The First-Perspective Alignment Effect: Spatial Memories from Verbal Descriptions, Virtual Environments and Object Arrays.

by

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A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of the University of Leicester

June 2004

Dedications

This work is dedicated to life, and the people with whom I share and have shared it.
To Dave, my husband and 'Rock,' to Mum, and Jenna and Rob. Thanks to you all for your encouragement and I wish you health and happiness always.
To Frank - I shall miss your bear-hug and "Well done."
And last, but far from least, to my Dad - "Chin up, a step up the ladder."

Acknowledgements

I am deeply indebted to the supervisor, Dr Paul Wilson, who has guided and supported this work for these past three years with knowledge, 'tolerance' and a very enviable ability to teach but not preach. Thank you.

I also wish to acknowledge the help and support of Dr Kate Garland, who took on 'unknown territory' in supervising this thesis to its completion during the final stages. Thank you. PhD students that you supervise in the future will be very lucky.

Finally, I extend very many thanks to Antoinette Hardy and David Taylor who helped to collect data for Experiments 5 and 10 respectively. I wish you well in your future lives and careers.

The above is not to mention anyone and everyone who took part in my experiments, or who may have helped or supported me in other ways. I thank you one and all.

In life and learning

Di.

Publication

Part of this thesis has been published:

Wilson, P. N., & Wildbur, D. J. (2004). First-perspective alignment effects in a computer-simulated environment. *British Journal of Psychology, 95,* 197-217.

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ABSTRACT

Fourteen experiments investigate the 'first-perspective alignment effect' (FPA), a novel finding that people sometimes encode a space preferentially in alignment with the first perspective they encounter. In Experiments 1-6, participants read verbal descriptions of three-path routes. A map-drawing task in Experiment 1 suggested that spatial memories are egocentrically encoded on the basis of forward-up equivalence. In Experiments 3 and 4, when a salient landmark was described in relation to the start orientation of the routes, orientation estimates to remembered test locations were most accurate when participants imagined themselves aligned, rather than 180° contra-aligned, with the first part of the route. However, in Experiments 5 and 6 the introduction of allocentric cardinal terms systematically affected the text FPA. Participants in Experiment 7 explored two versions of VEs based on the text descriptions used in Experiments 2-6. The FPA was found following the first VE exploration, but following the second VE exploration, the effect was attenuated. Experiment 8 omitted the alignment tests after the first VE, leading to similar results to those in the first test of Experiment 7, suggesting that prior experience of making orientation judgements in the first test of Experiment 7 had attenuated the FPA. Experiment 9 used a text-based procedure, in which participants were asked to make active spatial judgements after reading each section of the route, and the FPA was not found. Experiments 10-14 extended the above findings to learning about arrays of static objects from primary experience. In Experiment 10, when participants viewed an array of four objects from four perspectives, orientation judgements were similar for all perspectives. When arrays were viewed from two perspectives that were 0 and 90° (Experiment 11), and 0 and 180° (Experiment 12) misaligned from the centre of the array, no evidence for FPA encoding was found. The absence of this effect following primary, but not secondary learning Experiments 2-9; Wilson, 2001), was further investigated in Experiments 13 and 14, in which participants viewed the arrays under conditions of observer movement and display rotation. No evidence for FPA encoding was found; therefore, the presence of vestibular feedback in the primary case, does not explain differences in encoding between primary and secondary learning sources. The results are discussed in terms of spatial reference frames and spatial anchor points, and suggest that the FPA effect is the default form of encoding in spatial memory under some circumstances.

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CHAPTER 1

Spatial Memories, Orientation Effects, and First-Perspective Alignment Encoding

1.1. Orientation Specificity and the Alignment Effect

Unlike other animals, humans are able to mentally encode spatial information both directly, through primary interaction with the physical world, and indirectly through the knowledge acquired from a variety of secondary learning media such as verbal descriptions, maps, pictorial representations (e.g. Presson & Hazelrigg, 1984), and more recently, interactive computer simulations (see Péruch & Gaunet, 1998; Wilson, 1997 for reviews). Spatial information may be encoded in human memory in different ways depending on the source of that information, and possibly the extent to which it resembles perceptual experience (Wilson, Tlauka & Wildbur, 1999).

