh, 1998; Hamann, Ely, Grafton, & Kilts, 1999; Kensinger & Corkin, 2003).

How are the states important?

Firstly, emotional states, if induced by the goal scenarios may influence the general estimation process or, alternatively, a state may influence attention during navigation.

Studies of incidental affect investigate the influence of subjective emotional experiences that ought to be unrelated to other present judgments and choices. For instance, affect generated from watching a movie, enjoying sunny weather, or experiencing stressful exams has been demonstrated to influence judgments of unrelated topics and objects (e.g. Clore, Schwarz & Conway, 1994; Forgas, 1995; Forgas & Bower, 1988; Schwarz, 1990; Schwarz & Clore, 1996).

Strack, Martin, and Stepper (1988) demonstrated the influence of mood states during encoding through manipulating facial configuration, smiling or frowning which influenced rating of cartoons. By asking participants to hold a pen horizontally in one's mouth using only the teeth (and not the lips) thus forcing a partial smile or holding the pen by the tip, using only the lips, forcing a partial frown, one can simulate the bodily state corresponding to a particular emotion. Strack et al. stated that the facial configurations influence people's emotions and therefore participants rated cartoons as being funnier when holding the pen in their teeth, with a forced smile than when they were holding the tip of their pen in their lips, and frowning. Evidence for this effect has been replicated (e.g.Larsen, Kasimatis, & Frey 1992; Soussignan, 2002) and Glenberg, Havas, Becker & Rinck (2005) illustrated that the same bodily states can facilitate sentence sensibility tasks. That is pleasant sentences are read more quickly while holding the pen in a forced smile position and the converse for the unpleasant sentences. Whilst this demonstrates the influence of mood during encoding the next experiment aims to investigate if the scenario induction sufficiently initiates a state that will influence the retrieval of a path walked previously.

Anxiety consists of many factors, such as changes in physiological state, cognitive processing, and mood and it is claimed that any of these factors can distort the perceived size of an object or distance (Barlow, 2002). The role of arousal and anxiety is also considered a key factor in contributing to distorted memories, for instance recent clinical psychology research suggests that people with phobias may experience a different world to non-phobics (Riskind, Williams, Gessner, Chrosniak & Cortina, 2000). The role of arousal at the point of encoding can have enduring effects. For example, one can understand how arachnophobics (spider phobics) can become aroused if they are in close proximity to their object of fear, in this case a spider. Arachnophobics reported the spider as travelling closer towards them than others in the room and also at a faster pace, when asked to imagine and draw a spider and the path it could take if it were to be let out of a cage compared to nonphobics (Riskind, Moore, and Bowley, 1995). This demonstrates the enduring effect of the state on the perceived distance.

Similarly, people with a fear of heights report bridges as being higher, and longer than they really are (Rachman & Cuk, 1992). More recently, individuals with a severe fear of heights estimated a balcony to be taller compared to reports from individuals with a mild fear of heights (Teachman, Stefanucci, Clerkin, Cody, & Proffitt, 2008), resulting in anxiety contributing to height overestimation.

Arousal cues that generally accompany anxiety are considered to be vague and transferable from one source to another (Zillman, 1971). Conversely, Schachter and Singer’s (1962) two-factor theory of emotion states that physiological arousal does not influence cognition. Whilst this has been challenged (Reisenzein, 1983) it has been claimed that arousal may just serve to intensify the experience (Dutton & Carroll, 2001), which impacts on the role of attention. For instance, arachnophobics are still fearful of spiders following the administration of beta blockers to remove the effects of arousal (Bernadt, Silverstone & Singleton, 1980). Therefore, arousal alone may not be sufficient to distort a judgement.

Alternatively, it may well be that it is not the emotional state that is influencing the distance estimation process but that the states, if present, influence another cognitive process, such as attention. Cue utilisation theory (Easterbrook, 1959), predicts that high levels of arousal lead to the narrowing of attention; as such it decreases the range of cues from the stimulus and the environment. This postulates that attention focuses primarily on the arousing details (cues) of the stimulus, thus the information essential to the source of the emotional arousal will be encoded while peripheral details will not. Furthermore, evidence suggests that emotional arousal, such as fear and excitement modulates attention and memory (Adolphs & Damasio, 2001; McGaugh, 2004; Phelps Ling & Carrasco, 2006). This would suggest that if the scenarios induced heightened levels of arousal the effect of such a state would be evident immediately upon goal induction, even if we were to ask people to estimate a path walked previously.

A final consideration is the congruence of the mood state at retrieval as arousal and mood state can generally affect one's retrieval of information and associated judgments, due to congruence (e.g. Bower, 1981; Forgas, 1995) and/or as a consequence of differences in processing strategies (e.g. Luce, Bettman & Payne, 1997; Schwartz & Clore, 1983).

For example, people will selectively retrieve mood-congruent information from memory and then use that information in unrelated judgments (i.e. Bower, 1991). According to associative network models, this process explains why people in good moods make optimistic judgments and people in bad moods make pessimistic judgments (Kavanagh & Bower, 1985; Wright & Bower, 1992). Overall, individuals have a greater tendency to retrieve information when it has the same emotional content as their current emotional state.

If the results of distance and time are due to states of arousal induced from the goal scenarios, which reflect the reports of changes in anxiety, then we would expect there to be a change in the levels of arousal between the scenarios. Furthermore, we would anticipate that the low urgency and low desirability scenario to evoke a negative mood and thus influence their distance estimations

We know from much of the literature presented in Chapter 1 that individuals represent distance imperfectly. This aim of this experiment was to begin to tease apart the contributory psychological factors influencing the effect of goals by examining the possible role of mood and arousal in distance estimation. That is, to establish whether the experience of delivering the package affects distance and time perception, or alternatively whether the state induced by scenarios affects the estimation process without performing the task.

To establish whether the experience of delivering the package affects distance and time perception by investigating if states, induced by scenarios, affect the estimation process without performing the task, it was necessary to get participants to estimate a distance after scenario induction, without walking that distance in the scenario context. So at the end of the scenario induction and just before participants *thought they were about to perform the scenario task.* This experiment asks participants to estimate the distance of the path which they have walked previously. Additionally, arousal levels were recorded during the task and mood levels monitored in order to establish how goals affect judgments.

4.2. Method

4.2.1 Design

The design was a 3 Scenario (HU vs. LU vs. Control) between participants design, using the reference path VR environment from Experiments 2 and 3.

4.2.2. Materials

Participants thought they were about to walk a VR path (as in the VR conditions in Experiment 1). A SpOT+ pulsoximeter (RDSM Germany) was used to measure heart rate and an abbreviated version of the 20 item Positive Affect Negative Affect Scale (PANAS) was used to measure mood following the scenario inductions. The PANAS questionnaire (Appendix 4) consisted of seven positive and seven negative mood state questions, and has reliably been demonstrated to identify personality states and traits such as anxiety (Watson, Clark & Tellege, 1988).

4.2.3. Participants

Fifty four participants were recruited to take part from Northumbria University and were paid a nominal fee for their participation. Participants were aged between 18 and 38 years old (mean age 22.6, SD= 3.9) and were randomly allocated and evenly distributed for age and gender across all conditions.

4.2.4. Procedure

The procedure was the same as for the first series of experiments, with the exception that participants' heart rates were monitored and recorded prior to walking the real space reference path as a baseline measurement, immediately prior to induction of the scenario, and finally, when the participants removed the blindfold in order to deliver the object (when we expected the scenario induction to be most heightened). Participants did not walk the main VR path; instead they were asked a series of questions, starting with an estimation of the real space reference path they walked earlier, followed by the questions from PANAS and subjective urgency and anxiety ratings for the task.

4.3. Results

Outliers identified as exceeding the criterion of 2 standard deviations from the mean for distance estimations, were excluded. This resulted in 2 participants being excluded from the analyses, leaving 52 participants in the following analyses.

4.3.1. Heart rate, Mood State and Anxiety measures

A 3(scenario) x 3(heart rate period: at the start of the experiment, just before goal scenario induction in VR, and immediately after[4]) revealed no reliable differences in HR between conditions, $F(2, 49) = 0.220$, $p > 0.05$, partial $\eta^2 = 0.009$, and there was no interaction between scenario and HR period, $F(4, 98) = 1.578$, $p = 0.186$, partial $\eta^2 = 0.060$. However, there was a main effect of HR period, $F(2, 98) = 16.433$, $p < 0.0001$, partial $\eta^2 = 0.251$. HR after goal induction was significant higher (M = 80.56 bpm) than at the start of the experiment (M = 75.29) or just prior to scenario induction (M = 75.98) (both $p<0.001$).

Two one-way ANOVAs examining the effect of scenario on mood state for positive and negative emotions (scales from the PANAS) revealed an effect of scenario on negative mood state, $F(2, 49) = 6.273$, $p = 0.004$, partial $\eta^2 = 0.204$, but not on positive mood state, $F(2, 49) = 0.642$, $p > 0.05$, partial $\eta^2 = 0.026$. Negative mood state scores were significantly higher in the high urgency condition (M = 2.098) than in either the low urgency (M = 1.657) or control (M = 1.361) conditions (both $p < 0.005$).

After the task, ratings of urgency differed by scenario, $F(2, 49) = 16.307$, $p < 0.0001$, partial $\eta^2 = 0.400$, in the same direction as in Experiment 1. Significant correlations were found between the level of urgency and the subjective level of negative emotion reported, $r = 0.499$, $p <0.001$.

[4] It is also pertinent to note that the changes in heart rate between the three measures were also not reliably different across the scenarios.

There were no significant correlations between HR measures and mood state measures, nor between positive mood scores and urgency levels (all $p > 0.05$), but urgency ratings correlated positively with negative mood scores, $r = 0.499$, $p > 0.001$. (see Figure 4.2).

<table>
<tr><th colspan="3">States Induced by Goals</th></tr>
<tr><td>Arousal</td><td colspan="2">X</td></tr>
<tr><td>Anxiety</td><td colspan="2">✓</td></tr>
<tr><td>Mood</td><td colspan="2">✓</td></tr>
<tr><td rowspan="2">States Affect General Estimation Process?
X</td><td colspan="2">States Affect Experiemce During Task?
✓</td></tr>
<tr><td>Attention?
?</td><td>Mood Congruence?
✓</td></tr>
</table>

Figure 4.2.: Overview of results investigating the effect of goals. Highlighting that the scenario inductions did not increase arousal, but influenced mood states.

4.3.2. Distance Estimation

Critically there was no reliable effect of scenario on distance estimation, $F(2, 49)= 0.358$, $p = 0.787$, $\eta^2 = 0.033$. Distance estimates did not correlate with any of the arousal or mood measures, or with ratings of urgency (all $p > 0.05$).

4.4. Discussion

The outcome of this study does not provide conclusive evidence in providing the cause of the distance distortions in the first series of experiments. The levels of arousal and mood were not monitored throughout the task but focused on the effect of the scenario induction. Nevertheless, the results show that the scenario induction did not cause a specific increase in physiological arousal across the conditions. The heart rate levels, whilst varying from the experience of being immersed in VR, did not differ across the scenarios at the most heightened point – when the scenarios has just been induced and participants were about to embark on the delivery of the task. Most importantly, after the scenario had been induced, participants across conditions did not differ in their distance estimates for the previously walked reference path.

Consistent with the previous experiment, self reported urgency ratings confirmed that participants engaged with the role-play task, with both high and low urgency scenarios evoking higher urgency reports than the control condition. In addition urgency ratings correlated with negative mood scores, which were themselves reliably different across conditions. However, no correlations were found between distance estimation for the previous path walked prior to goal induction, urgency ratings, negative mood scores, or heart rate. This pattern of outcomes rules out possible contributory factors of physiological arousal or mood affecting the general process of estimation. The distortion of distance and time estimation is due to factors associated with the actual performance of the goal task.

4.5. General Discussion

Taken together, the results of the experiments show that why people go from one place to another is important for immediate memory for distance and time. Participants walked a route with the goal of delivering a small bottle of medicine or failed exam results to a friend at the end of the path, or they walked the route without a specific goal. The speed with which they walked through the environment was strictly controlled across conditions. Nevertheless, participants delivering the medicine reported longer distance and time estimates at the end of the path than those in the other conditions. This establishes the importance of goals on cognitive maps in both real space and VR.

The results of Experiment 6 are informative regarding the contributory mechanism. First, the absence of an effect of scenario induction on distance estimation without actually walking a route with a goal in mind eliminates the possibility that goal induction simply affected the general estimation process. Rather, walking with a goal in mind is necessary for goals to affect distance and time estimation. Second, the absence of arousal differences across conditions eliminates arousal as a candidate explanation as well. This leaves several intriguing possibilities.

Consistent with the effects of attentional modulation on the experience of time during choice-response tasks (Coull, Vidal, Nazarian, & Macar, 2004), goals may mediate how attention is allocated as one moves around the environment (Bugman & Coventry, 2008; Corbetta & Shulman, 2002). The more urgent the task, the more time is spent registering events in the environment, resulting in a more detailed memory for the route. So just as salient landmarks grab attention or turning in the environment grabs attention (according to the attentional shift account; Bugmann & Coventry, 2008). Chapter 2 identifies robust top down influences suggesting that learners intentions and strategies shape their spatial memories (i.e. Bruynè, Rapp and Taylor, 2008; etc.).

It has also been stated individuals find it difficult to explain what drives their behaviour (Bargh & Chartrand, 1999; Nisbett & Wilson, 1977). Several important factors have been highlighted establishing the various influences on attention, such as importance (e.g., Cicogna & Nigro, 1998; Jeong & Cranney, 2009; Kvavilashvili, 1987; Marsh et al., 1998), degree of social obligation for the task (Meacham, 1988; Penningroth, Scott, & Freuen, 2011) and social ramifications (e.g., Einstein et al., 2005; Kliegel et al., 2001). These examples provide strong evidence that goals do mediate attention, and, hence, memory for it. This line of explanation serves as the impetus for the experiments in the next section of the thesis.

A further possible explanation for the influence of goals has to do with mood congruence. The correlation between negative mood scores and urgency ratings in Experiment 6 suggests that mood at retrieval may play a part in estimation differences, but that the mood at retrieval needs to be congruent with the mood experienced during the task (Bower, 1981; Forgas, 1995). For instance, Bower et al. (1981) found mood states at retrieval influence accuracy of word recall. Participants learned a list of words following a mood induction into a happy or sad state. They were later induced into a mood state again, either the same or different as before and tested on recall of the words. Bower et al., (1981) concluded that mood can predict recall.

To test between this and the previous possibility it is necessary to modify mood state after delivery of the objects and just prior to retrieval in order to establish whether mood congruence at retrieval is necessary for differences in distance and time estimations to obtain. Future studies would do well to examine this possibility.

In summary, the results, in general, show that goals influence memory for time and distance in both real space and virtual space. Goals are a part of everyday life and the results suggest that the reasons why people move round space may well influence how that space is experienced and recalled. When one considers human behaviour in real space and what exactly VR is for, such as a training or research tool, we must then acknowledge that the roles of goals do matter in both spatial cognition and VR and need to be considered across tasks and environmental settings.

4.6. Conclusion

The first series of studies has demonstrated that goals affect distance estimation across a range of media. Experiment 6 began by unpacking why the effect of goals may be present. For instance, the role of arousal from the goal scenario induction did not influence the retrieval of a path walked prior to induction. The literature on anxiety suggests that it modulates attention through mood and arousal. Clearly further work needs to be conducted across a range of tasks to try to attempt to identify the underlying mechanisms contributing to the effect of goals on distance estimation. In order to understand whether goals mediate attention, we need to understand the effects of attention during navigation. It is to this issue that we now turn.

SECTION III-ATTENTION

CHAPTER 5.

Influence of Attention and Time

The series of experiments in Chapter 3 demonstrates that goals influence immediate memory for distance in real and virtual space. In addition, Experiment 6 eliminated arousal as a contributory factor in distance estimation distortions following induction of goals. This suggests goals may mediate attention whilst traversing an environment.

This section of the thesis aims to tackle the possible role of attention in memory for distance head on. The final set of studies test the proposal that attention is an important contributory factor in determining distance recall. This chapter has two goals; firstly to review models of attention and secondly to demonstrate the influence of attention in the context of time. This will set the scene for the final two experiments in Chapter 6 which demonstrate that drawing attention to the environment or taking attention away from the environment results in increased or decreased distance estimations respectively, directly mirroring effects found in the time estimation literature.

5.1. Attention

Attention plays a fundamental role in what individuals see in the environment around them because, at any one moment, they are presented with considerably more information than they can effectively process. Therefore, due to the constraints of limited capacity, the attention mechanism has evolved to focus on the most relevant information in accordance with ongoing goals and behaviours (Pashler, Johnston & Ruthruff, 2001).

The limitations of the processing capacity result in a need for selection between multiple competing stimuli. One could argue that the goal of attention is to bias competition in favour of certain aspects in the environment (Desimone & Duncan, 1995). Consequently, visual attention is controlled on a daily basis by both bottom-up, environmental factors (encompassing sensory stimulation) and top-down cognitive factors, such as knowledge, anticipation, and goals.

This approach not only defines the mechanisms of attention as automatic or controlled but also makes the distinction between exogenous and endogenous attention. Exogenous attention refers to the ways in which attention is drawn automatically to aspects of the environment such as the sound of a bee flying past or a visually salient object. This bottom-up process is dependent on external stimuli and is beyond the individuals' conscious control. In contrast, endogenous cues require volition and the voluntary direction of attention by the individual. For instance, the kind of attention which is utilised when an individual is attempting to find their way is a typical top-down controlled mechanism requiring conscious effort.

A further distinction has also been made between overt versus covert attention (Wright & Ward, 2008). Overt attention directs our senses towards a stimulus source whereas covert attention mentally focuses on one of several likely sensory stimuli. This means that an individual can either attend to a certain spatial location (overt attention) but will also be able to detect what is occurring in the periphery of their field of view (covert attention) otherwise known colloquially as ‘out of the corner of their eye.’

Both overt and covert spatial attention can be modulated by exogenous and endogenous cues, that is, with (overt) or without (covert) eye movements (Corbetta & Shulman, 2002; Egeth & Yantis, 1997). However, the specific underlying mechanisms between endogenous and exogenous cues have yet to be identified and to date there have been no studies that directly compare endogenously and exogenously driven shifts in covert and overt attention (de Haan, Morgan & Rorden, 2008).

Posner (1980) demonstrated attentional shifts and the influence of both bottom-up (exogenous) and top-down (endogenous) attention by utilising a cueing paradigm. Shifts of attention, considered in terms of reaction times, to a cued spatial location occur faster than to an uncued target. Posner demonstrated that exogenous and endogenous cues distinguish qualitatively different cognitive processes in the shifting of attention.

Exogenous, bottom-up, stimulus driven cueing was established by drawing attention to a location by means of an abrupt onset cue. In this instance a flashed stimulus, appearing in the same location as the target, was presented to the left or to the right of the fixation. Endogenous, top-down, goal directed cueing was demonstrated by cueing attention to a location. This was achieved using a symbolic cue, in this instance an arrow, to direct attention to the desired position (Figure 5.1). This effect has also been demonstrated using left or right word cues to direct attention (Hommel, Pratt, Colzato & Godijn, 2001). The symbolic arrow cue indicated the possible position of the target, which was presented to the left or to the right of a fixation point. Posner found RTs were faster when the target appeared in or where participants were directed to the cued location, as compared to a neutral condition without cue, and RTs were slower when the wrong location was designated.

Posner (1980) put forward the contention that participants covertly re-orient attention towards the direction given by the cue and that selective attention to the cued location in space influenced the neural processes of detection. Furthermore, it is claimed that attended events enter perceptual awareness with a shorter latency than unattended events, because selective attention filters out unexpected events.