An important example is that when spatial knowledge is acquired from a secondary source such as a map, the resultant representation is typically 'picture-like' in that it is encoded in a specific orientation that corresponds to the individual's view while learning (Levine, 1982; Presson & Hazelrigg, 1984). Levine (1982) noted that the "You-Are-Here" (YAH) maps commonly found in most cities are most easily interpreted when placed so that they are aligned with the environment they represent (i.e. so that the bottom of the YAH map corresponds to features of the depicted area closest to the observer, and its top corresponds to features furthest away from the observer). However, as the relationship between the map and the environment it depicts changes according to the map's rotation with respect to cardinal north, and it becomes misaligned with the actual environment, then YAH maps become more difficult to use. Levine and his colleagues demonstrated that an individual who studied an external representation of a simple pathway as illustrated in Figure 1 below, would store the memory as an image oriented in the same direction as it was learned (Levine, Jankovik & Palij, 1982).

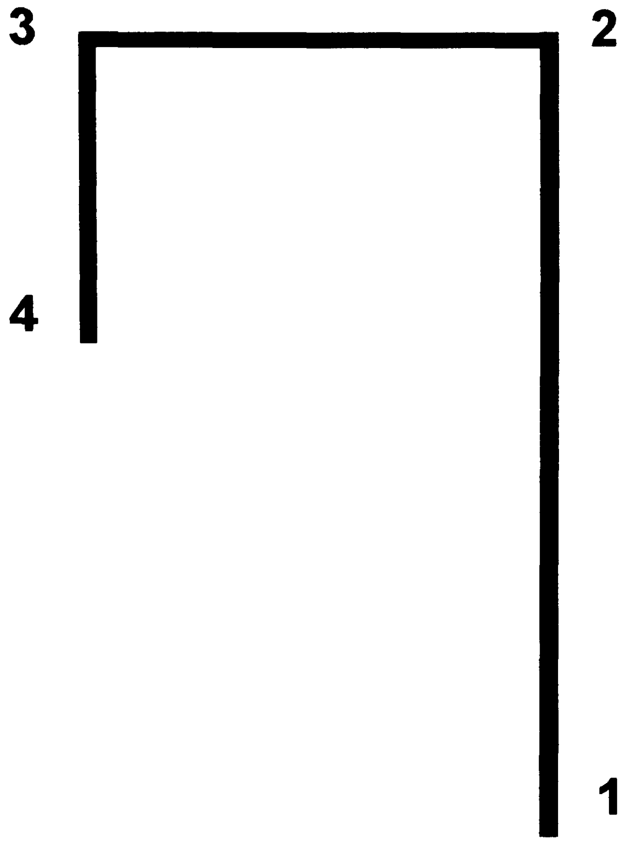


Figure 1. A map-like representation of a simple pathway (e.g. Levine et al., 1982).

An individual subsequently asked to imagine being positioned at Point 1 of the path with Point 2 in front of him or her would usually show little error and respond rapidly if asked to indicate the direction of Point 4. If asked to make the same judgement positioned at Point 2 facing Point 3, the judgement would be more difficult and take longer. If instructed to imagine him or herself at Point 2 with Point 1 in front, the task of indicating the direction of Point 4 would typically be most prone to error, and the judgement would take the most time. These three types of judgement are referred to as *aligned, misaligned* and *contra-aligned,* respectively (Levine et al., 1982), with the difference in performance accuracy and/or latency between these types of judgement described as an *alignment effect*. When the retrieval and use of spatial information that is linked to a particular orientation results in misaligned or contra-aligned judgements being less accurate or made more slowly than aligned judgements, the information is described as being encoded in an *orientation-dependent* manner (Presson & Hazelrigg, 1984).

In contrast to map learning, spatial information gained from a direct or primary interaction with the environment has been shown to be more flexibly used when making later orientation judgements. In a now classic study, Thorndyke & Hayes-Roth (1982) compared the performance of participants who had either actively explored the ground floor of an office building or learned its layout from a map. In later judgements, those participants who had learned through navigation appeared to have constructed orientation-free representations, in which spatial information was equally available irrespective of imagined orientation; the judgements of map learning participants, on the other hand, were biased in favour of the orientation in which the map had been learned. Evans and Pezdek (1980), speculated that this orientation-dependence of spatial representations derived from map learning is determined by the single viewpoint from which a map is usually studied, whereas in real-world exploration, multiple viewpoints are experienced and possibly integrated as an environment is explored; the resultant mental representation is therefore free of dependence upon a particular viewpoint to define subsequent orientation (see also Lloyd & Cammack, 1996; MacEachern, 1992).

Primary learning has also resulted in orientation-specific recall under some circumstances; for example, when participants have learned an environment directly, but under conditions where sensory information has been limited (e.g. Palij, Levine &

Kahan, 1984; Presson, DeLange & Hazelrigg, 1989), thereby reducing possible vestibular feedback. In addition, several procedural factors have been shown to influence the degree of orientation-specificity following perceptual learning, such as the degree of interaction with the environment (see McDonald & Pellegrino, 1993), the size of the information on display (Presson & Hazelrigg, 1984; Presson et al., 1989), and the size of the physical space (Presson et al., 1989). Presson et al. (1989, Experiment1), for example asked their participants to learn either small- (e.g. 40 x 40 cm) or large-scale (e.g. 4 m x 4 m) four point paths presented on the floor of a room from a single perspective. Following learning, participants were blindfolded then were walked or wheeled in a chair around the room in a manner that encouraged disorientation, before making orientation judgements based on their memories of the path. To make these judgements, the still-blindfolded participants were positioned in the actual location and in the facing direction required by the test question. These authors reported no reliable alignment effect for large-scale displays, but smaller displays were more likely to be encoded in an orientation-specific form.

However, more recently, Roskos-Ewoldsen, McNamara, Shelton and Carr (1998), in two experiments which investigated the relationship between layout size and orientation dependency, recorded orientation-specific encoding for both small- and large-scale spaces learned from four-point pathways (Experiment 1), and arrays of static objects (Experiment 2). In these experiments, the mental representations were similarly generated through experiencing a single perspective of the space, but blindfolded participants were tested while located either in the centre of the room (Experiment 1), or in an adjacent room (Experiment 2), rather than at the location required by the test question. Similarly, using a procedure based on that of Presson et al. (1989), Sholl and Nolin (1997) found that while a large spatial array might be a contributory factor, orientation-free learning from large displays only occurred when seated participants were tested in the same room, and were positioned at the imagined locations they had learned.

Collectively, these findings suggest that with respect to the mental representations derived from perceptual learning, general alignment effects are most likely to occur when the spatial display is small, when it is viewed from a single orientation, and when participants do not interact with, or physically explore the space either during learning or at test.