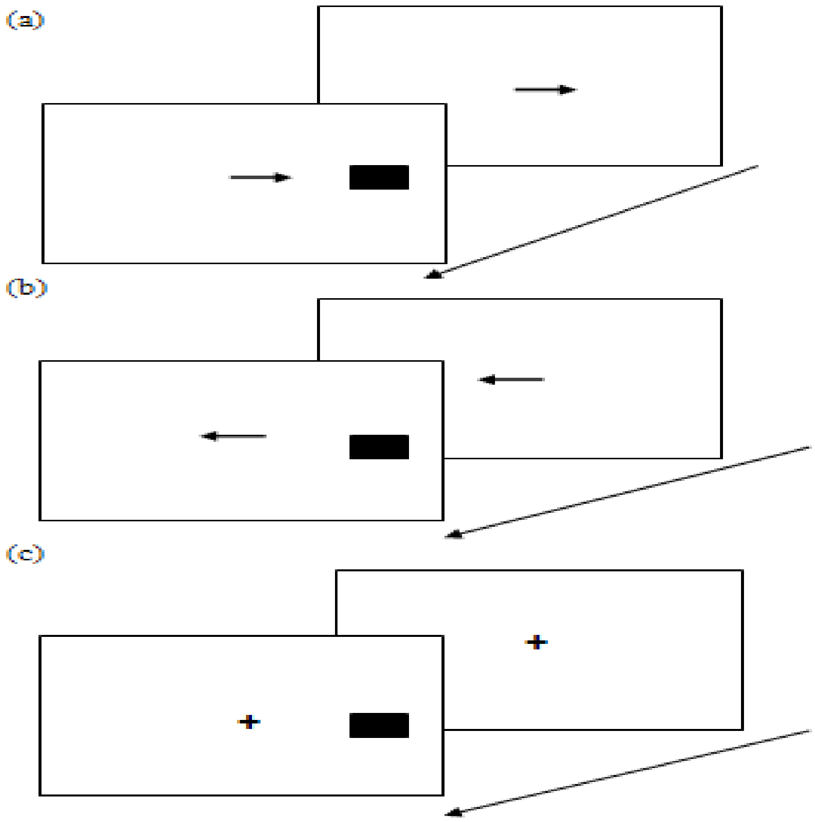

Figure 5.1: Experimental procedure of Posner (1980).

(a) Valid condition. The central arrow points to the location where the target will subsequently appear.

(b) Invalid condition. The central arrow points to a location that is different to where the target will appear.

(c) Neutral condition. The subject is not given prior information about the location of the target.

The distinction between exogenous and endogenous attention is important in understanding the deployment of attention, especially as there are multiple stimuli competing for attention in naturalistic settings. Consequently, it is important to identify the mechanisms and subsequent consequences involved when attention shifts to a location or object in space. For instance, when an individual has a goal or a purpose to accomplish, such as those explored in the last chapter, we need to understand how and when attention is allocated. It may be moved voluntarily in a goal directed manner towards or away from the environment or, alternatively, attention can also be focused; all of these factors can result in either a heightening or reduction of memory for environmental features. However, it is also important to understand situations where attention is captured by bottom up, external stimuli.

To date it has been established that there are different neural mechanisms for goal directed (top down/endogenous) and stimulus driven (bottom up/exogenous) attention. (Moore & Armstrong,2003; Saalman, Pigarev & Vidyasagar, 2007). For instance, prefrontal neurons are active first whilst target location processing occurs and the parietal areas are active during bottom up attention (Corbetta, Patel & Shulman, 2008). Therefore spatial attention can both facilitate the processing of certain objects or locations and also inhibit adjacent stimuli and spatial locations. As one would expect, cueing improves detection of appropriate information thereby allowing individuals to discriminate within the environment (Corbetta & Shulman, 2002; Yantis, Scwarzbach, Srerences, Carlson & Steinmetz, 2002).

Whilst there is evidence that goals or cues allow individuals to focus on the most relevant items (Folk, Leber & Egeth, 2002), there is no consensus, to date, that identifies which situations would result in a distraction or a shift of attention from those goals. It has been reported that abrupt onsets, such as the emergence of novel stimuli, cues that appear to be looming, or cues that appear to be on a collision path with the observer, all capture attention (Theeuwes, 2004; Yantis & Egeth, 1999; Abrams & Christ, 2003; Franconeri & Simons, 2003; Lin, Franconeri & Enns, 2008).

Similarly there is a lack of consensus regarding the stimuli features that are most likely to attract attention, however it is generally accepted that exogenous, bottom-up cues, result in attention being captured involuntarily. In some instances this can be instinctive in cases of fear or danger and would therefore be more automatic in comparison to endogenous cues (Koch & Ullman, 1985; Jonides, 1981; Remington, Johnston, & Yantis, 1992). However most attention processes are driven by top down (endogenous) goals, which determine the amount of attention that is devoted to incoming information. As a general rule, goal relevant information will capture attention much more than stimuli that are irrelevant, for instance, a thirsty person will pay more attention to something that they can drink as opposed to objects they cannot drink (e.g. Aarts, Dijksterhuis, De Vries, 2001; Folk et al., 2002)

One important aspect of top-down (endogenous) cues is that they can vary across many levels, which can impact on perceptual load. To understand where, how and what people pay attention to in the visual environment involves an appreciation of complex dynamic interactions. An even greater understanding of attentional processes during navigation is required, as factors, such as novelty and unexpectedness reveal a complex interplay between the cognitive and sensory influences on attention. Previous studies demonstrate that humans shift attention reflexively yet the evidence merely argues that attention is primarily best described either as space based (e.g. Posner, Snyder & Davidson, 1980; Tsal & Lavie, 1988, 1993), object based (Duncan, 1984), or both (Egly, Driver & Rafal, 1994; Kramer & Jacobson, 1991; Vecera, 1994, Vecera & Farah, 1994). These distinctions, in addition to the identification of endogenous and exogenous processes, serve to highlight the complexity of the processes involved during navigation in a real world environment.

Shifting attention allows individuals to redirect their attention to aspects of the environment that are relevant for their goal (Gazzaniga, Ivry, & Mangun, 2002; Posner, 1980). Attentional shifting occurs due to limitations of cognitive resources and restrictions within the visual field which hampers simultaneous processing of information (Gazzaniga et al., 2002). For instance, when multiple objects occur in a scene, only some may show up in our field of vision at any one time. Therefore, the eyes, along with one's attention, move and refocus to process multiple stimuli; the task of refocusing one's attention involves an attentional shift. These shifts occur on many levels and can result in greater efficiency for a specific object or task, generally at a cost to other stimuli.

To date, investigations into how exogenous and endogenous systems interact whilst orienting is scant despite awareness that multisensory processing is utilised in everyday life. There has been growth in recent years in investigating exogenous orienting on focussed attention (see Mazza, Turatto, Rossi & Umlità, 2007; Van Der Lubbe & Postma, 2005; Koelewijn, Bronkhorst & Theeuwes, 2009; Santagelo, Olivetti Belardinelli, Spence & Macaluso, 2009; Chica, Sanabria, Lupiàňez & Spence, 2007). Since Posner's (1980) study neatly demonstrated how endogenous and exogenous cues influence the distribution of attention it is important to consider the effects associated with these shifts.

Essentially, whilst navigating in an environment, one would assume that the level of attention allocated to the surroundings contributes to the person's subjective perceptions of the distance covered or duration taken to complete a journey. Therefore, if less attention is allocated to the distance covered this will result in shorter distances being reported for that journey.

Whilst this has not been specifically investigated in distance perception, investigations, the role of attention in time perception suggest that attention is important. It is to this literature that I will now turn.

5.2 Time

The evident relationship between distance and time has been highlighted across many situations; for instance the further one walks, the longer it takes (Montello, 1997; 2009). Montello also claims that time provides a convincing foundation on which to base distance knowledge, especially when there is restricted access to other kinds of information, such as in the case of passive VR systems. It is worth noting though that evidence identifying the relationship between time and distance estimation in the area of spatial cognition is negligible. Distance and time are generally observed as two interconnected features, that is, if individuals state the distance as a metric and are then asked about travel time, the distance measurement may be used as a guide (Bugmann & Coventry, 2008).

There is some evidence suggesting the influence of space on the perception of time and that other spatial factors affect the perception of time and other magnitudes. De Long (1981) found that people judge time to pass more quickly when they work with small-scale model environments. Participants were asked to conduct a task and stop when thirty minutes had passed with environments built to scales of 1/6, 1/12 or 1/24 of the actual size. It was found that the ratio of reported estimated time was scaled in accordance with the scale of the environment. The given explanation for these results was that individuals experience temporal duration in relation to the proportion of the scale of the model being observed.

This notion was developed further by Casasanto & Boroditsky (2008) and highlights the intimate relationship between space and time in human representations. In this experiment participants were presented with a series of lines that appeared and extended on a screen, of varying spatial length, across a variety of time periods. The task required them to estimate the duration of the presentation or the spatial length, using mouse clicks to identify either, the beginning and the end of either the correct length or the duration of time. The results demonstrated a cross-dimensional asymmetry between distance and time where shorter lines were reported as taking a shorter time, and longer lines were judged to take a longer. By contrast, the temporal duration of the stimuli did not influence judgments about spatial length. The resulting conclusions stated that distance influences the representation of time more than time influences the representation of distance.

Nonetheless, distance and time are undoubtedly inextricably linked and the time estimation literature has produced similar distortion effects to that in distance estimation literature (see Block and Zakay, 1997 and Brown, 2008 for a review). It has been demonstrated that segmentation influences time duration with an increase in segments resulting in an increase in time (Poynter, 1989; Zakay, Tsal, Moses & Shahar, 1994). More importantly, the explanation by Poynter is identical to the explanation concerning the effects of turns on distance estimation/perception (Sadalla, Burroughs & Staplin, 1980), that is, a greater amount of segments will result in an increase in perceived time. In addition, increased time durations are generally underestimated and estimations for complex stimuli are greater than estimations where the stimuli are less complex (Boltz, 1992, 1995, 1998; Brown & Boltz, 2002; Jones & Boltz, 1989). Attention has been argued to be the fundamental mechanism underlying this effect (for a review see Brown, 2008). For instance, disorganised events require more attentional effort as they are indiscriminate and unpredictable, thus resulting in greater inaccurate estimations. This mirrors the effect of features in an environment, whereby the greater amount of environmental features in an environment draw ones attention to the route and hence results in longer distance estimations.

The following section will cover the literature concerning the role of attention in time perception estimation with a view to developing predictions for distance estimations in the studies that follow.

5.2.1 Attention and Time

It is clear that attention plays a critical role in time perception as it is central to accounting for the variability of time estimates and is generally utilised in order to explain the findings of research into subjective time duration (Brown, 2008; Block & Zakay, 1997; Macar, Grondin, & Casini, 1994).

A 'watched pot never boils' is a colloqial expression which suggests that attending to time makes time pass much more slowly (Fraisse, 1963). The validity of the anecdotal 'watched pot' was investigated in an experiment during which participants were advised that the experiment would start after a delay and that the experimenter would return later (Cahoon & Edmonds, 1980). One group was advised that they must call the experimenter when the water in a glass coffee pot started to boil, as a favour to the experimenter, but the control group did not receive these instructions. In both cases the experimenter returned 4 minutes later and asked the participants to estimate how long he had been gone. Duration estimates were significantly longer for participants in the "watched-pot" group. In contrast, inattentiveness to time, such as being absorbed in some activity, can cause time to flow at a faster rate, as captured by the expression 'time flies when you're having fun.'

Our everyday life is crammed with episodes of physical regularities (Jones & Boltz, 1989) which are generally taken for granted. There is evidence that humans are particularly sensitive to time across a range of activities, i.e. temporal variations during a conversation, speech and music patterns (Grondin, 2010). Subsequently, investigations into attention and time elegantly demonstrate how attentional resources are shared through the use of dual task strategies where a key factor is whether each task demands the same or different amount of resources as each other. Thus, if two tasks are to be conducted simultaneously, less attention will be available for each one and if they utilise the same resources they will compete for attention. Hence, a pertinent focus in this research is to identify which stimuli or task is the most successful in obtaining resources and 'winning' the competition.'

Dual task paradigms provide many useful insights into the mechanisms of attention at a micro level as it is very easy to manipulate the conditions in these experiments. Coull, Vidal, Nazarian, and Macar (2004) demonstrated that the degree of attention directed to an activity or object plays a role in the subjective perception of time as the less attention given to a stimulus increases any misperception of the duration of time. Twelve participants were presented with a colour versus time duration dual task paradigm across five conditions. Following a training period, participants were directed, via an attentional pre-cue with various likelihoods, to attend to either the duration of the stimulus or, the stimulus colour, which was manipulated to various hues. Alternatively, the cue directed participants to attend to both time and colour to varying degrees, for instance 25% to time and 75% to colour. The data confirmed that the participants allocated attention appropriately across the five attentional conditions (as Figure 5.2 demonstrates).

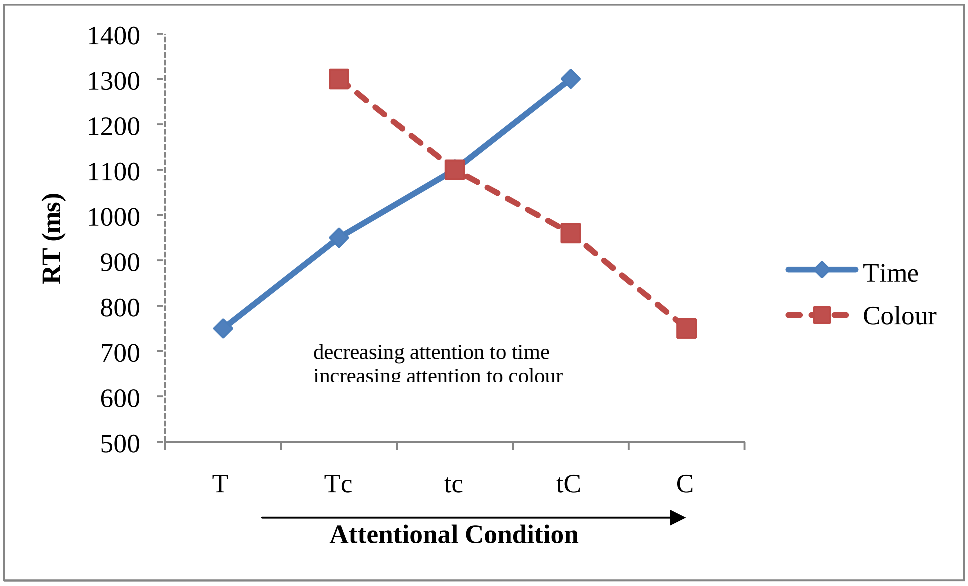

Figure 5.2: Behavioural data for time and colour choice response trials, adapted from Coull et al. (2004).

Horizontal axis represents the degree to which participants attended to either time or colour:-

- T: participants attended 100% to time and ignored Colour;
- Tc: participants attended to Time 75 % and Colour 25%;
- tc: participants attended to both time and colour to equal degrees i.e. 50%, etc.

Furthermore, fMRI data demonstrates that neural activation in the visual cortex (V4) increased in accordance with the degrees to which the colour stimuli were attended to. Moreover, the opposite pattern in preSMA activity was demonstrated when the degree of attention was focussed on colour. (Figures 5.3 and 5.4 refer).These data not only show that the amount of attention directed to time maps directly onto time judgements, but that the preSMA activation appears to 'clock' duration mediated by attentional resources.

Just as attention to time increases estimates of duration, taking attention away from time decreases estimates. There are several studies supporting the notion that timing is a resource-demanding task and the effect of interference can sometimes exhibit a graded response. That is, time judgment performance may display a progressive deterioration as greater amounts of attentional resources are diverted away from the timing task.

The literature using dual task paradigms demonstrates that time estimations are sensitive to interference. For instance, participants asked to concurrently attend to a passage of time and perform a distracter task and are then asked to judge time duration. The typical finding is that time judgements, in dual task conditions, are reported as being shorter, inconsistent and inaccurate compared to single task timing conditions, due to the division of attentional resources. Even when the distracter task is not demanding, the attentional requirements are likely to interfere considerably as the effect is robust.

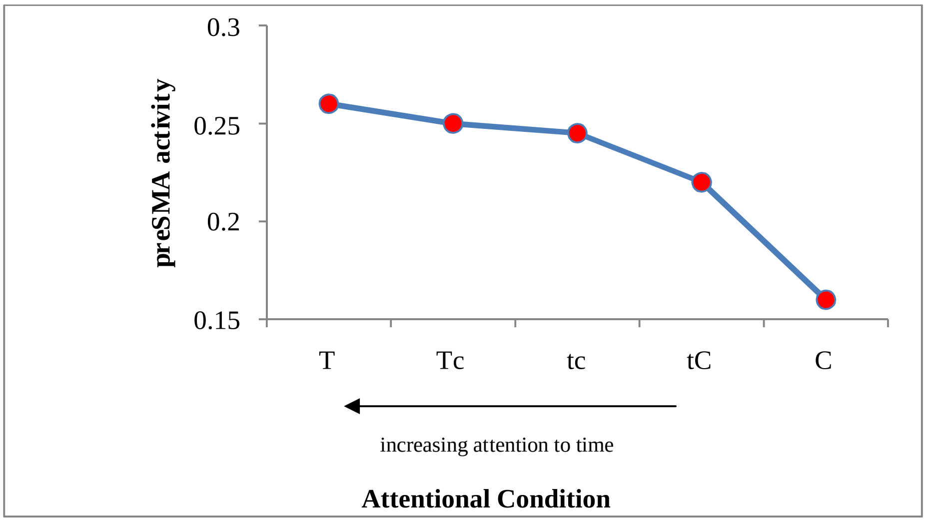

Figure 5.3: As participants paid progressively more attention to time, brain activity increases, most notably in preSMA, as well as in a network of other cortical and striatal areas. Adapted from Coull et al. (2004)

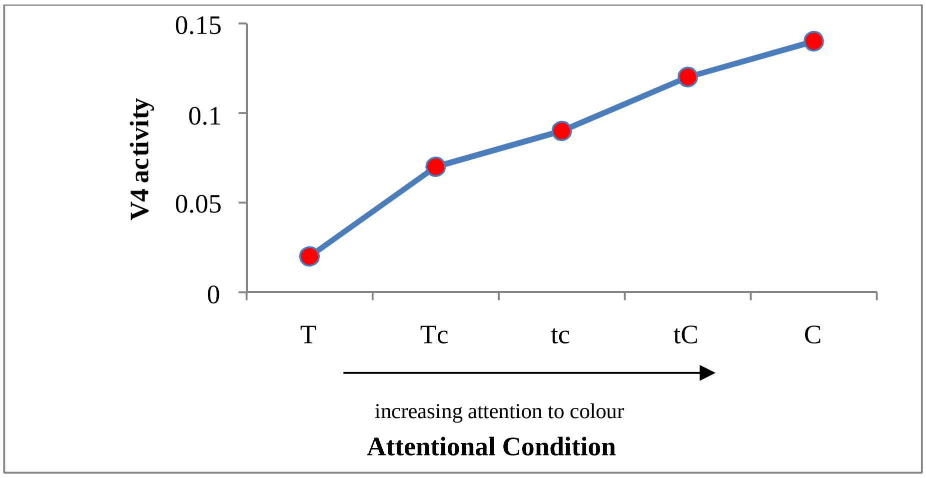

Figure 5.4: As participants paid progressively more attention to the colour attributes of a stimulus, brain activity increases in the visual cortex (V4), notably in the right hemisphere. Adapted from Coull et al. (2004).

It is claimed that distracter tasks disrupt timing by making time judgments shorter, more inaccurate, or more variable relative to timing. Direct manipulations of time and mental workload come from studies in which participants are instructed to devote specified amounts of attention to concurrent temporal and non-temporal tasks. These studies show that the less attention devoted to timing, the greater the underestimation error in time judgments (i.e. Casini & Macar, 1996; Zakay, 1998). In an attempt to investigate the effects of resource allocation on timing, Grondin and Macar (1992) asked participants to judge either the duration of a tone or the intensity, or both. The duration task required that participants judge whether the tone was long or short and the intensity task required participants to judge whether the tone was soft or loud. Similar to the Coull et al. (2004) study, participants were instructed to devote relatively greater amounts of attention to one task and correspondingly less attention to the other task. The results demonstrate that duration estimations decreased when greater attention was focussed on the intensity of the tone. This effect has been demonstrated across numerous studies (i.e. Franssen & Variendierendock, 2002).

There appears to be much evidence demonstrating that dual task conditions share resources between temporal and non-temporal tasks, resulting in less attention to time and directly reducing the amount of temporal information encoded and stored. In short, taking attention away from a task reduces the temporal judgments' for that task.

A range of other factors have also been shown to effect time estimation. For example, effort can play a major role in the division of resources with dual task strategies. If the distracter is more demanding, the increasing cognitive workload results in the deployment of greater attentional resources which in turn directly impacts on the resources available for timing. Put simply, the more difficult the task, the greater the impairment in the timing performance. Benuzzi, Basso and Nichelli (2005) asked participants to memorise stimuli consisting of random visuospatial patterns of 1, 3, or 6 black squares in a *7* x *7* grid. They were subsequently presented with the same grid containing only one black single square (probe). Their task was to identify whether the probe was present in the pattern previously presented and also to respond after a self paced, subjective 3 second delay. Longer reaction times were generated and longer intervals produced which were proportional to the complexity of the visual pattern. This supports the notion that timing performance is inextricably linked to the cognitive resources available.

5.3.2. Summary

To accurately perceive the duration of events and actions is crucial to many aspects of human performance. Time appears to be relatively abstract and therefore needs some form of representation to be actively maintained during temporal processing. Secondly, time processing requires attentional resources and it has been demonstrated that stimulus duration estimations vary depending on the degree of attention allocated to the time feature (Brown, 2008).

Attention plays a major role in processing and encoding cues from both bottom-up stimuli, such as the organisation of events, and top down factors, such as an individual's subjective source of time. Overall, increased attention to time increases the subjective duration of time. Guiding one's attention to the flow of time, either directly through instructions or indirectly through task requirements or, situations designed to promote expectancy and anticipation, tends to lengthen one's perception of time. In contrast, investigations using concurrent distracter tasks illustrate that judgments' of time become shorter when attention is diverted away from time. This emphasises the role of attention in time perception.

As yet, comparatively little is known of the relationship between attention and distance perception and whether this relationship mirrors the results in the time and attention literature. It is to this issue that I now turn.

5.4. From Time to Distance

The role of attention has received as little consideration in the area of distance estimation as the relationship between distance and time. Montello (2009) highlights the role of attention, distinguishing between active and passive travel, where active travel is identified as the individual being in control and being guided by one's own volition and passive, being lead by an escort. This discrimination is regarded as essential when it comes to an individual's subsequent knowledge of that environment. For instance, car passengers have less knowledge of their environment than drivers (Appleyard, 1970; Downs and Stea, 1973; Hart & Berzok, 1982). However, there are some studies which demonstrate that spatial learning in the real world is superior through passive as opposed to active travel, implying that the cognitive load of active travel inhibits environmental knowledge (Held & Hein, 1963; Herman & Siegel, 1978; Larish & Andersen, 1995). Nonetheless, these do not directly refer to distance estimation and highlight the importance of the appropriate task for ascertaining the role of attention in navigation.

Bugmann and Coventry (2008) emphasize the importance of attentional shifts as an explanation to account for differences in subjective distance estimations. For instance, environments frequently contain multiple stimuli, which compete, and attentional shifts generally occur as attention is focussed on one task and is grabbed by another. Imagine an individual walking in an environment with bottom up/exogenous salient objects such as large buildings, unusual features or statues, all of which can aid navigation and enable orienteering. Now consider walking in the same environment with an aim of finding a post box to post a letter, assuming that the same individual is focussed on the completion of the task. The individual will need to both attenuate (Treisman & Gelade, 1980) and filter (Broadbent, 1958) the appropriate information, relevant to the task and allocate the relevant or available amount of resources necessary for further processing.

Thus, shifting attention is necessary because it allows us to redirect attention to aspects of the environment we want to focus on, and subsequently process. This must, therefore result in a cost/benefit scenario, which is highlighted neatly by the Coull et al (2004) dual task time versus colour study mentioned earlier in the chapter. One explanation that attempts to explain how visual attention shifts is the moving spotlight theory (Sperling & Weichselgartner, 1995; LaBerge, Carlson,Williams, & Bunney, 1997). The principle here is that attention is similar to a movable spotlight which directs its beam towards intended targets and focuses on each target in a serial manner as opposed to concurrently. When the target is illuminated by the spotlight, or attended to, the spotlight is in effect, turned off from a current location whilst attention shifts to the next attended location and then reinitializes. An alternative metaphor is that of a zoom lens, with variable power (Eriksen and St. James, 1986; Eriksen and Yeh, 1985). These two metaphors differ because the zoom lens predicts an inverse relationship between the size of attentional focus and efficiency of processing, whereas the spotlight makes no predictions. Using the zoom lens analogy, one may assume that, in the medication scenario in the first series of experiments, the lens could narrow to focus attention on the task. This would have a similar effect to that of a camera lens, enhancing the features of that path and thus increasing memory for the distance traversed. However, neither the spotlight nor the zoom lens metaphor can be taken too literally as neither account for the fact that attention can be divided across two locations (Johnson & Zatorre, 2006). In some instances, shifts can be bottom-up, the result of a salient environmental feature like a large bridge that would refocus attention within the environment or say a bird that would shift attention outside of the environment. Alternatively shifts can be top-down, exogenous, and therefore driven by expectancies and, as stated earlier in the chapter, can be resistant to non goal related interference but drawn to goal congruent stimuli. It is the next stage in the process, the practice of refocusing one's attention which involves an attentional shift.

Whilst the role of attention with distance estimation has yet to be tested, Bugmann *et al.* (2008) postulate the importance of attention by suggesting that it accounts for many of the distance estimation effects reported in Chapter 1. For instance, Thorndyke (1981) demonstrated the relationship between memory, distance and the intervening landmarks en-route. When a route contains more landmarks, it is remembered as being longer than when it contains fewer intervening landmarks. The role of attention here can be explained in that landmarks grab attention, and therefore increase awareness of the distance travelled. Similarly, salient environmental stimuli (like large buildings or other objects of visual interest) are more likely to capture attention thereby influencing the distance remembered.

Chapter 1 considered a range of cognitive distortions providing evidence that cognitive representations do not reflect an exact replication of the environment. From the evidence presented so far, it can be proposed that the role of attention accounts for many of these effects in an elegant and systematic fashion. Clearly, when an individual walks in an environment, the extent to which the environment is attended to should influence memory for distance in the same way as attending to time affects the perception of time. Therefore, the more attention is focussed during a route, the longer the route will seem.

Montello (1997) makes reference to work from his unpublished thesis, reporting that participants who read and rehearse a list of words whilst walking in a corridor report the distance and time as being significantly shorter than in the no-word control group, despite the standardisation of walking times. Whilst this study has not yet been fully published, one interpretation of the results could be that the word rehearsal task captured attention, leaving fewer resources to attend to the environment. Since walking is considered to be a fairly automatised task, this will result in shorter pulses of time being registered.

Bugmann et al. (2008) revisit many of these distortions from an attention perspective, providing convincing arguments for many of these effects. For instance, asymmetrical effects (when an individual embarks on a journey in a new environment; the return journey is subjectively shorter (Diwadkar & McNamara, 1997)) can be explained via a presumption that a person is no longer required to attend to the environment to the same degree whilst navigating their way home. This will shorten their subjective estimation of that journey distance.

It is also proposed that the “cognitive effort” and the scaling hypotheses, which have been regarded as competing accounts for distance estimation, can be explained by attentional shifts (Bugmann et al. 2008). The cognitive effort hypothesis purports that the effort involved in traversing a distance directly results in the route appearing longer (e.g., Cohen, Baldwin, & Sherman, 1978; Newcombe & Liben, 1982). However, the scaling hypotheses states that environmental features break routes into smaller units which are then added up separately and because smaller distances are generally overestimated, this results in the routes also being reported as longer (Holyoake & Mah, 1982; Montello, 1997). Carrying a heavy load results in both walking at a slower pace and additional physical effort, and these combined roles will result in re-attenuation as the more tired an individual becomes the more aware they will be of the environmental features. Therefore a combination of environmental features and the restrictions of movement and physical effort from the task will then directly influence immediate memory for distance.

To conclude, a review of the dual task paradigms contained within time and attention literature provides compelling evidence that attention plays a major role in subjective estimations of temporal duration. To put it simply, the more one attends to a stimulus or task the longer it appears to be and if attention is taken away from an event, the shorter that event duration will appear to be. It is proposed that the first series of experiments provide results which support the idea that goals may mediate attention. In view of the relationship between distance and time, and the explanation proposed, which postulates that attention offers an explanation into a range of distance estimation effects, it is desirable to test the role of attention in distance estimation made directly. The next two experiments aim to mirror studies from the time literature, firstly by manipulating attention to increase attention to the environment and second by taking attention away from the environment to see if this directly influences distance estimations.

CHAPTER 6.

Influence of Attention on Distance Estimation

The previous chapter suggested that attention may play a fundamental role in subjective distance estimations and the results from the first series of Experiments, reported earlier in this thesis, have allowed us to observe the effect of goals on distance and time estimation in Real Space and VR across straight paths and environments with several turns. These results are consistent with the attentional account offered in the previous Chapter.

However, those experiments did not manipulate attention directly. The main aim of the experiments presented in this chapter is to manipulate attention directly using short bursts of auditory or visual stimuli.

A second goal is to examine the role of modality on attention and distance estimation. Environments constantly provide a large amount of information which is either selected or filtered out in order to guide behaviour. However, most research on spatial attention has been focused on purely unimodal situations. (e.g. Desimone & Duncan, 1995; Johansen-Berg and Lloyd, 2000; Luck, Chelazzi, Hillyard & Desimone, 1997; Pashler, 1998; Spence & Driver, 1994). But, environments are multi modal experiences (e.g. visual-acoustic, visual–tactile), typically producing multimodal signals and stimulating different senses simultaneously (e.g. when a seagull calls out above ones' head). Hence, attention must be coordinated across different sensory modalities, in order to select visual, auditory, and tactile information originating within the same spatial location.

The synchronized processing of visual and auditory information is crucial across a range of everyday situations. Yet, examples of auditory influence on visual perception are scarce (Schmidt, Postma & de Haan, 2001; Spence, 2010). A small number of studies have established some influence of auditory cues on visual tasks. For instance, endogenous cueing of auditory targets can successfully prime the location of a future visual target (Spence & Driver, 1996). Furthermore, peripheral (exogenous) auditory cues have been demonstrated to draw attention automatically to locations in discrimination tasks (Spence & Driver, 1994).

Conversely, investigations into attentional shifts between visual and auditory modalities established that presenting a stimulus in one modality reduces the processing of subsequent stimuli in the other modality equally across vision and audition (Turatto, Benson & Galfano, 2002). Participants were presented with either an auditory or visual prime which was followed by a target cue. Their task was to press the space bar of the computer keyboard as soon as the target was detected and to refrain from responding on presentations where there was no prime stimulus. Each modality had two levels, the visual stimuli consisted of a red (cue) and green (target) LED light,each with their own spatial co-ordinates i.e. they were just offset from the centre of a screen. The auditory stimuli consisted of 900-Hz pure tone (cue) presented at 70 dB(A) and a 1800-Hz pure tone (cue) presented at 70 dB(A). Each trial was matched for congruence with the prime and the target, i.e. 25% visual–visual, 25% visual–auditory, 25% auditory–auditory and 25% auditory–visual. In addition, there were 18% catch trials (no cue) per block. The results identified significant reaction time delays across both cross-modal conditions, where the primary and secondary stimuli were presented in different modes.

Similar evidence of cross-modal performance deficits were demonstrated using a methodology that presented simultaneous, as opposed to sequential stimuli (Tellinghuisen & Nowak, 2003). This resulted in the slowing down of response times and increases in response errors when participants performed visual searches simultaneously with auditory distracters that were incongruent with the visual target. When the auditory distracters were neutral to the visual search, there were fewer performance deficits. This suggests that a visual task, similar to navigation and encoding the information of places en route, are unlikely to be affected by a simple auditory distracter congruent to that environment, such as listening to the radio, but is more adversely affected by complex, cognitively weighted auditory distractions, such as talking on a mobile phone or tasks that require decision-making.

Thus the focus of the next experiment is to address whether or not manipulation of attention via stimulus representations from different modalities influence on distance estimation to the same extent.

6.2. Experiment 7.

The Influence of Visual and Auditory Distracters in VR on Distance Estimation

The time and attention literature indicates that drawing attention to time results in an increase in subjective temporal duration. In the example of a watched pot, (Cahoon & Edmonds, 1980) the attention to time is captured by focussing on another stimulus, a boiling coffee pot. Dual task studies (reviewed in the last chapter) also show that dividing or sharing cognitive resources or directing attention influences ones subjective experience of time. Bugmann and Coventry (2008) propose that there are a variety of situations where focussing or shifting of attention within the environment influences distance estimation. For instance, Bugmann and Coventry (2008) claim that turns in the environment (Sadalla

& Magel, 1980) re-initialises attention to the environment resulting in a greater part of the path being attended to, which directly influences the increased reported distance.

The goal of this study was to investigate whether the presence or absence of attentional cues in a modified version of the VR environment, used in Chapter 3, would influence participants immediate memory for distance in an environment using a within participants design. A further aim was to investigate the influence of the modality of cues - visual versus auditory – in a between-participants presentation. Three flashes or auditory bursts were presented in either the first or second path for 500ms each.

Because the study deals with stimuli from differing modalities, phenomenological and qualitative differences may well be present. Attempts were made to ensure that the visual and auditory stimuli were equivalent in their intensity and salience. To my knowledge, there is no specific guideline across previous studies which make specific efforts to equate perceptually visual and auditory stimuli (e.g. Spence & Driver, 1994, Turatto et al. 2002)

The environment was somewhat different from those used in the first series of studies as they were slightly longer and were also divided by a virtual turntable to discriminate between the paths. In addition, the ceiling of the paths were not covered in opaque tarpaulin in order to allow for the presentation of the visual flashes, ahead and slightly above the environment, without the participant thinking they would possibly collide with the objects. However, the virtual rendering was identical to that used in the previous experiments.

The following experiment aims to present participants with two VR paths, similar in length, and to test directly whether drawing attention to the environment, through short auditory bursts or visual flashes, results in greater distance estimations, consistent with studies in time perception. A secondary goal is to address whether the modality of the cue influences subjective distance estimations. We hypothesised that re-engaging ones attention, as a result of the auditory or visual cues, to the environment will result in greater distance estimations than when no attention stimuli in the environment are present.

6.2.1. Method

Participants walked a virtual path. During one half auditory or visual flashes occurred. At the end of the route they were asked for distance estimates for the first and second sections of the route.

6.2.1.1. Materials

The computer model was generated using an identical VR system and software as the experiments in the first series of studies (see Figure 6.1).

Two paths were created, 19.78m and 20.09m in length with identical rendering to that of previous experiments in this thesis. The top of the environment was open to allow for the visual attention stimuli to be viewed without appearing to be obstructing the path. The paths were distinguished by a turning circle at the end of the first route and beginning of the second. Both paths were preceded and terminated with an identical circular enclosure, to ensure that the start and end field of views were identical. The circular enclosures were 4m in diameter. Figures 6.1 and 6.2 provide an allocentric and egocentric view of the paths. The curvature of the walls in the circles acted as an indicator to signal to participants when they were either commencing or finishing their journey.

The auditory stimuli were generated in Matlab. They were sampled at 8192 samples/second and had a frequency of 300Hz with duration of 500msec. They were pure sinusoidal tones with the volume increasing linearly from zero to full volume over the first 800 samples and decreasing linearly from full volume to zero over the last 800 samples to prevent noise effects caused by abrupt changes in volume. The stimuli were presented via stereo speakers, placed 1 metre above the projection screen.

The auditory or visual stimuli occurred three times in either Path 1 or Path 2 and were counterbalanced across participants (see Figure 6.1). The occurrence of each stimuli was triggered at set distances in each path. In Path 1, the stimuli occurred after 1.75metres, 8.47 metres and 13.45 metres. In Path 2, the stimuli were presented at 1.75 metres, 8.2 metres and 10.2 metres. The paths and the presentation of the stimuli were designed to be slightly asymmetrical in order to prevent participants stating that both paths were identical in length.

Participants were notified prior to navigation that there might be visual or auditory bursts which were caused by a glitch in the VR system. They were told to ignore them.

The visual stimuli consisted of black cuboids presented slightly above and ahead of the participant within the environment. They were also presented for duration of 500ms and flickered 5 times to draw attention to them (see Figure 6.1).

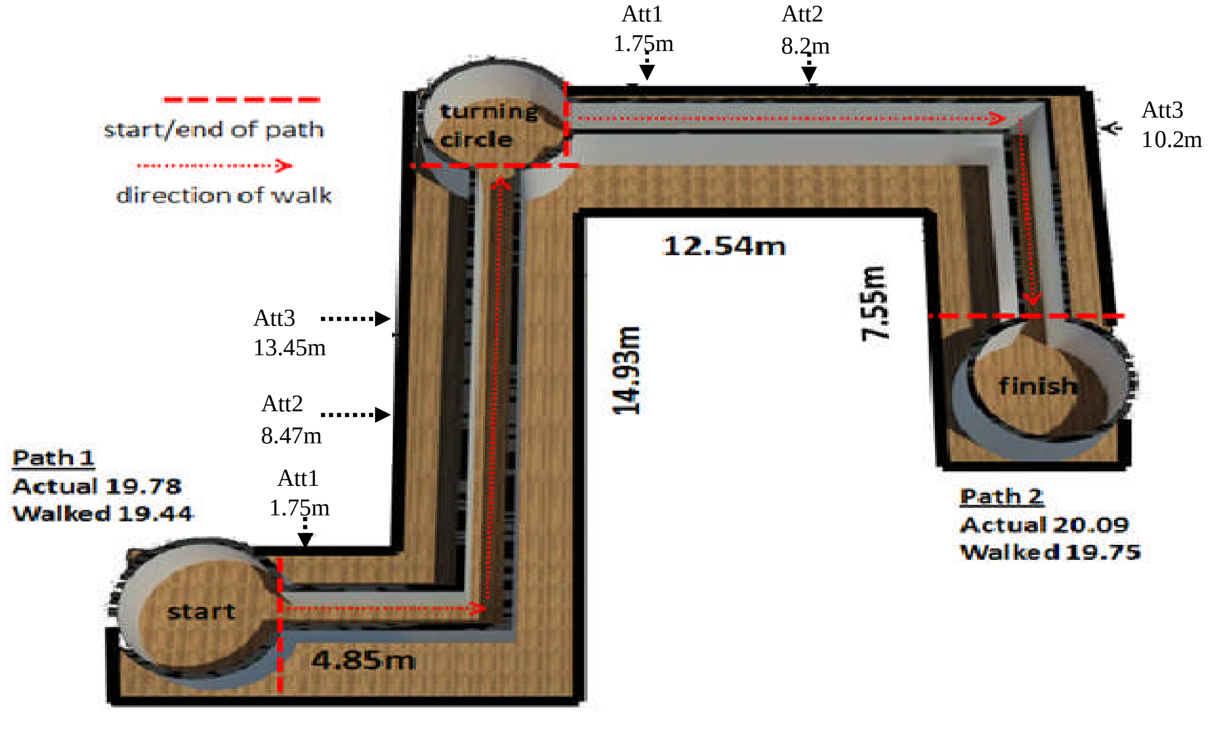

Figure 6.1: Allocentric views of the two VR paths.

The first half (path1) was 19.44m and the second half (path 2) was 19.75m (not to scale). The dimensions identify the actual distance, with the walked distance being slightly shorter due to the 'smoothing' of the corners. Attention indicators highlight the 'trigger' to produce the auditory or visual distracters.

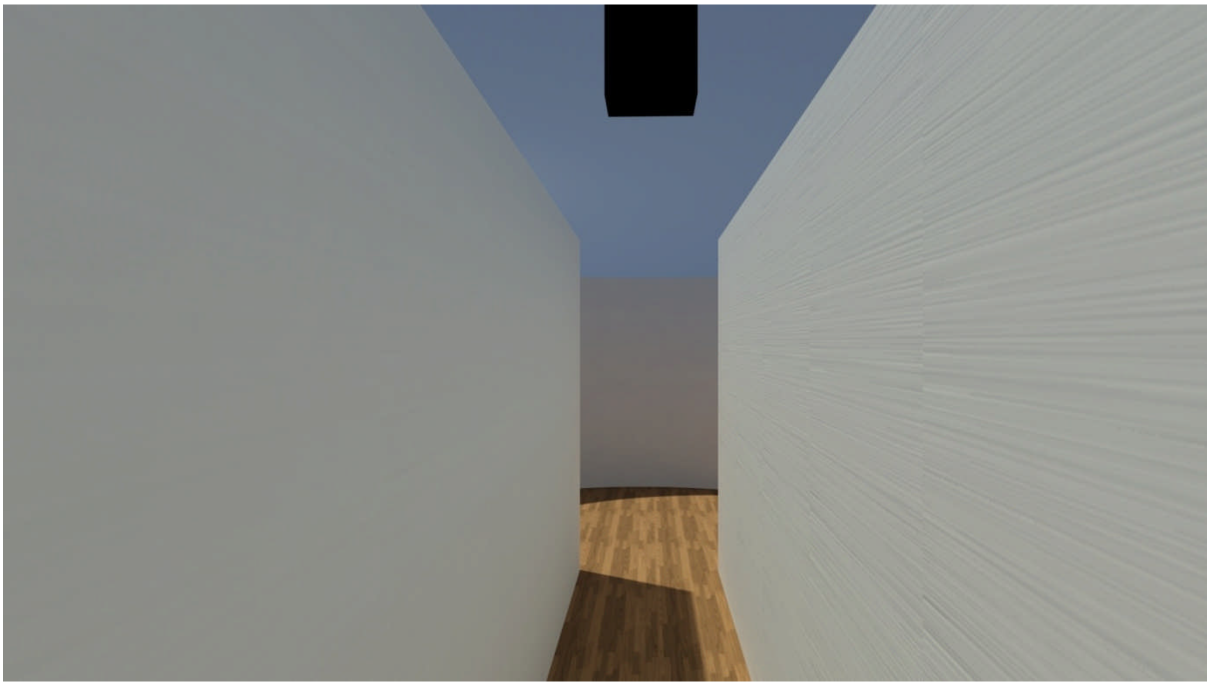

Figure 6.2: Egocentric view of the second section of the first half of the Visual Distracter VR path. (19.44m).