1.2. First-Perspective Alignment Encoding and Recall

A novel form of alignment effect has recently been described by Wilson, Tlauka and Wildbur (1999). These authors asked their participants to learn a layout from a description of a symmetrical three-path route (similar to that in Figure. 1), described as though they were viewing a map; subsequently, participants were asked to imagine themselves at a location on the route facing in a direction that was either aligned or contra-aligned with the orientation of the described map. Consistent with the results of studies in which participants have studied a physical map (e.g. Levine et al, 1982), errors in orientation, and the time taken to make judgements were lower when the test question described a scene that was aligned with the orientation of the described map, as though it had been seen. This outcome suggested that verbal and visuo-perceptual information are encoded in a common form (e.g. Bryant, 1992; Denis, 1996; Jackendoff & Landau, 1991; Talmay, 1983). However, when a similar route that comprised a return journey around city streets was described in a form that was designed to promote multiple imagined views from a ground level perspective, as would be experienced during real world exploration, participants preferentially encoded the route in an orientation aligned with the first part of the route. This 'first-perspective alignment' effect is surprising, because the route was not described in a way that should encourage encoding in a particular orientation, neither did participants see a map of the route. Of even greater interest is that the first-perspective alignment effect was not significantly replicated following real-time, visuo-perceptual exploration of three-dimensional computer-simulated environments (VEs), that had the same relative dimensions as the environments described in text (Wilson et al. 1999, Experiment 3C). Wilson et al. (1999) interpreted this result as inconsistent with a common form of encoding for text and perceptual representations of space, and cumulatively, their findings suggested that learning from text descriptions might not be isomorphic to perceptual learning (e.g. Mani & Johnson-Laird, 1982); text led to an orientation-dependent representation, whereas related perceptual learning did not.

As one account of their findings, Wilson et al. (1999) hypothesized that an important variable in determining the alignment of the spatial representation may be the type of secondary learning medium employed. Because VEs are primarily visual and interactive, and because spatial learning from exploration of simulations can transfer to equivalent real-world environments (e.g. Wilson, Foreman & Tlauka, 1997; Witmer, Bailey, Knerr & Parsons, 1996), spatial learning from virtual environments might result in knowledge that is closer to that acquired from primary learning than that acquired from other secondary learning media such as verbal descriptions. From this viewpoint, spatial learning from different sources may be continuous, across a secondary-primary continuum, rather than discrete in nature (Wilson, 1997). One implication of this hypothesis is that the first-perspective alignment effect should be minimal, if it occurs at all, following participants' exposure to a real route.

A second plausible account of the first-perspective alignment effect can be developed in terms of the reference system that participants use to encode the described environments. Spatial reference frames are commonly defined as egocentric, intrinsic and allocentric. In egocentric frames, locations are represented according to the particular perspective of the human observer, with respect to retinal coordinates, or his or her natural bodily axes (that is, head-feet, front-back and left-right), and updated as that person moves. For example, the spatial framework model (Franklin & Tversky, 1990), predicts that access to memories of real or imagined spatially distributed objects is dependent on the hierarchical organization of these axes. Asymmetries due to gravity render the head-feet axis dominant, so judgements on an 'above below' dimension can be made most rapidly. The front-back axis is the next most prominent because humans are more easily able to interact with objects in front of them than behind, due to forward dominance of the senses, and this dimension is also asymmetric. Access to objects to the left and right should be slowest and most error prone because this direction is not correlated with gravity, and does not have the degree of asymmetry found for front and back. Locations may also be represented in intrinsic reference frames in relation to the top, bottom, front, back, left and right of a specified location within an environment, and retrieved within a body-centred reference system that is dependent on the position which is physically taken or imagined by an observer (Easton & Sholl, 1995; Sholl & Nolin, 1997). Finally, in allocentric reference frames, locations are specified relative to stable or global features of an environment such as prominent landmarks, cardinal directions or gravity (Carlson, 2000).

Different reference frames may be responsible for different results in text-based experiments. For example, Taylor and Tversky (1992), developed descriptions of naturalistic environments that employed cardinal terms, and which were 'bordered' by large environmental landmarks; these authors found that when such allocentric cues were included, participants made equally fast and accurate inferences at test, whether or not the test perspective had been described in the text. In contrast, the text descriptions presented by Wilson et al. (1999) did not provide allocentric cues and their participants appear to have encoded the space using an egocentric frame of reference that was determined by the first orientation and the first part of the route described in the text. Reliance on these factors to define a reference frame may have been responsible for the noted first-perspective alignment effect in subsequent orientation judgements.

A third possible account of Wilson et al.'s (1999) findings is that first-perspective alignment encoding may share similarities to the well-researched 'primacy effect' in free recall tasks. Welch and Burnett (1924, as cited in Parkin, 2001), for example, noted that when participants were asked to recall a list of items in any order, their data produced a serial position curve; recall of the most recently presented items was best (recency effect), followed by recall of the initially presented items (primacy effect), and poorest recall for items in the middle of the list. When recall was delayed following presentation of the last word by asking participants to count backwards in threes, the recency effect was removed, but recall from the primacy and middle parts of the list were unaffected (Glanzer & Cunitz, 1966). However, in another experiment, following their participation in a series of free recall experiments, when participants were asked to remember as many words as they could from the whole series, words that were well remembered initially (i.e. those that comprised the recency effect) were remembered less well than items presented earlier in the list (Craik, 1970). If exploration of the return journeys used in Wilson et al.'s experiments is analogous to a list of words (e.g. in Figure 1: 1-2, 2-3, 3-4, 4-3, 3-2, 2-1) then participants may respond more accurately to 1-2 than 2-1 judgements (assuming that such an effect is not obscured by a recency effect) because 1-2 was encountered first in the list. By contrast, the sections 3-4 and 4-3 would be in the middle of this list and the poorest judgement performance would be predicted.

While proposed 'independently' above, the accounts of first-perspective alignment encoding explored here may be complementary in nature if considered with respect to cognitive load. According to Sweller (1988, 1994), cognitive load can be defined as the total amount of mental activity in short term memory at a given time, with the overall capacity of short term memory affected by intrinsic and extrinsic cognitive load. Intrinsic cognitive load is determined by the difficulty of the task, and therefore may lead to subsequent recall effects such as primacy and recency, whereas extrinsic cognitive load is determined by the learning medium used to present the information. Encoding from multiple perspectives described in text might involve greater cognitive load than from perception for a number of reasons: First, as encoding is via a single modality, extrinsic cognitive load may be greater in the verbal than the perceptual case because the former excludes any influence of kinaesthetic or vestibular information. Second, as Wilson et al. (1999) pointed out, intrinsic cognitive load might be lower in the construction of a mental representation defined by a single orientation, than one that requires encoding from multiple perspectives. Third, if the first-perspective alignment effect shares similarities to the primacy effect found in verbal free-recall tasks, better memory for the first segment of the route may also occur as a consequence of lowered intrinsic cognitive load. Therefore, the factor that links these accounts might be the extent to which the particular medium under study provides a reference system that simultaneously reduces intrinsic cognitive load, and subsequent reliance on the first part of the route in later orientation judgements.

1.3. Aims of Thesis and Overview of Experiments

At the outset of this research programme, a large body of experimental evidence suggested that the distinction between orientation-dependent and orientation-free effects reflects fundamental differences in encoding or retrieval of human spatial memories. The first-perspective alignment effect is a novel variation on more general alignment effects, and could imply differences between learning from text and learning from more perceptually based media. This possibility is of crucial importance to theories of spatial cognition, and forms the basis of the experiments reported here.

The six experiments presented in Chapter 2 directly address the research reported by Wilson et al. (1999) by examining the conditions under which the first-perspective alignment effect from text occurs, and the manipulations that might attenuate or eliminate this effect. In Chapter 3, Experiments 7 and 8 resolve a major discrepancy between recent studies that have recorded different first-perspective alignment outcomes following exploration of desktop virtual environments; Experiment 9 tests a prediction from these studies using text descriptions. Chapter 4 broadens the investigations of the first-perspective alignment effect from simple routes to object arrays, and from text and virtual environments to learning from primary experience. Following earlier text and VE experiments, five experiments are reported that seek evidence for first-perspective alignment encoding or retrieval following participants' exposure to real-world arrays of static objects. Finally, Chapter 5 presents a summary and theoretical interpretation of the overall research findings, and suggests future directions for their extension.