The black square in the centre flashed five times for a total of 500ms, it appeared three times during navigation, in either the first or second half of the total route and.

6.2.2.2. Walking Pace and Speed

The calculations were identical to that of the path with turns in the previous experiments. Again the head bob was synchronised to the sound of the metronome and corresponded to the visual flow.

6.2.2.3. Participants

Forty individuals participated in the visual cue condition and forty individuals participated in the auditory condition. They were recruited from the University of Northumbria and were paid a nominal fee for participation. Participants were aged between 18 and 28 years (mean age = 20.42, SD = 2.67). Participants were randomly allocated and evenly distributed for age and gender across all conditions. No participant had any previous experience of the VR Suite or of the Virtual Environment.

6.2.2.4. Presentation

The study was presented as an experiment in a series of studies that investigated people's various experiences across many VR environments. They were told that they were going to be transported to the experimenters Virtual World which involved walking two paths – which were differentiated by a virtual turning circle. They were also informed that they would be asked a series of questions at the end of their journey about their VR experience, thus encouraging them to focus on the environment

6.2.2.5. Procedure

Participants were tested individually in a session lasting around 15 minutes. The procedure was identical to that of the control conditions in experiments 1, 2 and 3. For instance, participants were met in an area separate from the environment and asked to walk the same pre-designated reference path to enable the experimenter to calibrate their steps to the metronome.

Next the experimenter blindfolded the participants and guided them to the Virtual World. Again, participants walked a virtual reference path, identical to the previous experiments, to familiarise the participant with the VR environment and to ensure speed and pace of walk was acceptable. After walking the reference path, participants were blindfolded and seated in front of the screen during the period of transition between the reference path and the main experimental paths.

At the beginning of the experiment, the participants were informed that they would be walking along two different paths and that the paths would be differentiated by a turning circle. They were informed that leaving or entering a circle indicating the end or beginning of the route accordingly. In addition, they were also informed that the department had been experiencing a slight glitch with the VR system and that this may result in either minor audio or visual interference. They were assured that they must ignore these glitches and just focus on the environment that they were walking through.

The auditory or visual stimuli occurred three times in either in Path 1 or Path 2 (see Figure 6.1). Immediately after completing the task, the participants were asked a range of questions, including: - how long they thought the routes were in distance, in the order of path 1 and then path 2 and, also, a duration estimation of how long they thought they had spent walking each path. Participants were also finally asked if they had noticed any auditory or visual interference/glitches and, if so, during which path and how many bursts of interference.

6.2.2.6. Experimental Design

To examine the influence of attention on distance and time estimation, the experiment employed a 2 Attention Cue (cue vs. no cue) x 2 Modality (auditory vs. visual) mixed design. Distracter cues were within participants and the modality of the cues, visual versus auditory, was between participants. The section in which they received the auditory or visual bursts was counterbalanced. Each participant gave 2 distance estimates, one for each path (Appendix 4).

6.2.3. Results

Data was evenly distributed across both modality conditions. Responses from 1 individual in the auditory condition and 3 in the visual condition were removed as their distance estimations were extreme, using the criteria of 2 standard deviations above the mean (Field, 2009, p. 153). Data from a further 9 participants in the auditory condition and 10 in the visual condition were excluded as they reported the stimuli (auditory or visual bursts) occurring in the incorrect path. There was therefore a possibility that may have mixed up their distance estimates of the two paths, i.e. the path without distracters could have been recalled and reported as the path with distracters. In total responses from 28 participants from the auditory and 29 participants from the visual condition were included in the following analysis.

6.2.3.1. Preliminary Analysis

Whilst participants were walking to the pre-programmed metronome, a series of between one-way ANOVAs were conducted to ensure that participants' natural walking speeds walking speeds or time spent in the VR environments were the same across the modalities. This ensures that the participants were equally matched for pace and time spent in the environments across the conditions. No significant differences were found for pace of walk, $F_{(1,56)} = 0.047$, $p > 0.05$, or time spent in the environment $F_{(1,56)} = 0.008$, $p > 0.05$.

6.2.3.2. Main Analysis

Again, actual distances were converted to distance ratios, (estimated distance or time / actual distance or time) as the two paths were subtly different in length. A 2 way Attention Cue (cue vs. no cue) x 2 Modality: (auditory vs. visual) mixed design ANOVA was performed on distance and time ratio estimations. (Table 6.1).

Table 6.1: A 2 Way Mixed ANOVA for Distance Estimation Ratio According to Attention and Modality in Experiment 7

Source	df and F value	MS	Significance
Modality	$F_{(1,55)} = 3.61$	1.194	0.06
Attention	$F_{(1,55)} = 5.044$	0.322	*
Attention vs. Modality	$F_{(1,55)} = 0.029$	0.865	ns

Note. ns: $p > 0.05$; * $p < 0.05$

There was a main effect of attention $F_{(1,55)} = 0.322$, $p > 0.05$, partial $\eta^2 = 0.08$, with the paths that included the attention stimuli (M = 0.73) being reported as being significantly longer than the paths with no visual stimuli (M = 0.63), (see Figure 6.3). There was also a trend, approaching significance, for modality $F_{(1,55)} = 3.61$, $p = 0.06$, partial $\eta^2 = 0.001$, with the paths including the visual stimuli being reported as longer (M = 0.78) than the paths with the auditory stimuli (M = 0.58), (see Figure 6.4) There was no reliable interaction between modality and attention, $F_{(1,55)} = 0.865$, $p < 0.05$.

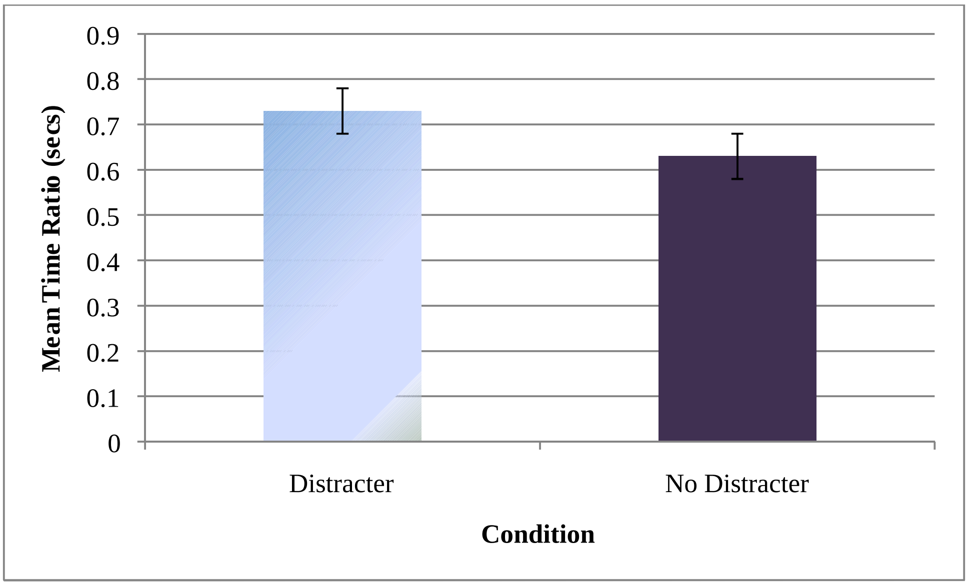

Figure 6.3: Mean Distance Ratio Estimations According to Attention Condition, in Experiment 7, with standard error bars (+/- 1SE)

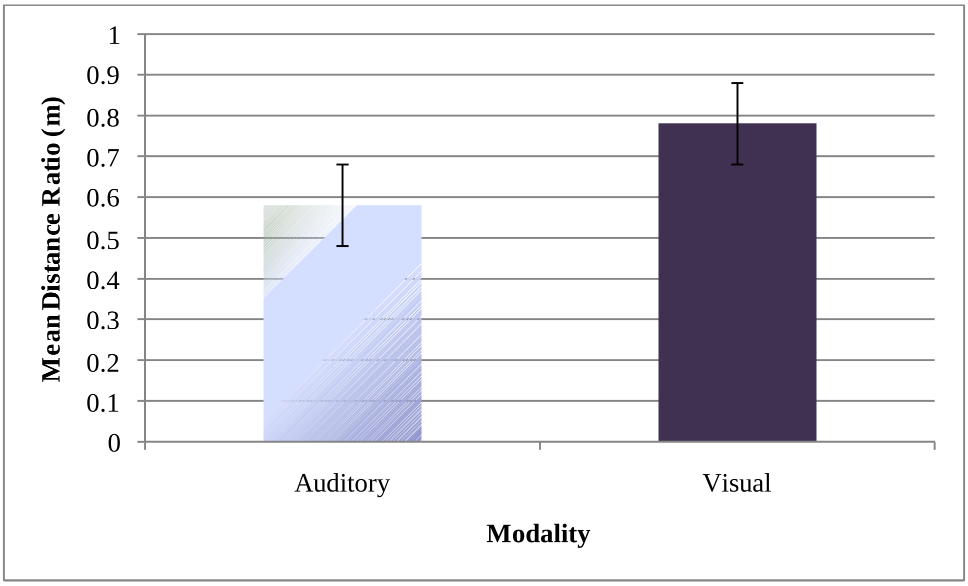

Figure 6.4: Mean Distance Ratio Estimations According to Modality, in Experiment 7, with standard error bars (+/- 1SE)

6.2.4. Discussion

The results confirm our expectations that the stimuli within the environment capture attention which causes participants to attend more to the environment and results in increased distance estimations compared to the paths with no stimuli presented. This is consistent with the time literature which states that drawing attention to a task will result in increased estimations (e.g. Fraisse, 1963; Mattes & Ulrich, 1998; Enns, Brehaut & Shore, 1999; Coull et al, 2004).

In addition, there was a marginal main effect of modality, where the route with visual stimuli resulted in greater distance estimations than the auditory condition. These results may well be explained as the visual stimuli are more successful in grabbing attention towards the environment than the auditory stimuli. The auditory stimuli, whilst being presented from speakers designed to provide an impression of sound being emitted within the environment, clearly did not have did not provide as strong an effect, although, the sound was still perceived to be part of the environment. Although there is some evidence that suggests that peripheral (exogenous) auditory information draws attention automatically to locations in discrimination tasks (Spence & Driver, 1994), it would seem that within modality cues draw attention more directly to the environment, which is primarily visual in this case.

Finally the results are in line with previous research in VR as the distances were consistently underestimated in both the paths with and without the attentional stimuli (Jansen-Osmann & Wiedenbauer, 2006).

The goal of the next Experiment is to examine the reverse hypothesis, that is, if attention is taken away from the environment, will it result in shorter distance estimations.

6.3. Experiment 8.

The Role of Attention and Goals through Imagined Traversal

The time literature at the beginning of the chapter, demonstrates that when attention is drawn to a task or stimuli then that will result in increased subjective estimations. Likewise, when attention is directed away from a task, the estimations decrease. Experiment 7 has demonstrated that when attention is drawn to the environment through visual flashes or auditory tones, distance estimations increase. Therefore, this experiment aimed to test the reverse, that is, whether taking attention away from an environment results in a reduction in distance estimations, which would be consistent with the time literature.

In order to examine if attention taken out of the environment will result in shorter distances, we adopted another methodology, which was developed to examine the acquisition of cognitive maps through auditory linguistic descriptions (Bugmann & Coventry, 2008). The manipulations we wanted to use were not functional using VR environments. In the method, participants are required to imagine walking through an environment to the sound of a metronome while listening to auditory descriptions played via headphones. It is presented as a memory task for the environmental features, such as the landmarks and their descriptions. The blindfold methodology (Bugmann et al., 2008) enables the investigation of large scale space and allows strict control over events and features both within and outside of the environment. Linguistic descriptions provide a rich setting whilst easily allowing descriptions of spatial environments removed from the events directly on the route being traversed. The environment described consisted of five landmarks, each associated with subsidiary features (e.g. statue, ornate iron gate, carved wooden door etc.). In addition, each landmark was described by its physical or historical features and secondary features were included in order to contextualise the landmark in its surroundings. Participants then rewalked the route at their own pace and recall the landmarks and their descriptions en-route. They were informed that they must replicate the distances between the landmarks en-route by asking the experimenter to engage and disengage the metronome during navigation.

Bugmann and Coventry (2008) found an effect of turns, using the blindfold methodology, which is in line with other literature stating that imagining walking in a learned environment shares properties with actual traversal in that environment (i.e. Decety & Michel, 1989; Jeannerod, 1994). For instance, it has been demonstrated that imagined actions are subjected to the same environmental and physiological constraints (Decety & Michel, 1989; Jeannerod, 1994). Furthermore, there is no difference in the time taken to carry out or to imagine tasks that involve walking (Decety, Jeannerod, & Prablanc, 1989), or reaching to targets (Cerritelli, Maruff, Wilson, & Currie, 2000). Decety, Jeannerod, and Prablanc (1989) asked participants to imagine distances of 5m, 10m, or 15m, and then to walk these distances either blindly or mentally. They found very high correlations between active and mental durations. When participants were instructed to use mental imaging strategies, differences became even smaller, particularly for longer distances. In a second part of the experiment, they repeated the procedure carrying a 25kg load. This led to increases in mental durations which implies that the role of effort required was also taken into account.

The blindfold methodology offers a more controlled approach to the investigation of attentional shifts, which VR cannot offer as we cannot be certain that stimuli extraneous to the environment will not be perceived to be part of the VR environment.

As an example, imagine walking in an environment and hearing a bird overhead. If there is consistency with the time estimation literature, this should distract one's attention away from the environment and result in a reduction of subjective distance estimation.

Intuitively one expects attention to be sensitive to the goals of an individual. We have seen in the previous chapter that both stimulus-driven cues, bottom-up and goal-driven, top-down, cues can influence attention. The environment often poses information that conflict with our goals. Such interfering information needs to be ignored or inhibited for effective goal performance to proceed.

In addition to the prediction that taking attention away from the environment might result in a reduction of remembered distance, the use of the blindfold method also afforded testing whether goals influence distance perception when routes are imagined, rather than physically traversed. Moreover, if goals direct attention to the environment, as was suggested in Section II, then it is of considerable interest to examine the interplay between top down and bottom up factors in distance memory.

Furthermore, the time literature has demonstrated that the allocation of attention within a scene is dependent upon the cooperation and competition of bottom-up and top-down cues. Obviously, both sources of information are a key influence on behaviour. For example, our visual system needs to be responsive to bottom-up cues because these cues contain information concerning salient information in the external world. Therefore, to maintain flexible behaviour that is not entirely stimulus driven, visual processing must be modified by an observer's goals.

We therefore set out to test, firstly, whether stimuli presented that are relevant but extraneous to the environment, under the strict control of visual information, will attract attention away from the environment, and secondly, we aim to examine the influence of goals on memory for distance using this different (imagined) method.

It is predicted, during imagined navigation in the control condition, that the extraneous stimuli will grab attention and result in a reduction of distance estimation. However, the predictors for the goal scenarios conditions are intriguing. If goals affect distance perception by a mechanism not involving attention, one would expect to find effects of goals on distance memory separate from effects of attentional cueing. However, if goals direct attention, then the effects of attention should cancel each other out and no effect of goals should be found on distance estimation.

Therefore, it is hypothesised that participants in the control scenario will report distances as being shorter when their attention is grabbed by the extraneous cues and the goal scenarios will yield no affect of attentional cues on distance estimation.

6.3.1. Method

To examine the effect of goals and attention on traversed distances, the experimental design used was a 3 Scenario (Route A vs. Route B) x 2 Attention Cues (with vs. without) counterbalanced x 2 Half (first vs. second) x 2 Turns (one vs. three) mixed-participants design. The between participant condition was the role play scenario and whether the participant was presented with the extraneous attention stimuli in the first or second half.

Participants were blindfolded and taken on an imaginary walk using linguistic auditory descriptions played via headphones. Five attentional cues such as “Look there’s a bird” were presented during either the first or second half of the route. Participants were informed that they were being tested on their memory for described places and were taken on the guided walk twice. The participants were then told that they had to re-walk the route using the metronome as their guide to reproduce the distances covered and describe what they ‘saw’ en-route. The dependent variable was the rewalked distances, represented by the metronome beat for each route.

6.3.1.1. Materials

The experiment was presented as a guided tour around the streets of an imaginary town, which introduced a series of landmarks. The attention stimuli consisted of naturalistic objects that one would find whilst walking in an environment but not be associated with an actual route (e.g. balloon, cloud etc.) The environmental descriptions were read by a female colleague and recorded for use in the experiments and the following is a typical description of a landmark (the landmark is highlighted and the other features are subsidiary items).

> *"You are currently standing in front of **Abbott's House**. Abbott's house is a medieval house well preserved to this very day. The bay window is very ornamental. Notice the marble statue of the house's owner at the entrance. In front of the entrance, there is a large pot of colourful shrubs."*

The attention stimuli e.g. "Look, there's a plane" were developed to replicate as much as possible naturalistic occurrences outside of the environment. The reference to a an aeroplane, balloon, bird kite and cloud were used as they were all properties that would direct attention out of the environment to the space above. All of the attentional stimuli were recorded by a male colleague. This enabled participants to differentiate between the environmental features and the irrelevant extraneous stimuli. Visual information was controlled by using a blindfold, ensuring that no other features within the laboratory could interfere with the imagined walk (Figure 6.5).

You are in a place called Charles-town, a typical New England town. Your starting place is the Abbott's House.
I am going to take you on a walk from the Abbott's House to Emmanuel Church. It is quite a nice walk with lots of things to look at on the way.
You are currently standing in front of **Abbott's House**. Abbott's house is a medieval house well preserved to this very day. The bay window is very ornamental. Notice the marble statue of the house's owner at the entrance. In front of the entrance, there is a large pot of colorful shrubs. I am going to get you to walk away from Abbott's House along a road called Admiral Street.
Start walking.

[Route A] Look! A kite flying by

Stop.
Now you turn onto Albany Street.
Start walking.

[Route A] Look! A bird overhead

Stop.
You are now in front of a place called **Belgrave Museum**. Belgrave Museum is one of the most interesting museums in the country. The wooden door is intricately carved. Notice the marble stone relief at the entrance. In front of the entrance there is a modern statue lying on the ground. I am going to get you to walk away from Belgrave Museum along Beacon Street.
Start walking.

[Route A] Look! A cloud in the sky

Stop.
Now you turn onto Bellevue Street. Start walking.
Stop.
Now you turn onto Boston Street.
Start walking.

[Route A] Look! An aeroplane up above

Stop.
Now you turn onto Budeaux Street.
Start walking.

[Route A] Look! A balloon flying by

Stop.
You are currently standing in front of a place called Cooper Library. Cooper Library is very popular among people in Charles-town. The large granite lion statue sits at the entrance. Notice the intricately carved iron gate at the entrance. In front of the entrance, there is a cast iron bench.
OK. Now you are going to walk away from the Library along Cambridge Street. Start walking.
Stop.

[Route B] Look! A kite flying by

Now you turn onto Cedar Street.
Start walking.

[Route B] Look! A bird overhead

Stop.
You turn now onto Clarence Street.
Start walking.
Stop.
You turn onto Columbia Street.
Start walking.

[Route B] Look! A cloud in the sky

Stop.
You are currently standing in front of a place called the **Derby Hall**. Derby Hall is the home of the Charles-town Symphony Orchestra. The big stained glass door is multicoloured and very decorative. Notice the beautiful water fountain at the entrance. In front of the entrance, there is a marble sundial. OK. Now I am going to get you to walk away from Derby Hall along Dickens Street.
Start walking.

[Route B] Look! An aeroplane up above

Stop.
Now you turn onto Dover Street.
Start walking.

[Route B] Look! A balloon flying by

Stop.
You are currently standing in front of a place called **Emmanuel Church**.
Because of its Gothic architecture St Emmanuel Church stands out against its surrounding. The large rose window is magnificent. Notice the marble statue of St Emmanuel at the entrance. In front of the entrance stands tall granite cross. This is your final destination

Figure 6.5: Description of the Route used in Experiment 8

The experiment used the same props and goal scenarios from the first series of experiments, i.e. one medicine bottle and one failed exam script. In addition, a reminder for the appropriate scenario was incorporated into the recording, in order to integrate the goal into the task as presented below:-

High Urgency Scenario Script

OK, remember, you must deliver the medication in order to save your friends life. The medication is going to be placed in your hand ***[PAUSE –placed object in left hand]*** *and you must deliver it to your final destination. They are waiting for you.*

Low Urgency Scenario Script

OK, remember, you must deliver the bad news to your friend. The exam results are going to be placed in your hand ***[PAUSE- placed object in left hand]*** *and you must deliver it to your final destination. They are waiting for you.*

The guided walk was played using a Sony digital stereo Dictaphone via two sets of headphones, using a Y-split; the participant also wore a blindfold.