CHAPTER 2

Attenuating Factors in First-Perspective Alignment Encoding from Verbal Descriptions

Language often serves as a powerful and practical medium for spatial knowledge acquisition and exchange, and may be presented textually, for example in travel manuals, or verbally, by providing directions or describing scenes. There is considerable debate over the extent to which spatial memories that lack a perceptual basis possess properties that make them comparable to those derived from perception. The results of a large number of experimental studies have led some theorists to suggest that verbal and perceptual spatial information are encoded in a common form (e.g. Bryant, 1992; Denis, 1996; Jackendoff & Landau, 1992; Talmay, 1983). For example, language has been shown to effectively convey spatial relations and relative distances (e.g. Bryant, Tversky & Franklin, 1992; Denis & Cucode, 1989; Franklin & Tversky, 1990; Glenberg, Meyer & Lindem, 1987), and to facilitate the updating of relative positions and perspectives as new information becomes available (e.g. Bryant et al., 1992; Denis, Pazzaglia, Cornoldi & Bertolo, 1999; Franklin & Tversky, 1990; Franklin, Tversky & Coon, 1992; Glenberg et al., 1987; Morrow, Greenspan & Bower, 1987). However, other related experiments have demonstrated important differences in the characteristics of verbal and perceptual spatial representations with respect to spatial distance (Rinck, Hähnel, Bower & Glowalla, 1997), or when descriptions are of surface properties such as texture and colour rather than metric in nature (Brandimonte, 1999).

Language is also able to provide different types of perspective on a scene (Perrig & Kintsch, 1985), which Taylor and Tversky (1996) categorised as gaze, route or survey perspectives. In a gaze description, a scene is described from a single viewpoint, with objects located relative to one another from that viewpoint in terms of right, left, front and back (Ehrich & Koster, 1983). A route description is similar to real exploration, with the viewpoint updated from the changing perspective of someone physically travelling in an environment; relationships between objects are described as that person moves with respect to what is in front of and behind them, or to their left and right. Finally, in a survey, or map-like description, the observer's viewpoint is from a stationary perspective that is picture-like and from above or outside the scene, with objects described in relation to one another, or in terms of cardinal north, south, east and west (Taylor & Tversky, 1992).

Participants may switch perspectives when describing verbally depicted environments (Taylor & Tversky, 1996); however, Perrig and Kintsch (1985), found that inference judgements were made faster when the form of the description (route or survey) was compatible with the form of the test question. By contrast, Taylor and Tversky (1992) reported equally fast and accurate judgements from read and unread (i.e. inferred) perspectives, irrespective of whether the route was presented in survey or procedural terms. However, using procedural route descriptions that described all of the to-be-tested viewpoints (so inference was not even required at test), Wilson et al. (1999) consistently found that the most accurate and rapid orientation judgements at test were those aligned with the first part of the route description.

At the start of this research programme, a review of the available evidence suggested that exploration of real space typically leads to an orientation-free representation (Evans & Pezdek, 1980; Thorndyke & Hayes-Roth, 1982), therefore Experiment 1 initially examines factors that might determine the alignment of spatial memories when learning is from a text description in which all orientations are described.

Experiment 1

Early studies of learning derived from "You-Are-Here" (YAH) maps (Levine, 1982), provide important clues as to how participants directly walking a route might form a mental representation of that route. Levine proposed that when people view a fixed, vertical map, they interpret the upper part of the map as corresponding to features of the environment that are in front of their egocentric position. Levine termed this forward-up equivalence, and showed that the greater the degree of misalignment between the map and the environment it represents, the more difficult the map is to use.