The route included 8 turns; as participants were blindfolded, they were physically guided to the left or right to allow control for the speed and size of the degree of turning. The attention stimuli occurred at five places en-route. Each stimulus was played at the mid route point along a segment, which was pre-calculated in accordance with the participants' pace of walk and in accordance with the length of the street.

Prior to participation, all participants were instructed to learn the twelve street names as a pre requisite for taking part in the experiment as a pilot[5] study indicated that the

[5] Because there were extensive changes to the original methodology as used by Bugmann and Coventry (2008), that is, the addition of the goal scenarios and the attentional stimuli, pilot tests were conducted to ensure that the experiment ran smoothly. After 6 participants it was decided to record the attentional stimuli with a male voice as the participants appeared to be unable to discriminate between the environmental and extraneous stimuli. In real environments stimuli extraneous to the environment would be differentiated by spatial location, for instance, an aeroplane in the sky would not be considered to be a fixed feature required for future way finding. Therefore, it was considered appropriate to define the auditory extraneous information by pitch, this made it clearer to the participants what they were required to attend to in the environment.

goal scenarios may be adding to the cognitive load. The participants were told that they were going to listen to descriptions of imaginary walks through a town and that, during the simulated walks, they had to visualise the landmarks they passed along the way. Additionally, they were informed that they would have to imagine a scenario where they were going to be the main character delivering an object to a friend and that more information would be given to them later concerning this.

Once the participants were ready to commence their walk, the role play scenarios were also introduced, and informed that their role was to deliver the object to a friend at the end of the path, whilst imagining they were walking in Charlestown.

Memories for traversed distances were measured through recall, which involved participants re-walking the route alone towards the destination. They were advised that they had to describe what they 'saw' on the way and to advise when they had reached the end of a path or building by informing the experiment to stop 'walking'. The experimenter would stop & start the metronome in accordance with the instructions. Traversed distances were measured by metronome beats.

6.4.1.2. Environmental Stimuli

One environmental description, previously demonstrated as having the greatest success rate with participants, was utilised from Bugmann & Coventry (2008). The environment contained five landmarks, contextualised in streets, which were all presented in alphabetical order. Each landmark was described by its function and physical features and the descriptions were controlled with the number of words used. The structure of the second half of the route was the exact mirror image of the first half. The environmental

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A further 13 participants were tested and the methodology was still problematic for 11 participants allocated to the High Urgency scenario. They were unable to recall the landmarks in the correct order and either stated that they were lost or rushed to the end of the route without naming landmarks. Therefore, it was decided to ask all of the participants to learn the twelve street names as a pre requisite for taking part in the experiment.

descriptions were read by a female researcher and recorded for use in the experiment. The detailed description of the route is given above, with the critical landmarks highlighted. Routes A and B were differentiated by the attentional stimuli occurring in the first half or second half of the route, counterbalanced across participants. Figure 6.5 illustrates the linguistic descriptions and Figures 6.6 and 6.7 provide an allocentric view of the route, including the attentional cues.

6.4.1.3. Attentional Stimuli

The attentional stimuli consisted of five items that were considered to be ecologically valid, yet extraneous to the environment (e.g. bird, aeroplane etc.). The purpose of the stimuli was to grab participants' attention out of the environment yet without adding to their cognitive load. The stimuli were introduced at the middle section of segmented paths in either the first or second half of the route (see Figures 6.6 & 6.7). Importantly, the metronome beats were maintained and the participants continued their imaginary walk whilst the stimuli were presented.

6.4.1.4. Characteristics of the Environment

The route contained eight intervening 90° turns. Figure 6.6 illustrates the route.

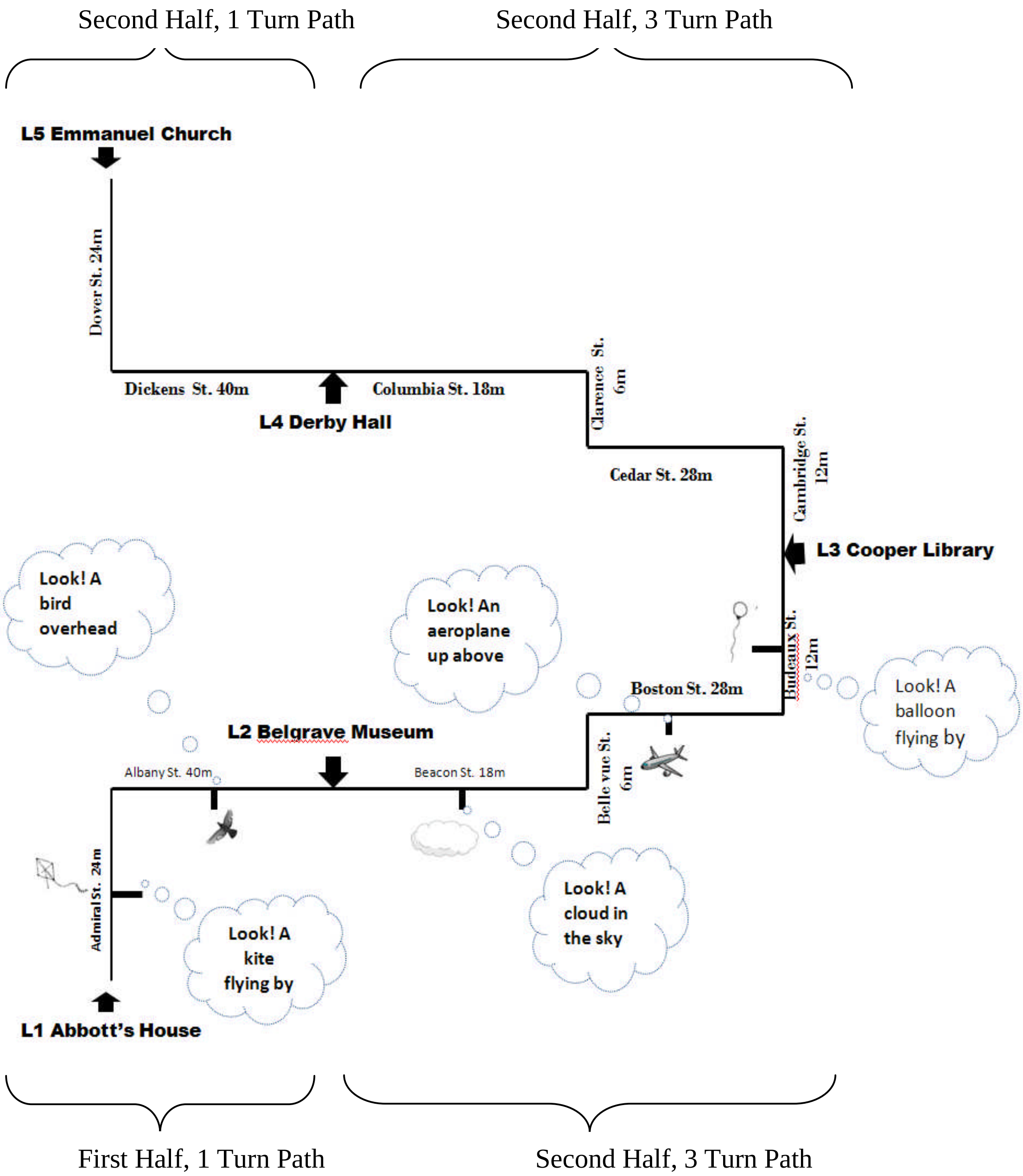

Figure 6.6: Configuration of Route with Attention Distractors in the First Half in Experiment 8

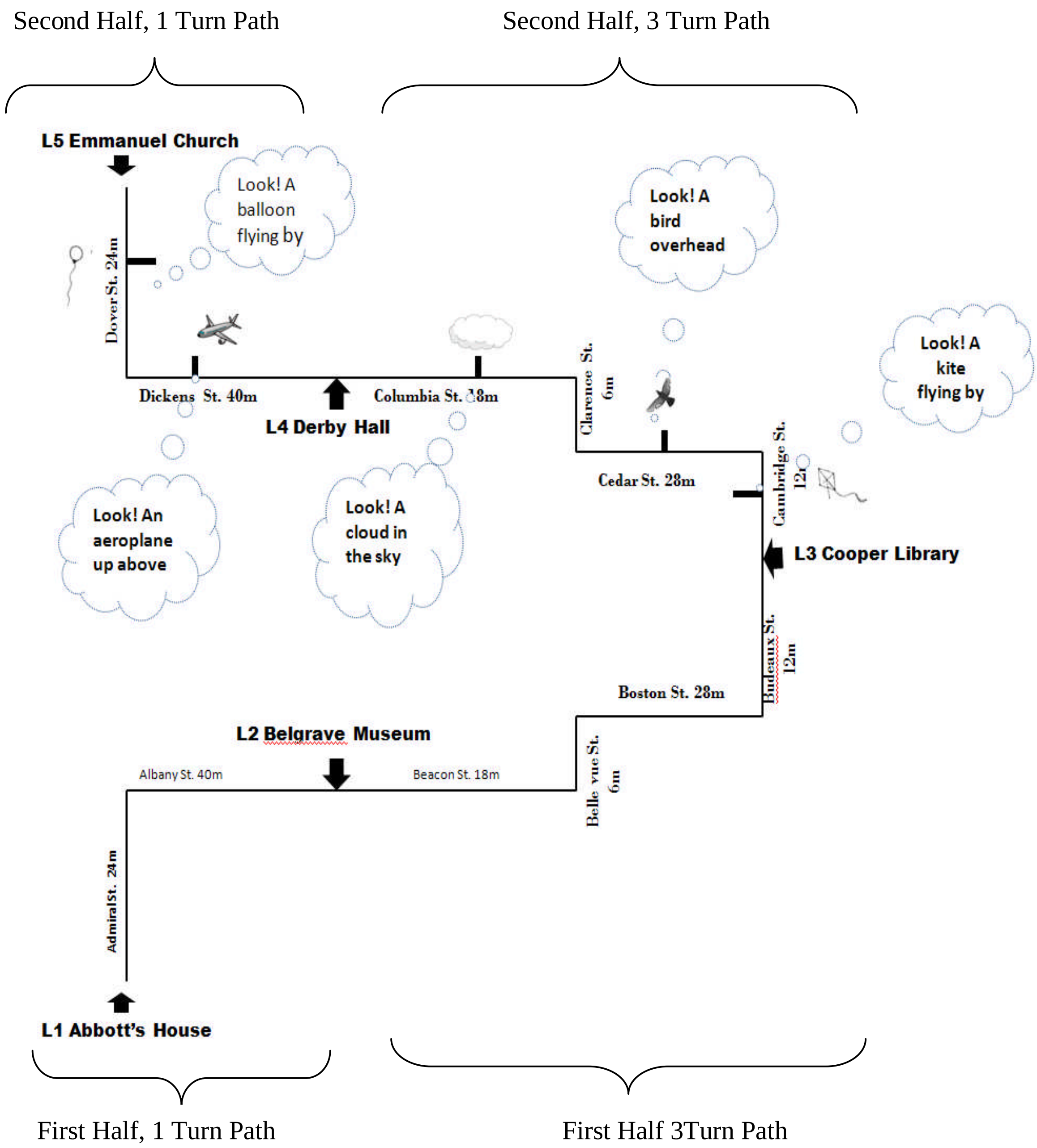

Figure 6.7: Configuration of Route with Attention Distractors in the Second Half in Experiment 8

The total route contained 5 landmarks, resulting in four intervening paths in total – named P1 to P4, each measuring 64 metres in length. The total route length was 64 x 4 = 256 metres. Paths 1 and 4 contained two turns each and Paths 2 and 3 contained 3 turns each.

There were two routes in total, route A was identical to route B, with the exception that the attentional distracters were presented in *either* the first or second half of the route. The segment lengths were fixed at 24, 40, 18, 6, 28, 12, 12, 28, 6, 18, 40 and 24 metres. The second half of the route was a complete mirror image of the first half.

P1 = 24 + 40,

P2 = 18 + 6 + 28 + 12,

P 3 = 18 + 6 + 28 + 12,

P4 = 24 + 40,

6.4.1.5. Mental Walking Pace

Identical to Bugmann and Coventry, (2008), the restriction of physiological effort was obtained by replacing the actual walking with a mentally simulated walk; it also served to control speed of walk and restricted body movement to just turns. Therefore a natural walking pace was required to determine the metronome pace so that participants could mentally imagine walking the required distances.

The calculations for the mentally simulated walk were identical to that used in the previous experiments in this thesis. In this instance a 6 metre reference path was used and the calculation was based on the participants walking the full length of the path, turning and walking back. Several calculations were required, for instance, in addition to calculating the pace, the step lengths' needed to be computed for each segment. The calculation for the journey was computed as follows:-

6.4.1.6. Speed of walk

[Number of steps to walk the reference path/ Time taken to walk the reference path] * 60 secs.

If, for instance a participant walked the reference path with 15 steps in 8.22 seconds, the metronome beat would be 110 beats per minute (15 steps / 8.22 secs * 60 secs). Participants were advised that each metronome beat represented one step forward.

6.4.1.7. Step lengths

The participants' step lengths were also calculated by dividing the length of the reference path by the number of steps taken to walk it. For instance, continuing with the previous example, the calculation would be 12 metres / 15 steps = 80 cms step length.

6.4.1.8. Path Segment Length

To translate the distance to be traversed for each segment (X) into metronome beats, the following formula was used:-

[Number of steps to walk reference path / Length of reference path] * X metres.

Therefore, using the same example as before; 30 beats would represent the first distance of 24 metres; 50 beats to cover 40 metres etc. For the experiment, the calculations were generated in Excel which enabled the chart to be printed off and be discretely be attached to the participants back for reference during the walk. (see Figure 6.8)

	A	B	C	D	E	F	G	H	I	J
1		REFERENCE PATH	12M							
2										
3		STEPS	15							
4		TIME	8.22							
5		METRO	109.4890511							
6										
7										
8			LENGTH	TIME	STEPS	OBJECT	STEPS	BEATS	METRES	
9		ADMIRAL ST	24	16.44	30	kite	15	11	8.8	
10		ALBANY ST	40	27.4	50	bird	25	15	12	
11		BEACON ST	18	12.33	22.5	cloud	11	15	12	
12		BELLE VUE ST	6	4.11	7.5			20	16	
13		BOSTON ST	28	19.18	35	aeroplane	18	18	14.4	
14		BUDEAUX ST	12	8.22	15	balloon	7.5	16	12.8	
15		CAMBRIDGE ST	12	8.22	15			20	16	
16		CEDAR ST	28	19.18	35			34	27.2	
17		CLARENCE ST	6	4.11	7.5			16	12.8	
18		COLUMBIA ST	18	12.33	22.5			13	10.4	
19		DICKENS ST	40	27.4	50			24	19.2	
20		DOVER ST	24	16.44	30			20	16	
21										

Figure 6.8: Sample of steps chart

The chart also informed the experimenter at which point to introduce the attentional stimuli.

To ensure that the participants felt comfortable during the test, they were asked to close their eyes and to imagine walking in time with the metronome beats calibrated to their natural walking pace. If the participants were comfortable with the pace then the experiment proceeded, if not then participants rewalked the reference path in order to find the correct speed of walk.

6.4.1.9. Arrangement

The experiment took part in a laboratory discretely near to the reference path and where the pre-experimental paperwork was completed. A series of lines was marked on the floor with masking tape to form a virtual circle of 60 centimetres diameter. Each quadrant had 5 marks representing 15 degrees each (Figure 6.9). This provided a guide for turning, and also ensured that the participant was unaware of the amplitude and direction of the turns.

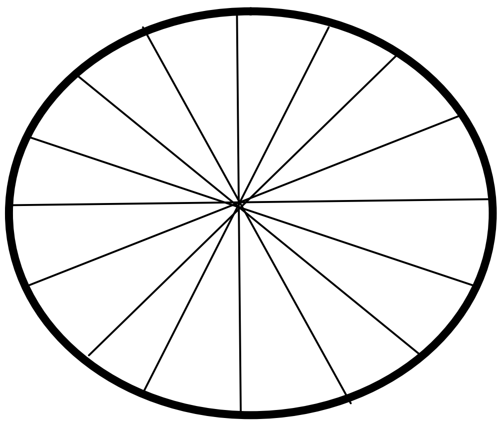

Figure 6.9: Illustration of turning circle used in Experiment 8

Participants were asked to wear a blindfold and headphones and were required to stand at the centre of the marked circle (see Figure 6.9). A Y-split joint allowed both the participant and the experimenter to listen the route description simultaneously during the guided walks. The participants also had the steps chart on their back so that the experimenter could monitor the progress of the test. The experimenter carried a digital tape recorder and a metronome and always stood behind the participant (see Figure 6.10). During the test the experimenter consulted the steps chart in order to engage the metronome that was always kept just below shoulder level. During the free recall the Y-split was removed and only the participant wore the headphones for recording the descriptions.

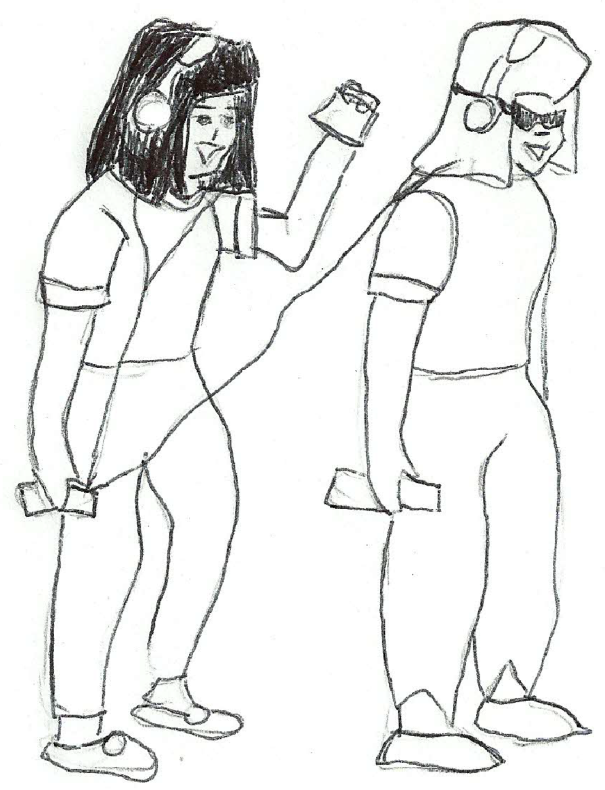

Figure 6.10: Arrangement in Experiment 8

6.4.1.10. Turning

To familiarise the participants with the task, the participants were gently turned once to the left and once right at 90˚ turns.

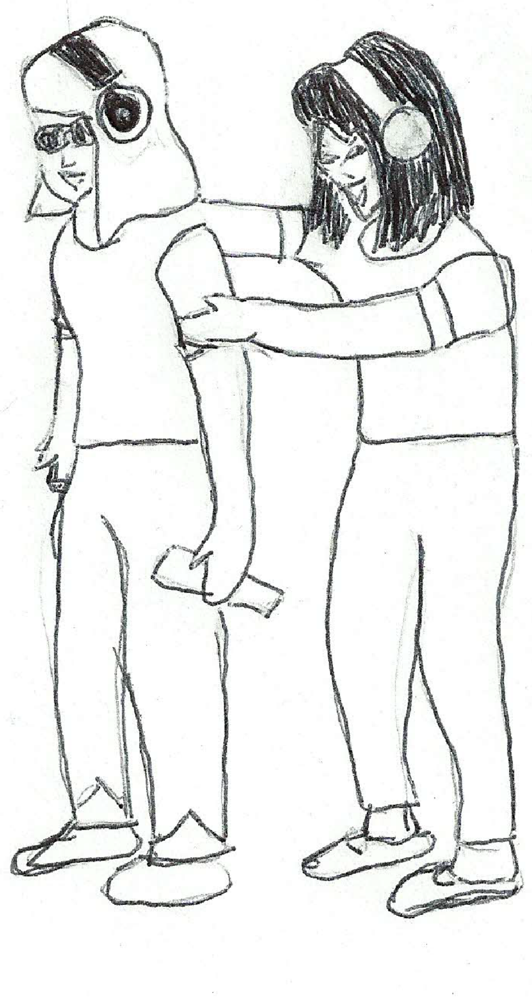

Figure 6.11: Turning in Experiment 8

If the participant was comfortable with this they were then turned 360˚ anticlockwise and clockwise until they were facing the starting position. (Figure 6.11).

6.4.1.11. Experimental Design

In the present experiment, participants learned twelve street names prior to the experiment and there was only one route. The presentation of the attentional stimuli, for instance in the first or second half of the route was counterbalanced among participants, as were the goal scenarios. Participants were not aware that the second half of the route was the mirror image of the first half of the route.