Palij, Levine and Kahan (1984) extended this proposal in two experiments that investigated the alignment of spatial memories following learning by directly walking a path; these authors hypothesised that when a blindfolded participant experienced a journey from 'Point 1' to 'Point 2' (see Figure 1), he or she would later imagine Point 2 as being forward of, or above, Point 1. Therefore, the first segment of the route would be encoded egocentrically, with respect to the participant's body, with the remainder of the route encoded in relation to that first segment. In both experiments, blindfolded participants walked along five-point paths laid out on the floor of a room. In Experiment 1, they were asked to draw a line diagram of the path they had just experienced, and in Experiment 2 participants answered orientation questions that were aligned or contra-aligned with the first segment of the route. All participants in Experiment 1 drew their line diagrams with the first segment of the path depicted vertically, from the bottom to the top of the page, suggesting that they had applied forward-up equivalence when translating their first forward movement on the path to an upward line segment on paper. In Experiment 2, data from a new group of participants showed that orientation performance was more accurate and judgements were made faster when the test questions were aligned rather than contra-aligned with the first direction of travel. Taken together, these outcomes suggest that when blindfolded, participants generate orientation-specific spatial memories that are egocentrically defined with respect to their first forward movement on the path.

However, as suggested by Palij, et al. (1984), an alternative explanation for the results of their Experiment 1 is that a pre-existing bias in map drawing (i.e. that people might always draw a path diagram with its first segment depicted vertical and up) may have over-ridden participants' reliance on their mental images from which they drew their paths. To address this question, Palij et al. asked 95 undergraduate students to imagine and draw a picture of a five-point path; as an example, the students were shown a diagram of a sample path that had the first segment drawn horizontally from left to right, and which had been used in Experiments 1 and 2; a similar path is depicted in Figure 2.1.1 below.

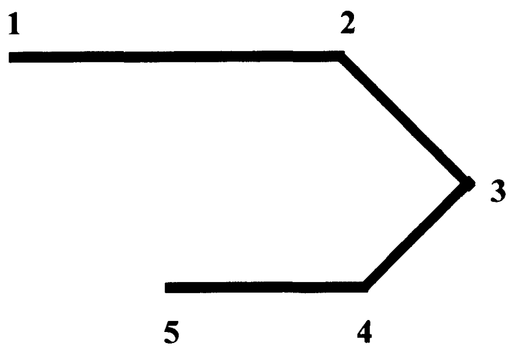


Figure 2.1.1. Diagram of a similar five-point pathway to that used by Palij et al. (1984), with the first segment (Points 1 - 2) depicted horizontally from left to right.

The resultant drawings were categorised into four groups according to the direction in which the first segment of the path was drawn: vertically from the bottom to the top of the page; vertically from the top to the bottom of the page; horizontally from left to right, or horizontally from right to left of the page. Analysis of these diagrams indicated that there was no preferred orientation in which the first segment of the path was depicted (the category with the greatest frequency was horizontal, drawn left to right as in the example provided) and Palij et al. (1984) concluded that there was no bias to drawing paths that could have influenced participants in their experiment.

However, at least two factors could potentially influence the orientation in which map-like diagrams are depicted. First, it may be that participants find it more difficult to imagine a pathway that comprises a series of relationships between abstract points, than one that comprises relationships between discrete objects or locations, in a manner that is other than egocentric. Second, the fundamental 'north-up' principle of cartographic map learning is taught from early childhood, and used as an indicator of geographic ability (Boardman, 1983, 1989, 1990), and environmental spatial knowledge acquisition (Bluestein & Acredolo, 1979; Blades & Spencer, 1986, 1990; Presson, 1982). It has been recently speculated that map learning and cognitive development may not only go hand-in-hand, but also that our understanding of maps and the way they are arranged may affect the way in which we understand and mentally represent spatial information (Uttal, 2000). It could be that either or both of these factors may have biased the map drawing found by Palij et al. (1984), and that this effect was obscured by the presentation of a sample diagram.