To examine the influence of action and the effect of goals and attention on traversed distances, the experimental design used was a 3 scenario (Route A vs. Route B) x 2 attention cues (with vs. without) counterbalanced x 2 half (first vs. second) x 2 turns (one vs. three) mixed-participants design. The between participant condition was the role play scenario and whether the participant was presented with the extraneous attention stimuli in the first or second half.

6.4.1.12. Participants

Sixty Six undergraduate students agreed to participate in the Experiment in exchange for course credit. They were between 18 and 38 years old (mean = 22.02, SD = 5.39). Participants were matched for age and gender across all conditions. By agreeing to participate in the experiment, they were aware that they would wear a blindfold throughout the test.

6.4.1.13. Presentation

The experiment was presented so that participants focussed on the landmarks along a route in order to convey a naturalistic feel to walking in the environment. The role play scenarios integrated well with the original experiment and the participants stated that they were not just trying to remember distances, but also imagine they were walking in the environment naturally whilst conducting a task.

Therefore, the study was presented as an investigation into people's memory for their environment, particularly for described places, in line with the original methodology (Bugmann & Coventry, 2008). The participants were told that they were going to listen to descriptions of imaginary walks through a town and that, during the simulated walks, they had to visualise the landmarks they passed along the way. Additionally, they were informed that they would have to imagine a scenario where they were going to be the main character delivering an object to a friend and that more information would be given to them later concerning this. None of the participants were aware that the focus of the experiment was for their memories for rewalked distances.

6.4.1.14. Procedure

Three groups of participants were used, and randomly allocated to each scenario. Within each scenario group, the attentional stimuli were counterbalanced, e.g. first or second half. Each session lasted about 45 minutes and each participant was tested individually.

Initially, participants were tested on their knowledge of the street names as the methodological adjustments required that these were learnt to a sufficient degree prior to taking part. This involved writing the street names in alphabetical order three times and also, being able to write all twelve street names in less than 45 seconds. This ensured that the environment was not learnt on a superficial level as the pilot study found that participants, in the high urgency condition, were prone to losing their way and becoming stressed. Participants were then instructed to walk the reference path at their own natural walking pace, and they were informed that this was to calculate their natural walking speed for the task.

Participants were then blindfolded and gently guided to the room where the experiment was being conducted. In line with the previous experiments, participants were constantly reassured that there were no obstacles en route or other individuals in the room. Participants were then guided to the centre of the turning circle and turned both clockwise and anti clockwise, before the headphones were placed on them. During this time the experimenter gave a running commentary of events, e.g. “I will now turn you this way…and the reverse. And now I will place a set of headphones on your head and I will also be wearing identical headphones….”, so that the participant would be aware of the events around them. Participants were then familiarised with the imaginary walking and also the turning procedure. Once the participant had stated that they were comfortable and ready to begin, the experimenter either introduced the scenario or stated that the experiment was about to commence.

Participants in the scenario condition were asked if they understood the task and all were asked if they were ready to commence the task. All participants were asked to focus only on the descriptions reported by the female voice only.

The participants were then instructed to imagine they were walking in time with the metronome beats, and to stop imagining walking when the metronome beats ceased. They were then informed that when they stopped walking it would be to turn a corner or to view a landmark and their role was to visualise the landmarks as best as they could from the descriptions.

The experimenter then started the recording and both listened to the descriptions through the headphones. The role play scenarios involved delivering an object and this was integrated into the recording in order for the task to appear more consistent, e.g. the recording would set the scene for placing the object in the participants’ left hand before they continued with the task. The route descriptions would then be played through the headphones.

At the appropriate times, the experimenter stopped the recordings and engaged the metronome to execute the simulated mental walk. Participants imagined walking until the metronome stopped, this was associated with a “stop” in the recording and was also part of the original methodology, at which point participants had to imagine themselves stopping. During turns, the experimenter physically moving the participants 90˚ left or right, as appropriate, on the spot.

Once the destination was reached, the role play objects were handed back to the experimenter, the Y - split was disconnected and the participant was turned to the correct position. Still blindfolded, the participant's memory for the route was tested by free recall.

The free recall involved participants being told that they were to commence their journey from the starting place and re walk the routes. They were asked to inform the experimenter when they wanted to stop and start walking so that the metronome could be engaged or disengaged. In addition they had to describe out loud, as accurately as possible, what they "saw" en-route. They were to turn themselves in accordance with the direction en route and indicate verbally the direction of turns. Once it was established that participants understood the instructions, the experimenter placed the role play objects in the participants left hand and switched the recorder on to document their journey. The experimenter carried the recorder and metronome at all times during the experiment.

6.4.1.15. Data Treatment

In order to ensure that participants had sound knowledge of the environment, the order of landmarks had to be recalled in the correct order; if the order of the landmarks were incorrect or omissions made, then the data could not be used for the analyses. The free recalls were transcribed and the correct responses were then used for the analysis. The dependent variables were segments, paths, and landmarks' descriptions in addition to the metronome clicks for the rewalked distances for the route. Data were obtained by first translating the number of metronome clicks (= steps) into traversed distances expressed in metres.

6.4.1.16. Dependent Variables

The dependent variables were segments, paths, and landmarks' description, the metronome clicks for the rewalked distances between each land mark, and the anxiety and urgency scores across the scenario conditions. The data was collated from the participants' protocols in line with the original methodology (Bugmann & Coventry, 2008) as follows:-

First, the number of metronome beats (= number of steps) were converted into traversed distances, expressed in metres. The lengths of recalled segments were calculated as follows:

1) Segment = [Recalled number of steps / Reference path steps] * 12 metres.

Each segment was checked against the original route segment with regard to its name. When routes' names were not mentioned but the number of segments in the path mapped the original path they were recorded as such. The adjustment to the original methodology meant that participants did not create additional segments or forget certain segments; therefore the analysis was more straightforward.

2) Paths were recorded by summing all recalled segments containing in each path.

6.4.2. Results

Participants' responses that demonstrated the correct sequences of landmarks were only used in the analyses; this ensured that they had reasonable knowledge of the route.

Protocols that presented the data in the incorrect order were eliminated and not used in the analyses.

Responses from 7 participants (11%) were excluded. Six exclusions, from the High Urgency scenario, were due to either incorrect sequences of landmarks or omissions and 1(from the Low Urgency Scenario) was for an inaudible recording. Also, consistent with previous experiments, responses were eliminated if they were 2 standard deviations above or below the Mean in the re-walked distance, this resulted in a further 2 participants (3%) being excluded. Responses from 57 participants were used in the analysis (86%). This resulted in an analysis with 19 participants in each condition.

6.4.2.1. Distance Estimation

Firstly, the accuracy of the memory for segments was examined. Figure 6.12 illustrates the estimate for each segment averaged across all of the participants against each of the actual distances in the route.

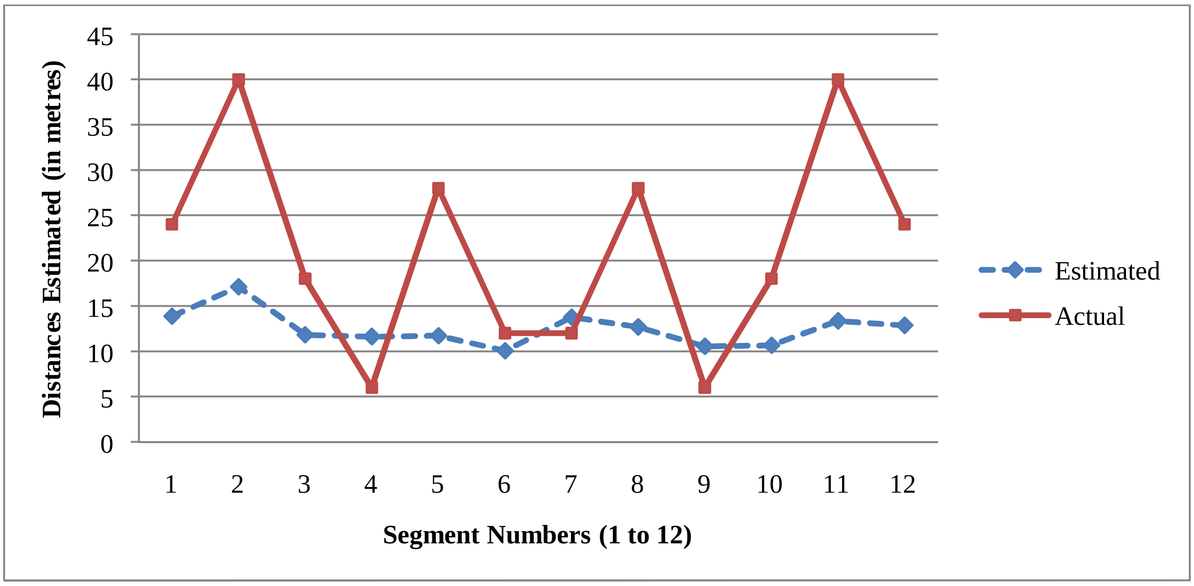

Figure 6.12: Actual and remembered Segments, Experiment 8

A significant relationship was found between the recalled distances for segments and their actual distances, $r = 0.693$, $p < 0.01$ (one tailed). This indicates that longer segments were recalled as having more steps and shorter segments were also recalled as being shorter.

The main analyses examined the role of scenario, attention, route position and route structure on recall. A 3 Scenario (HU vs. LU vs. Control) x 2 Attention Cues (cues in first half vs. cues in second half) x 2 Half (first half vs. second half) x 2 Turns (one vs. three) ANOVA[6] was performed on the path distances. Given that the distances between landmarks were all the same length, it was unnecessary to convert the estimated distances into ratios. The results of the four-way ANOVA are displayed in Table 6.2.

6

Factor	**Levels**	**Between/Within**
Goal Scenario	Control vs. HU vs. LU	Between
Attention Cue Presentation	Presented First Half vs. Second Half	Between
Half of the route	First Half vs. Second Half	Within
Turns	1 turn vs. 3 turns	Within

Table 6.2: Results of the 4 – way ANOVA on Distance Estimation in Experiment 8

Source	df and F value	Ms (error)	Significance
Scenario (S)	$F_{(2,51)} = 0.018$	98.61	ns
Attention Cues (A) (presentation first vs.second half)	$F_{(1, 51)} = 0.048$	98.61	ns
Half of route (H) (first vs. second)	$F_{(1, 51)} = 1.226$	57.86	ns
Turns (T) (1 vs. 3)	$F_{(1,51)} = 81.92$	206.46	***
S x A	$F_{(2,51)} = 0.954$	394.43	ns
S x H	$F_{(2,51)} = 1.59$	57.86	ns
S x T	$F_{(2,51)} = 0.012$	206.46	ns
A x H	$F_{(1,51)} = 1.26$	57.86	ns
A x T	$F_{(1, 51)} = 0.017$	206.46	ns
H x T	$F_{(1,51)} = 6.81$	99.03	*
A x H x T	$F_{(1,51)} = 6.56$	99.03	*
S x A x H	$F_{(2,51)} = 3.72$	57.86	*
S x H x T	$F_{(2,51)} = 1.15$	99.03	ns
S x A x H x T	$F_{(2,51)} = 1.08$	99.03	ns

Note. ns: $p > 0.05$, *: $p < 0.05$, ***: $p < 0.001$

No main effects of scenario, attention or half were found. However, there was a significant main effect of turns for distance estimation, $F_{(1, 51)} = 81.92$, $MS_e = 206.46$, $p < 0.001$, partial $\eta^2 = 0.62$. Overall path distances were under-estimated (the actual distance of each path measured 64 metres). However, participants remembered walking significantly longer on the paths containing three turns than on the paths which contained one turn, as displayed in Figure 6.13

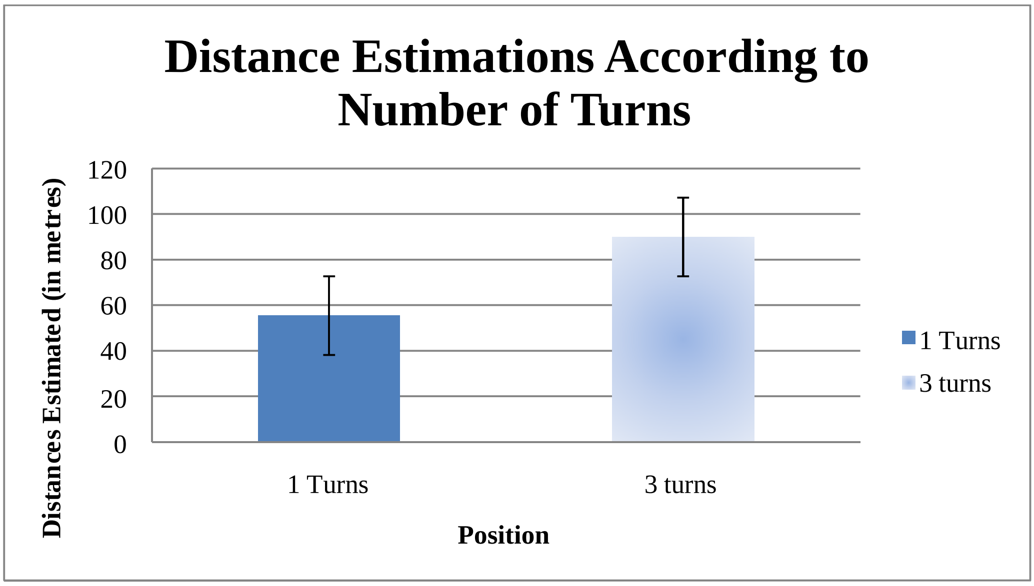

Figure 6.13: Main effect of Position on Distance Estimation, in Experiment 8, with standard error bars (+/- 1SE).

There was a significant 2 way interaction between the half of the route and the amount of turns $F_{(1,51)} = 6.81$, $p = 0.012$, partial $\eta^2 = 0.12$ (displayed in Figure 6.14)

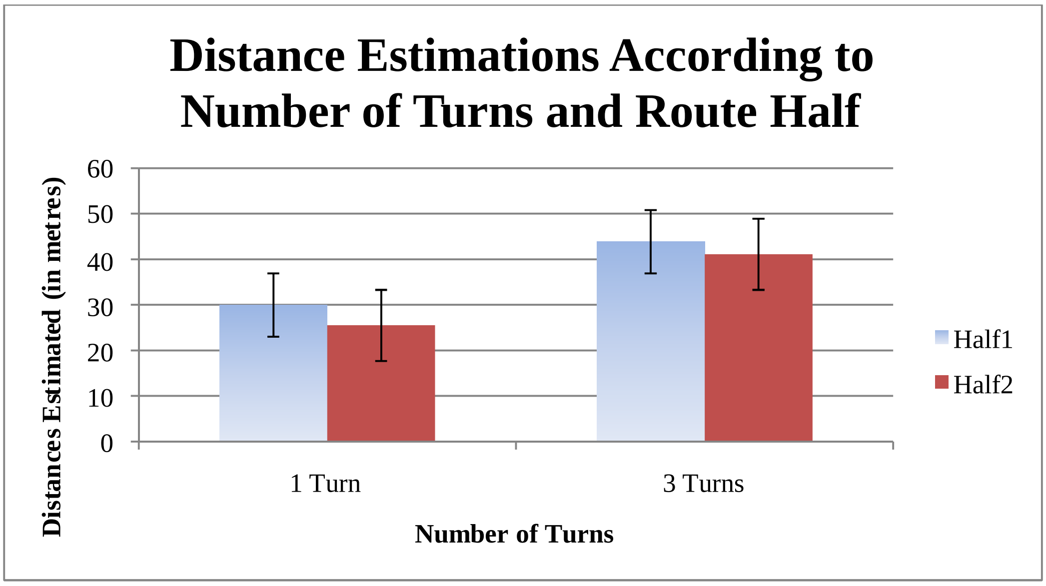

Figure 6.14: Two-Way Interaction between Half and Position on Distance Estimation in Experiment 8.

Whilst the overall effect of turns was evident and robust across all of the conditions, the path with 1 turn in the second half of the route was recalled as being shorter than path with 1 turn in the first half of the route. The same pattern was illustrated with the paths with 3 turns, with the second half, again, being reported as shorter than the 3 turn path in the first half. Paired sampled t – tests comparing 1 turns paths and 3 turn paths separately, indicated that there was a significant difference between the paths with 1 turn, t(57) = 2.8, p = < 0.01. There was no reliable significant difference between the paths with 3 turns, t (57) = 1.19, p > 0.05. There was also a significant three way interaction between Attention Distracter, Half and Turns $F_{(1,51)} = 6.56$, $p = 0.04$, partial $\eta^2 = 0.23$, as displayed in Figure 6..15

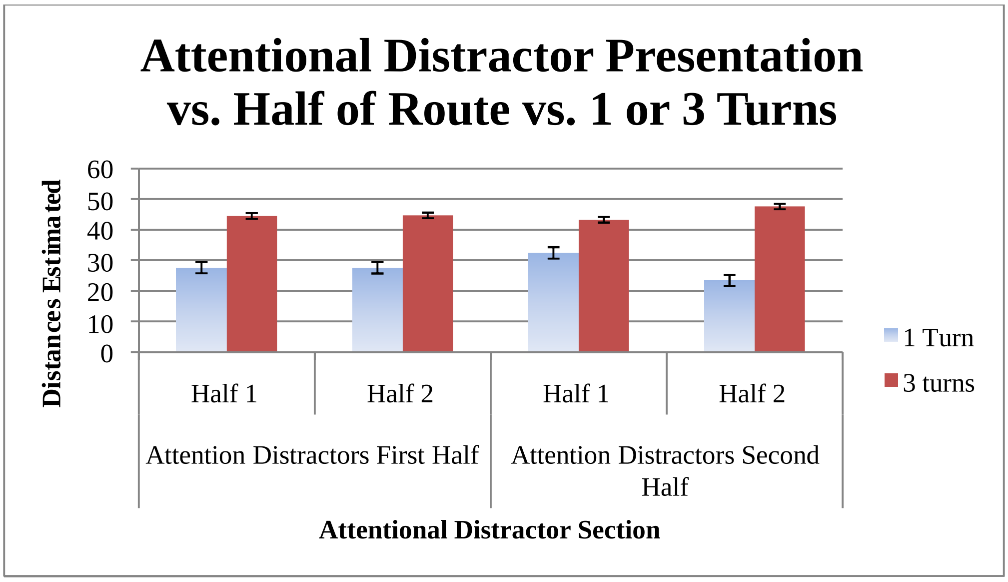

Figure 6.15: Three-Way Interaction between Attention Distracter, Half and Turns on Distance Estimation in Experiment 5 with standard error bars (+/- 1SE).

Again, the effect of turns was robust and a follow up analyses indicated that the path with 1 turn in the second half was recalled as being significantly shorter when the attention distracters were present than when they were not, $F_{(1, 55)} = 404$, $p = 0.04$. None of the other differences were significant.

Finally, and importantly, there was a significant three way interaction between the Goal[7], Attention Cue (first half or second half) and Half of the route (first or second), $F_{(2,51)} = 3.72$, $p = 0.031$, partial $\eta^2 = 0.14$. (displayed according to Scenario in Figures 6.16; 6.17; 6.18).

The following analysis unpacks the effects of the attention distracters according to each scenario condition. Follow up analyses, consisting of a series of mixed ANOVAs were conducted on each scenario separately, with half being the repeated measures factor and attention distracter section being the independent groups' factor. The results are displayed in Table 6.3.

7

Factor	Levels	Between/Within
Goal Scenario	Control vs. HU vs. LU	Between
Attention Cue Presentation	Presented First Half vs. Second Half	Between
Half of the route	First Half vs. Second Half	Within

Table 6.3: Results of the mixed ANOVA on distance estimation according to scenario, first or second half of route and attention distracter in Experiment 8.

Scenario	df and F value	MS (error)	Significance
Control			
Half of route (first vs. second)	$F_{(1,17)} = 0.011$	1.041	ns
Attention Cue (presentation first vs. second)	$F_{(1,17)} = 0.017$	6.973	ns
Half x Attention Cue	$F_{(1,17)} = 7.29$	709.752	**
High Urgency			
Half (first vs. second)	$F_{(1,17)} = 3.817$	508.106	0.062
Attention (presentation first vs. second)	$F_{(1,17)} = 0.631$	409.84	ns
Half x Attention	$F_{(1,17)} = 0.603$	80.275	ns
Low Urgency			
Half (first vs. second)	$F_{(1,17)} = 0.006$	777	ns
Attention (presentation first vs. second)	$F_{(1,17)} = 0.861$	1125.715	ns
Half x Attention	$F_{(1,17)} = 1.806$	216.272	ns

NB: ns: $p > 0.05$; * * $p < 0.01$

Recall, the prediction for an effect of attention shift, if present, would be illustrated most clearly in the control condition. The control condition yielded no significant differences for distances reported for either the first or second half, or overall main effect of attentional distracter. However, there was a significant interaction with the half of the route and where the attention distracters were presented, $F_{(1, 17)} = 7.29$, $p = 0.014$, partial $\eta^2 = 0.31$.

In the control condition, the first half of the route was reported as being significantly shorter when the attentional cue distracters were present (M = 68.34) than when they were not present (M = 76.14). Furthermore, the second half of the route was also reported as being significantly shorter if the attentional cue distracters were present (M = 67.81) than when they were not present (M = 77.33), (see Figure 6.16.). This interaction provides direct evidence to support the claim that when attention is grabbed outside of the environment, distances are remembered as being shorter.

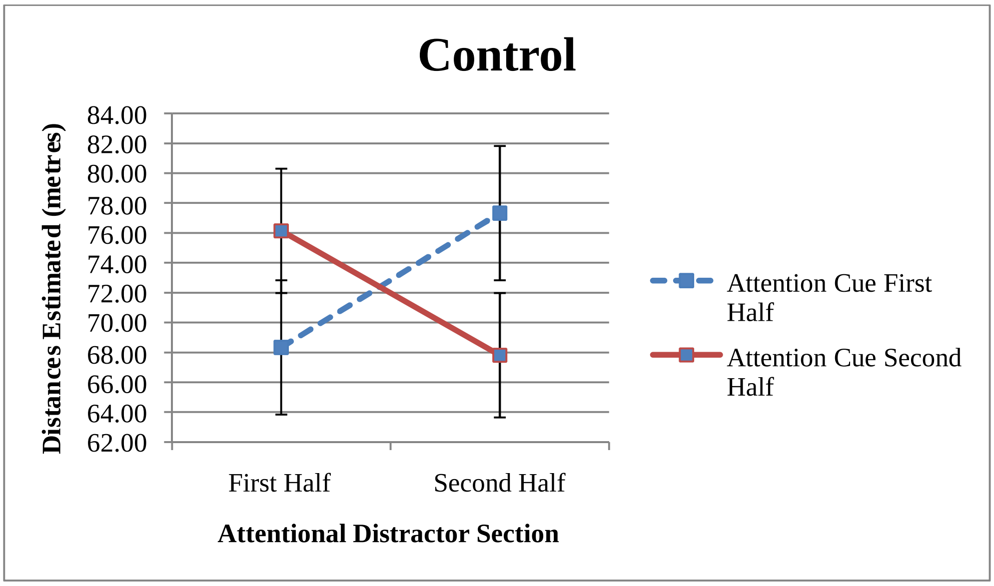

Figure 6.16: Distances estimated for the Control Condition according to the first and second half of the route and the presentation of attentional stimuli in Experiment 8.

Furthermore, it was predicted that the influence of goals and the presentation of attention cues may cancel each other out. In the High Urgency, medication condition, there was a trend approaching significance for the main effect of Half of the route $F_{(1,17)} = 508.106, p = 0.064$, partial $\eta^2 = 0.034$, with the first half (M= 77.14) reported as being significantly longer than the second half (M = 69.67). However, there was no main effect of attentional cue presentation and no significant interaction between the scenario and attentional cue. (see Figure 6.17).

The Low Urgency scenario yielded no significant results for the half of route, attentional cue or interaction between the two conditions (see Figure 6.18).

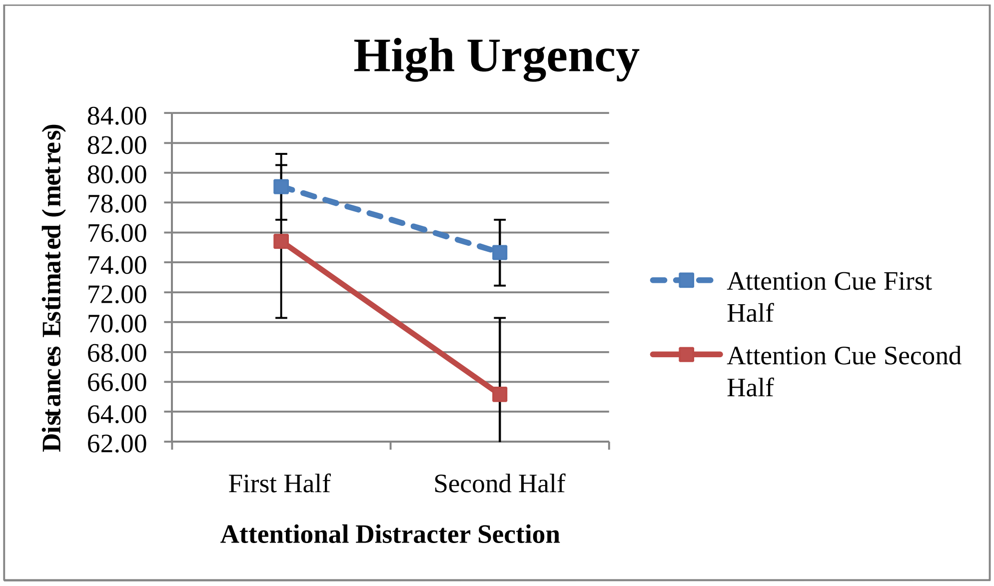

Figure 6.17: Distances estimated for the High Urgency Condition according to the first and second half of the route and the presentation of attentional stimuli in Experiment 8

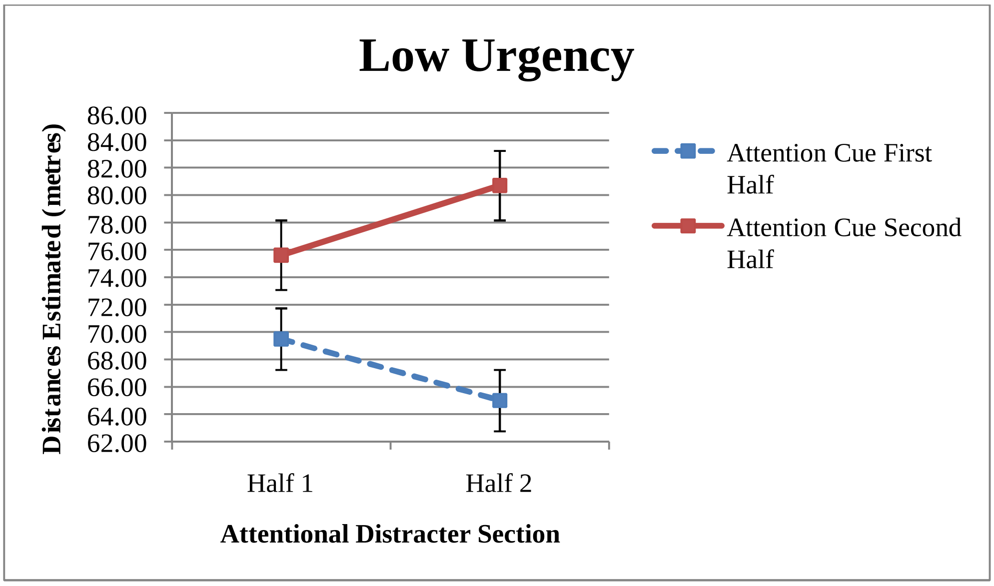

Figure 6.18: Distances estimated for the Low Urgency Condition according to the first and second half of the route and the presentation of attentional stimuli in Experiment 8

6.4.3. Discussion

The experiment highlights the usefulness of the blindfold methodology as it can tease apart a variety of factors in very strict and controlled conditions. The decision to expose participants to the street names prior to taking part in the study substantially improved the data collection for the High Urgency Scenario, with the 11% rate of exclusion being substantially lower than the 22% experienced in the original Bugmann & Coventry (2008) experiments. The adaptation of learning the street names beforehand alleviated cognitive load and allowed participants to be able to recall the landmarks across all three conditions.

As expected, the results identified the influence of turns on distance estimation; paths containing three turns were recalled as being significantly longer than paths beginning with one turn. This result is in line with evidence from other studies (Sadalla & Magel, 1980; Jansen Osmann & Berendt, 2002; Bugmann & Coventry, 2008; Johnson, Coventry & Thompson, 2010).

With direct reference to the influence of attentional cues, we found that the control (no scenario condition) was responsive to the extraneous stimuli, that is, when the attentional distracters were present, outside of the environment distances were reported as being shorter. This demonstrates that extraneous distracters shift attention in no-goal conditions, which results in shorter distance estimations as attention is grabbed from the environment by the distracter. This is consistent with the attention models (e.g. Posner, 1980; Phelps, Ling and Carrasco, 2006) and also the literature on attention and time (e.g. Casini, Macar & Grondin, 1992; Coull et al. 2002).

Furthermore, it was predicted that, if goals led to increased estimations of distance and attentional distracters lead to reduced estimates of distance, then the effects of these conditions, if presented simultaneously, would cancel each other out. Whilst participants in the High Urgency Scenario rewalked a shorter route for the second half of the journey, given the scant literature on goals in spatial cognition, it is difficult to explain this result. One can hypothesise that the walk may seem shorter on the way home, as demonstrated by the interaction between the half of the route and paths with turns; the path with 1 turn in the second half of the route was recalled as being significantly shorter than that in the first half of the route. This effect may be due to the journey appearing shorter on the way home (McNamara & Diwadkar, 1997).

6.5. General Discussion

Taken together, the results of the experiment demonstrate neatly that when attention is drawn to an environment (Experiment 7), distance estimation increases and conversely, drawing attention away from the environment (Experiment 8) results in shorter distances being estimated. This effect directly mirrors the work on time and attention (i.e. Coull et al. 2004).

The influence of modality across both studies was interesting. In Experiment 7, the within modality cues had a greater influence on drawing attention to the environment than the auditory stimuli. Whilst no conclusive theoretical implications can be derived from this, as it is difficult to state empirically whether the auditory tones were comparable to black square flashes, this does warrant further attention for future investigation concerning the efficacy of attentional cues within either a virtual or real environment. Interestingly, the attentional cues in Experiment 8 were also within modality but we were able to draw the individuals' attention away from the environment by drawing attention to items that would generally not be directly in the environment i.e. "Look, there's a bird!" This highlights the influence of top down processing when using attentional cues, that is participants' attention will initially be drawn to the spatial location associated with that object.

Furthermore, when goals and attentional distracters are present in the environment simultaneously, the effects cancel each other out. Whilst the literature on goals in spatial cognition is scant, the effects are supported somewhat by reports that goal specificity acts as an inhibitory factor in the development of survey knowledge (Rossano & Reardon, 1999). Furthermore, the study states that goals sacrifice schematic development by diverting attention from the environment and focusing more resources towards the goals.

6.6. Conclusion

Overall the data highlights the importance of attention when considering the underlying mechanisms contributing to how environments are represented. The next chapter will discuss our study's contribution to the role of goals in both real and virtual environments and discuss further the role of attention as an alternative explanation to encompass cognitive distortions and therefore outline future studies to contribute to our understanding of mental representations.

SECTION IV - GENERAL DISCUSSION AND CONCLUSION

CHAPTER 7.

7.1. Chapter Overview

The experimental work outlined in this thesis aimed to investigate firstly, whether goals influence distance estimation in Real Space and VR. Secondly, a review of the literature on time and attention provided the impetus to investigate the influence of attention on distance estimation.

This present chapter will firstly summarize the main findings presented in the thesis, and will then consider how these findings integrate with and impact upon the distance distortions reviewed in Chapter 1. Future directions will be discussed followed by general applications and conclusions.

7.2. Summary of Results

The first set of experiments which set out to investigate the role of goals was partly motivated by evidence that distance estimation is distorted. Chapter 1 reviewed a range of evidence, challenging the assumption that cognitive maps are direct metric representations of the environment. In addition to this, it was acknowledged that goals exert a strong influence on many higher cognitive processes, and therefore the reason why individuals move around in environments was thought to influence immediate memory for distance and time. The first series of experiments investigated the role of goals under conditions of experimental control whilst trying to maintain ecological validity. In addition, goals were investigated in both real space and VR. The results of the first series of experiments revealed an effect of goal scenario on distance estimation across these media.

The results for the straight line path (Experiments 2 and 3) and the path with turns in VR (Experiment 5), demonstrated that goals exert a powerful influence on immediate memory for distance travelled. Furthermore, increased urgency reports were associated with greater distance estimates in both real and virtual space. Moreover, there was a reliable correlation between urgency ratings and distance estimates, suggesting that individual differences in perceptions of urgency may also play a role in perception of distance (consistent with Golledge, 1987; 1999). This effect cannot be explained by the amount of time spent traversing the path given that time and speed of walk were strictly controlled. In addition the absence of differences in scenario effects as a function of media supports the robustness of VR as a methodology despite acknowledged limitations with regard to simulating real life experience (Campos et al., 2007).

The outcome for Experiment 4 is still unclear, as an effect of scenario was not found for the real human maze containing many turns. One explanation could be that goals remove the effect of turns. Another explanation seems more likely; participants walking in the human maze with many turns found it difficult to walk in time with the metronome clicks when navigating the turns, distracting them from the role play task at hand. However, the VR replication was able to iron out any motoric issues and an effect of goals was demonstrated in the complex VR path, suggesting that methodological issues reported by participants in the real space complex path interfered with the effects of goal scenario.

Experiments 2 and 3 and 5 demonstrated a robust effect of turns on memory for distance, consistent with previous findings in both real space (Sadalla & Magel, 1980; Bugmann & Coventry, 2008) and VR (Jansen-Osmann & Berendt, 2002; Ruddle, Payne & Jones, 19997). Whilst there was a robust effect of goal scenario on both distance and time estimation, the effects of goals on distance estimation were weaker in virtual space and the effects of time were weaker in real space. Both of these outcomes may suggest that the lack of vestibular and proprioceptive information (Campos et al., 2008) in VR results in greater cognitive resources to attend to time compared to distance. Nonetheless, the results directly contradict claims that the spatial experience in a passive VR system cannot be the same as real space (Montello, 2009). Montello (2009) claimed that active and passive travel, with regards to distance knowledge, must be qualitatively different as they use different information sources and cognitive processes. This is expanded upon further by explaining that the key factors in distance cognition are travel time, speed, and physical effort (Durgin et al., 2005; Rieser, Pick, Ashmead & Garing, 1995).

Whilst the first set of experiments, focusing on the role of goals, demonstrated that goals do indeed influence memory for distance and time in Real Space and VR, and highlight the importance of why people move around space as being fundamental to how that space is experienced and recalled, they do not provide any explanation into the underlying contributory mechanisms. Experiment 6 established that the effect of scenario on memory for distance and time cannot be explained by the influence of physiological arousal induced from the scenario induction. Measures of arousal did not differ across the scenarios. Negative mood was more prevalent in the High Urgency condition. However, the influence of mood and/or anxiety on retrieval alone was discounted as participants did not differ in their estimations of route distance for the reference path walked prior to the scenario induction.

A further possible explanation is that goals mediate how attention is allocated as individuals move around the environment (Bugmann & Coventry, 2008; Corbetta & Shulman, 2002). This would be consistent with Bruyné and Taylor's (2009) study where participants in the route learning condition demonstrated different behaviour to learning an environment than participants in the survey condition, that is, streets and street names versus buildings and compass directions.

The second series of Experiments aimed to test directly the role of attention using two very different methodologies. Experiment 7 aimed to establish whether drawing attention to the environment, through short auditory bursts or visual flashes, would result in greater distance estimations, consistent with studies in time perception. A secondary goal aimed to address whether the modality of the cue will influence subjective distance estimations. Participants were exposed to two paths, one with attentional cues and one without. The results confirmed our expectations; Experiment 7 found that the stimuli within the environment presumably captured attention resulting in increased distance estimations compared to the paths where no attention grabbing stimuli presented. In addition, a marginal main effect of modality was found in the condition with visual flashes resulting in longer distance estimations than the auditory condition, consistent with evidence supporting cross modal interference (Turatto, Benson & Galfano, 2002).

The results from Experiment 7 led directly to the hypothesis for Experiment 8, that is, if attention is taken away from the environment we expected distance estimations to be shorter. With regard to the effect of goals, there were two possible reasons as to why these effects were present. Firstly, goals may induce a state which influences distance distortion, if this mechanism was present, then we expected to find effects of goals on distance memory separate from effects of attentional cueing. However, if goals direct attention, then the effects of attention should cancel each other out and no effect of goals should be found on distance estimation. Therefore, we also aimed to test the effect of goals utilised in the first series of Experiments, using a blindfold methodology (Bugmann & Coventry., 2008). This methodology allowed strict control over the environmental features and stimuli. The control of the attention shift stimuli was an important feature so that participants would perceive them to be extraneous to the environment.

Experiment 8 yielded several important results; firstly, it demonstrated neatly that extraneous distracters shift attention in no-goal conditions as shorter distance estimations were reported when attention is grabbed from the environment by the distracter in the no scenario (control condition). This result is consistent with the attention models (e.g. Posner, 1980; Phelps, Ling and Carrasco, 2006) and also the abundance of literature on attention and time (e.g. Casini, Macar & Grondin, 1992; Coull, Nazarian & Macar, 2004).

Secondly, the effects of goals and attentional distracters when presented together, cancel each other out. A possible hypotheses from the first series of studies demonstrated that goals may draw attention to the environment. The attentional cues, such as “look, a bird overhead”, take attention away from the environment, resulting in decreased distance estimations. Thus, these competing attentional cues effectively cancel each other out.

Thirdly, the paths containing three turns were recalled as being significantly longer than paths with one turn; in line with evidence from other studies, hence providing evidence for the fidelity of VR, at least in this respect (Sadalla & Magel, 1980; Jansen Osmann & Berendt, 2002; Bugmann & Coventry, 2008; Johnson, Coventry & Thompson, 2010).

The results from Experiments 7 and 8 offer a possible explanation as to why goals distort distances as the amount of attention participants allocate to their environment when performing the goals could be mediated by scenario. This would be consistent with the 'attentional shift' hypothesis (Bugmann & Coventry, 2008). For instance, it is possible that the high urgency condition, in the first series of Experiments, (with the exception of the real space complex path) induced a narrowing of attention. This process would result in greater resources being attended to the environment which would increase awareness of change in the environment, resulting in longer distance estimations. This explanation is consistent with much of the literature on attention mentioned in Chapter 5 (i.e. Treisman & Gelade, 1980; Eriksen & St. James, 1986).

In summary, the data reported in this thesis suggest that goals and attention do indeed influence memory for time and distance in across a range of environments and also through imagined traversal. These results suggest that the reasons why people move round space are fundamental to how that space is experienced and recalled, and that VR provides an excellent platform in which to test spatial cognition. More importantly, similar effects of distance estimation were found by manipulating attention, consistent with evidence from the literature on time and attention. The mechanisms underlying goals and attention may be related.

7.3 Methodological Concerns

The impetus for investigating the role of goals in Experimental Series 1 was a tradeoff between experimental control and ecological validity. To obtain greater ecological validity it would be necessary to test goals in real space environments within an appropriate context. However, asking participants to conduct tasks in real environments, such as delivering medication whilst navigating in a hospital environment may result in demand characteristics. The maze structures, whilst not realistic, allowed for stringent control of visual factors, distance navigated and time spent in the environments through controlling the speed of walk.

The use of simple maze structures was considered to be an important factor in controlling many of the variables involved whilst navigating in an environment, and was found to be most useful in providing a strict control over visual factors. However, Experiment 4 - the real space complex path - as mentioned previously, was reported as being difficult to navigate at corners, due to the necessity to walk in time with the metronome, and participants reported afterwards that this distracted them from the task at hand. This was the most likely reason for the absence of an effect of scenario in that Experiment.

Another issue with testing in real space in comparison to VR for complex paths is that, unless motion tracking is present, it can be difficult trying to control the exact distance participants cover in a real environment. The development of the VR model of the path with many turns highlighted that individuals do not naturally approach corners centrally and then take a 90º turn. The pilot VR study in Experiment 5 resulted in paths being smoothed at corners to replicate naturalistic walking conditions. Surprisingly, this issue has not been highlighted in any previous research comparing real space and VR (i.e. Thomson et al. 2004; Ziemer, Plumert, Cremer & Kearney, 2009). The studies presented in this thesis are the first to provide visually directed walking in real space and identical VR comparisons, as opposed to non-visually guided locomotion (Witmer & Sadowski, 1998). Clearly, the experiments investigating the role of goals highlighted the complex multi faceted nature of endogenous and exogenous cues, which can be difficult to encompass when attempting to include greater ecological validity.

In addition, the range of scenarios was limited. Whilst the two scenarios chosen were appropriate and provided evidence for the effect of goals on distance estimation, the conclusions drawn from these studies are limited. The goal scenarios used were high urgency/high desirability and low urgency/low desirability. A further modification could therefore be to test a range of goals factoring in high urgency with low desirability etc., as there is much evidence for the role of individual differences across a range of distortions (i.e. Proffitt et al., 2003). Furthermore, a wider range of scenarios allows greater control which would benefit assumptions drawn from subsequent findings.

The second series of experiments investigating the role of attention in VR involved a different set of challenges. Establishing a comparison between visual and auditory stimuli is challenging (i.e. Robinson & Sloutsky, 2010) in order to adequately examine potential modality differences. It is difficult to establish whether the auditory and visual stimuli were uniformly equivalent or not, which would possibly impact upon later distance estimation. For this reason very short stimuli bursts were used, therefore ensuring participants would notice both types of stimuli when they appeared, without fear that they would habituate, which may occur with longer bursts. Another approach could be to employ a dual task method. For instance, Coull et al. (2004) demonstrated graded effects of attention through training participants to attend to two tasks, apportioning various levels of attention to either time or colour.

Finally, the relationship between distance and time is unclear. Casasanto and Bottini (2010) claim the relationship between space and time is similar in the mind to that in the real world, unlike distance, where we have already demonstrated that systematic errors occur. The first series of studies requested time estimates after distance judgements and undoubtedly the first answer will prime the next. Therefore, an obvious progression from the first series of studies in this thesis would be to run separate studies requesting distance <u>or</u> time estimates in order to compare the distance and time relationship objectively.

Overall, the experiment findings and methods used form a solid basis for future research, which will be discussed in the following section.

7.4. Theoretical Implications

Cognitive maps are claimed to be constructed whilst navigating through the generation of a "bird's eye" representation or topographical knowledge of one's environment. Chapter 1 demonstrated that there is much evidence of systematic errors in distance estimation which violate the metric properties attributed to cognitive maps. In spite of the widely held belief, supported by a variety of research (e.g. Burgess, 2006) that allocentric representations are employed in conjunction with the individual's egocentric knowledge of the environment, the contributory mechanisms have yet to be addressed and consequently, the underlying mechanisms are still unknown.

It has been demonstrated that goals can influence our representations of our environments, in both real space and VR and the role of attention in distance estimation has been established.

Navigating in space is experienced as a 'seamless whole', involving cross modal interactions, where participants effortlessly focus, shift and divide attention as the need arises in order to manoeuvre effortlessly with ease. The deployment of attention is understood and simplified by a distinction between exogenous and endogenous attention and this distinction is important for understanding its contribution to an individual's experience in an environment. Exogenous, bottom up, cues are external to the individual and grab attention, such as a turn in a path or the salience of a building. In contrast, endogenous, top down cues, are voluntary and reflect internal states of the agent. It is therefore logical to assume that processing information in the environment is influenced by a complex interaction of competing endogenous and exogenous factors such as visual stimuli, action, sensory organs and goals, in addition to any associated affective valence (Ittleson, 1960; Briggs, 1973; Stea, 1969).

The interdependency between time and distance for journey estimations (Montello, 1997; 2009; Bugmann & Coventry, 2008), together with several similar effects in the time estimation literature to that of distance estimation, identified the area of time and attention as a fruitful source of information through which to investigate the role of attention on distance memory. For instance, segmentation in time estimation (Poynter, 1983; Zakay, Tsal, Moses, & Shahar, 1994) directly reflects the effects of turns in distance estimation studies, through the segmentation of the path (Sadalla, Burroughs & Staplin, 1980). Therefore, when one walks through an environment, the turns in the path grab the individuals' attention more often than a straight path and, the more attention that is paid to the environment, the greater the distance that will be reported. These shifts of attention have been suggested as a unified theory to account for a range of effects on memory for distance and time (Bugmann & Coventry, 2008).

Taking examples of distortions of distance in Chapter 1, we can expand on how these various distance distortions may occur if attention is recruited as an explanatory source of misrepresentations. According to hierarchical theories, spatial memories include nested levels of detail; and region membership is an important property. For instance, McNamara (1986) demonstrated that spatial arrangement and division of regions resulted in participants in two groups responding quicker to objects when they were primed by an object in the same region, than locations in different regions, irrespective of Euclidean distance. Both groups were presented with transparent divisions, and one group had to treat the divisions as barriers whereas the other group could walk freely across the divisions. If we consider the role of attention in these results we could argue that the barriers naturally grabbed participants' attention across the conditions resulting in the groups naturally organising the objects into the regions.

Similar explanations could enlighten us to the differences in spatial judgements between the Arab and Jewish settlers, where Arab and Jewish individuals perceived distances between buildings in their own territory to be shorter than distances between Arab and Jewish buildings (Portugali, 1993). For instance, a Jewish person would be less familiar with the paths leading from their territory to Arab buildings. This unfamiliarity with the environments between the buildings may result in greater attention being drawn to the environment, or, in line with the time literature, the political tension between the two groups may result in greater vigilance being directed to the environment (Cahoon & Edmonds, 1980; Fraisse, 1963) thus resulting in increased distance estimates.

Asymmetry in distance estimation is also amenable to an attentional explanation. For instance, when travelling in a new environment,t distances from A - the starting location, to B - the goal location, are generally reported as being longer than distances from B to A (McNamara & Diwadkar,1997). This could easily be explained as a result of greater attention being allocated to the environment from A to B as it is unknown and less attention needs to be allocated for the return journey.

Finally, the route angularity effect, (Sadalla and Magel, 1980) which demonstrates that enforced changes of direction, such as right angled turning, result in longer distance estimations than a route of the same physical length containing fewer turns. This could also be partially explained with attention being drawn to the environment, similar to Experiment 7, and thus resulting in greater distance estimations as salient changes in bodily position may cue attention to the environment.

These examples all demonstrate the effect of exogenous characteristics in the environment drawing attention whilst navigating, but endogenous cues; that is, individuals attending through their own volition (Posner, 1980). Bruyné and Taylor (2009) found, when giving participants separate instructions to learn a route or survey perspective, that their visual attention was influenced by their perspective, but only early on in the study. For instance, the survey condition participants focused on buildings and compass coordinates, aspects crucial to gaining knowledge about the overall layout of the environment, whereas participants in the route goal condition biased attention towards streets and street names. This is in line with research in other areas which state that goal relevant information will capture attention more than irrelevant stimuli (Aarts, Dijksterhuis, De Vries, 2001; Folk et al., 2002). Furthermore, Rossano and Reardon (1999) identified goal specificity as an inhibitory factor in the development of survey knowledge, claiming goals sacrifice schematic development, possibly by diverting attention from the environment and focusing more resources towards the goals.

The research in this thesis therefore highlights the need to examine the environmental experience through a variety of ecologically valid tasks, separating out top down and bottom up influences of attentional allocation.

7.5. Future Directions

Overall, the experiments highlight the importance of goals and attention on cognitive maps in both real space and VR. The role of goals and attention need to be considered across a variety of tasks and environmental settings, and may go some way to accounting for variability in performance in past studies. There are several ways in which these lines of work can be developed.

If attention plays a predominant role in influencing how individuals engage with and reconstruct environmental representations then it would be reasonable to suggest ways of measuring behaviour whilst moving in an environment. One might expect individuals in a High Urgency scenario to attend to the environment for greater periods of time and be more sensitive to change. Eye tracking devices could capture frequency or duration of fixations in VR across a range of goal scenarios. Alternatively, memory tests for objects within the environment could be administered in order to establish whether recalled information correlated with memory for distance.

Secondly, the relationship between distance and time requires clarity. Walsh (2003) developed A Theory of Magnitude (AToM) which proposes that space and time are mentally represented by a common analogue magnitude system, which also shares the same processes as number and quantity. One of the implicit assumptions of AToM is that the dimensions of space and time are symmetrically interrelated. This assumption has been challenged as Casasanto & Boroditsky (2008) demonstrated an asymmetry between distance and time judgements where distance is seen to influence time but not vice versa. For instance, shorter lines were reported as taking a shorter time, and longer lines were judged to take a longer time, despite the duration of both conditions being strictly controlled. By contrast, estimations for stimuli that were the same average spatial length were not influenced by the duration that it took to extend the line. This resulted in their conclusion that mental representations of time are dependent on representations of space, but time is not dependent on space. Furthermore Bottini and Casasanto (2010) claim that time is multi-representational, using examples through language and that individuals use representational plasticity for time. In order to tease apart these explanations, future studies need to ensure that distance and time estimations are not conflated and therefore ask participants for either distance or time estimation judgements.

The final suggestion refers to the media through which environments can be understood and experienced. One interesting outcome in the first series of studies was the sensitivity to distance estimation for goals in real space compared to VR. These results may give support to Montello (2009) who postulated that VR cannot be the same as the real space experience or, that we use different mechanisms as distance influenced by speed, travel time and physical effort and that attention varies as a function of locomotion and way-finding decisions. In order to investigate further whether the sensitivity to time was a result of using a large screen projection system and hence a reduction of motor input, a replication study could be conducted in an immersive VR system with a head mounted display.

Furthermore, future VR studies could implement ecologically valid visual and auditory attention stimuli, for instance, an immersive VR system with naturalistic stimuli, such as a bird accompanied by a bird call.

Finally, environments are generally complex and vary across many factors, not just turns. Future studies would benefit from employing realistic ecologically valid environments in order to fully understand the effects of both goals and attention

7.6. Applications

The range of literature addressed in Chapter 2 demonstrated that estimations of physical dimensions, including distance, size and slope, are affected by a range of variables going beyond immediate perceptual cues. For instance, there is a full range of evidence supporting the role of many processes on perceptual judgements (e.g. Proffitt & Stefanucci, Banton & Epstein, 2003; Witt & Dorsch, 2009; Witt et al., 2009; Witt Proffit & Epstein, 2010). For example, differences in perceptual judgements have been identified from a range of factors, such as physiological arousal and anxiety from the top of a tall building (Stefanucci & Storbeck, 2009) or expertise (Witt, Linkenauger, Bakdah & Proffitt, 2008; Witt & Dorsch, 2009; Witt & Proffitt, 2005). This research merely reflects perceptual judgements from a single perspective, as opposed to dynamic environments, which are more representative of real world settings. Therefore, whilst this evidence would be useful in an industry using 2D images, such as maps or photomontage, the use of such information with regards to VR can be limited. Furthermore, Balcetis & Dunning (2007) demonstrated that distance travelled whist actually walking in the environment can be mediated by other factors, such as cognitive dissonance.

Therefore, there appears to be a tension between conducting useful studies that are directly relevant to how individuals behave in environments compared to studies which aim to identify the underlying mechanisms contributing to distance distortions or way finding. Nevertheless, exploring this tension can be fruitful for design purposes.

Unlike maps, VR provides the potential to interact with a virtual world across a range of visual displays; from simplistic desktops, large screen stereoscopic projections, "CAVEs” or immersive head-mounted displays (HMDs). More importantly, the use of real time offers an important opportunity to gain insight into experiencing Virtual Space with similar dimension to Real Space.

Additional advantages demonstrated by VR are the ability to have tighter control over environmental parameters and to design and adapt an environment economically, quickly and in accordance with the hypotheses to be tested. Furthermore the spatial experience can be obtained as environments can be experienced with continuous measurements (Schmelter, Jansen-Osmann & Heil, *in press*; Peruch & Gaunet, 1998; Wartenberg, May & Peruch, 1998). Therefore, VR has the capability to provide a greater degree of interactivity as participants can explore the environment actively as they can be passive navigators or control what they experience.

An area that has been identified as problematic is the conflict between the aesthetics of a building and its functionality, with architects and laypeople extracting different information from building designs (Gifford, Hine, Muller-Clemm, & Shaw, 2002) resulting in added complexity during way finding. VR has the value-added potential to possibly test environments for specific users.

Furthermore, complex buildings can also be enhanced through the utilisation of VR as models can be developed in order to identify where individuals attend to in their environment. The general attitude for dealing with complex space is signage and, whilst some might consider aided navigation to be a simplistic task, (that is, merely following a trail) (Allen, 1999) others can find it quite a daunting experience (i.e. Peponis, Zimring, & Choi, 1990). There is also evidence that wayfinding difficulty significantly increases during emergency scenarios (Arthur & Passini, 1992; Bryan, 1995) with individuals automatically heading for familiar locations (Sime, 1985). This issue can be relevant even in more mundane daily activities such as locating toilets in public buildings.

It therefore seems that identification of the most suitable location and type of signage is not intuitive. In order to address this issue VR and eye tracking systems could identify where individuals are looking in the environment for signage across a range of scenarios. This could then be developed further to adapt the salience of the signs or even auditory cues to grab attention.

In everyday non emergency way finding situations, navigation can still be complex i.e. Seattle Central Library (Carlson, Hölscher, Shipley & Conroy- Dalton, 2010) or hospitals. Where signage is frequent there may be a tendency for individuals to become habituated to these cues, whilst uniformity or colour schemes can be useful, changes in cues may be relevant such as manipulating attention by cueing at complex decision points to avoid habituation. This development would allow for way finding behaviour to be adapted as opposed to investing in expensive rebuilds.

At this present time cross modal cuing effects across these regions of space are under investigated and, given the multi modal experience of space across distance and time, there is an plethora of opportunities to explore future possibilities.

7.7 General Conclusion

To summarise, the work carried out for this thesis provides evidence that goals influence distance estimation. Furthermore, attention has been identified as a critical factor when investigating the acquisition of memory and spatial knowledge in both real and virtual space. It is therefore feasible to propose the role of attention as a unifying construct through which to understand distortions of distance and time in space.

Appendix

Appendix 1:Scripts for scenario inductions.

Control

You have now been transported to the beginning of my Polystyrene Block World. When I eventually take the blindfold off you will notice that the beginning of the path is marked by tape – identical to that which you walked along on earlier, when I measured your steps to calibrate them to the sound of the metronome. The end of the path is also identified by exactly the same tape.

As I mentioned earlier the purpose of this task is to walk through the maze but you must keep in step with the metronome, you are not allowed to walk any quicker or slower than the sound of the metronome. The metronome has been purposefully set to replicate your natural walking pace – do you understand the task?

OK – are you ready to have your blindfold removed? Remove your blind fold & and you will start your task when you are ready (blindfold removed). You must go to the end of the path and keep in pace with the sound of the metronome.

High Urgency

As I mentioned earlier, the purpose of this task involves role play. I would like you to concentrate completely on what I am about to say.

Your closest friend is seriously ill in hospital. The medics are around the bed as we speak and state their condition is critical. Your friend is wired up to a life support machine. They need medication as soon as possible. Only you have the medication that is going to save your friends life. If you don't get there in time there is a chance that this could be fatal. The only person that can save them is you.

Do you understand the seriousness of the task?

You must keep in step with the metronome; you are not allowed to walk any quicker or slower than the sound of the metronome. The metronome has been purposefully set to replicate your natural walking pace. Do you understand? Do you also understand the seriousness of the task?

Here is the medicine, you must deliver the medicine but keep your steps to the sound of the metronome. OK – are you ready to have your blindfold removed? Remove your blind fold & you will start your task when you are ready. (removal of blindfold)

Low Urgency

As I mentioned earlier, the purpose of this task involves role play. I would like you to concentrate completely on what I am about to say.

Today is the day the exam results are released. You have received a first in your exams and are very pleased with yourself. Your closest friend has had to attend a job interview and wasn't able to pick up their own results. The admin staff have agreed that you can deliver the results to them, due to extenuating circumstances. You are about to deliver the exam results.

Unfortunately…….. the envelope is not sealed and you look at the results. …………Your friend has failed every - single - module! They will be required to do a full year resit!!!

You know how hard your friend has worked for the exams and you also know that they will be devastated when they received the news, and you are the bearer of that bad news.

Your friend is waiting for you as we speak for you to deliver the results.

Do you understand the seriousness of the task?

You must keep in step with the metronome; you are not allowed to walk any quicker or slower than the sound of the metronome. The metronome has been purposefully set to replicate your natural walking pace. Do you understand? Do you also understand the seriousness of the task?

Here are the exam results, you must deliver the medicine but keep your steps to the sound of the metronome. OK – are you ready to have your blindfold removed? Remove your blind fold & you will start your task when you are ready. (removal of blindfold)

Appendix 2: Playback factor calculation for Experiments 3, 5 and 7

	B	D	E	F	H	J	K
2	**STRAIGHT LINE VR**					USE:	
3	Default speed (m/s)	1.25					
4	length (m)	8				1.	Get volunteer to walk the real life 8m line and time them
5	time (s)	6.4				2.	Enter time into box D7 highlighted in **RED**
6						3.	Load up the straight line VR file
7	User real time to walk	15		PLAYBACK FACTOR	0.426667	4.	Press F8 to bring up the playback control panel
8						5.	In the right speed field enter the playback factor shown here in **YELLOW**
9						6.	Click mouse back on the main window titlebar
10						7.	Press F11 to go to Fullscreen (press Enter to accept message)
11						8.	Press ALT+NUMPAD 6 to play the animation
12	**CORRIDOR VR**					9.	Press ALT+NUMPAD 7 to rewind the animation
13	Default speed (m/s)	1.25					
14	length (m)	18.5	(full distance walked in VR)				
15	time (s)	14.8					
17		34.6875		PLAYBACK FACTOR	0.426667		
21	**SHORTCUT KEYS**						
22	F8	Displays playback control panel					
23	F11	Toggles fullscreen mode					
24	ALT+NUMPAD 6	Plays the animation					
25	ALT+NUMPAD 7	Rewinds animation back to start					

Appendix 3: Details of the ratings for distance travelled, time, urgency and anxiety for Experiments 2 , 3, 4 and 5

Part no.

Date:

Rating Experiment

I am now going to read out some statements for you to respond to in order to identify how you felt as you walked through the route.

1) How long do you think the path you travelled was? ______________________________

2) How long did you think it took you i.e. length of time, to walk the path? ____________________

3) Your speed was set at your normal walking pace. Do you think the pace you were walking at was:-
a) Too slow
b) Just right
c) Too fast

If A or B, how would you have liked to adjust your speed? i.e. 10% more/less etc?

4) This line represents 5 times the length you walked when we were measuring your natural walking pace at the beginning of the experiment. Please mark on the line the distance you think you have just walked in the 'Polystyrene Block World'

____

5) How anxious did you feel when you were performing the task? On a scale of 1-10 where 1 is not at all anxious and 10 is extremely anxious?

1	10
Not at all anxious	Extremely Anxious

6) Again, on a scale of 1-10 How anxious did you feel as you were approaching the end of the task?

1	10
Not at all anxious	Extremely Anxious

7) On a scale of 1-10 How Urgent did you think it was for you to get to the final destination? Where 1 is not at all urgent and 10 is extremely urgent?

1	10
Not at all urgent	Extremely Urgent

8) How anxious did you feel after the task was over?

1	10
Not at all anxious	Extremely Anxious

Appendix 4: Details of the ratings for PANAS, distance travelled and urgency estimations for Experiment 6.

1) How long did you think the reference path was that you walked along earlier?

____

This scale consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to the word to **indicate how you feel at this moment.**

		1 Not at all	2 Some what	3 Moderately	4 Very much
1)	Calm	☐	☐	☐	☐
2)	Tense	☐	☐	☐	☐
3)	At Ease	☐	☐	☐	☐
4)	Over-Excited	☐	☐	☐	☐
5)	Inspired	☐	☐	☐	☐
6)	Afraid	☐	☐	☐	☐
7)	Alert	☐	☐	☐	☐
8)	Upset	☐	☐	☐	☐
9)	Excited	☐	☐	☐	☐
10)	Nervous	☐	☐	☐	☐
11)	Enthusiastic	☐	☐	☐	☐
12)	Scared	☐	☐	☐	☐
13)	Determined	☐	☐	☐	☐
14)	Distressed	☐	☐	☐	☐

On a scale of 1-10 How Urgent did you think it was for you to get to the final destination? Where 1 is not at all urgent and 10 is extremely urgent?

1 — Not at all urgent
10 — Extremely Urgent

Appendix 5: Details of the ratings for distance travelled, time, urgency and anxiety for Experiment 7

Rating Experiment

Part no.
Date:

I am now going to read out some statements for you to respond to in order to identify how you felt as you walked through the route.

1) How long do you think the distance of the first path you have just travelled was? _______________

2) How long did you think it took you i.e. length of time, to walk that path? __________-_____________

3) How long do you think the distance of the second path you have just travelled was? ____________

4) How long did you think it took you i.e. length of time, to walk that path? _______________________

5) The speed at which you travelled was set at your normal walking pace. Do you think the pace you were 'walking' at was:-
a) Too slow
b) Just right
c) Too fast

If A or B, how would you have liked to adjust your speed? i.e. 10% more/less etc?

6) This line represents ***the length of the first path*** you walked in the Virtual Environment at the beginning of the experiment. Please mark on the line the two distances you think you have just walked in the 'Polystyrene Block World'

——X——————————————————————

7) How long did you think the very first path that you travelled in the VR was? __________________________

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