Nonetheless, the finding of forward-up equivalence in real-world spatial learning has important connotations for those spatial memories that are derived from text descriptions. In text, participants can only infer from what is described, and in the descriptions used by Wilson et al. (1999), initial orientation was described as 'ahead' under all conditions. If forward-up equivalence also occurs following learning from text, this factor may account for participants' construction of memories that appeared to be egocentrically aligned with the first part of the route description in their studies, with the remainder of the route encoded with respect to that first segment.

Experiment 1 was designed in part, as an extension of the map-drawing task used by Palij, et al. (1984), with the principle aim of investigating whether the forward-up equivalence found for map and walk-generated learning also applied when learning was from text descriptions and no example was provided. A comparison was made between two versions of a three-path walk that involved 90° turns, described as internal to a large open room. In one description, the walk was described as between sequentially numbered points marked on the floor of the room; in the second, the walk was between every-day objects laid out on the floor of the room. No initial orientation was described in either version of the description. After reading, and without referring back to the description, participants were asked to draw a line diagram of their remembered route. In line with Palij et al., it was hypothesised that if forward-up equivalence occurs following participants' reading a very short description of a simple three-path route described as internal to a large open room, diagrams should be preferentially drawn with the first segment of the route depicted vertically from the bottom to the top of the page. Equivalent frequencies between four categories that reflected the direction in which the first segment of the path was drawn would indicate no preferred direction in spatial memory and no general bias in map drawing.

Method

Design

Participants read a description of a three-path route that described a walk between four locations in a large open room. The between-participants independent variable was whether the locations were described as a series of numbered points marked on the floor of the room, or whether the locations were described as objects laid out on the floor of the room. The dependent variable was the direction in which the first segment of the walk was depicted between four categories: vertical from the bottom to the top of the page, vertical from the top to the bottom of the page, horizontal from right to left, or horizontal from left to right.

Participants

The participants were 60 undergraduates from the University of Leicester, UK, of whom ten were male. They had a mean age of 19.2 years (range: 18-21), and all participants received credit towards the fulfilment of a first year practical course requirement.

Materials and Procedure

Four versions of a description of a walk within a large open room that involved 90° turns were prepared; these were adapted from one of the text-route descriptions used by Wilson et al. (1999, Experiments 2 – 3B), and comprised four locations (objects or numbered points), joined by three paths. A plan diagram of this route is illustrated in Figure 2.1.2.

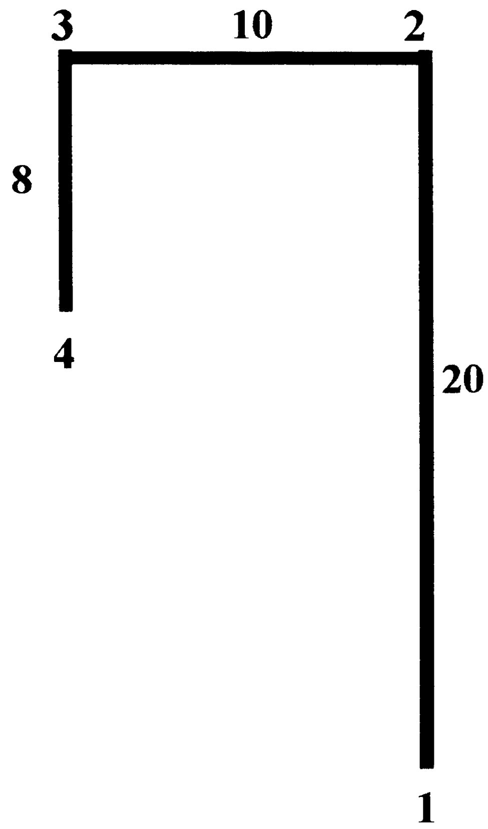


Figure 2.1.2. Plan view (not to scale) of the three-path walk used in Experiment 1, illustrating the relative distances (described in metres) between four locations (1, 2, 3 and 4) on the route.

Participants were randomly allocated to two equal groups. For group 'points' the locations on the route were described as numbered points from 1 – 4 (as in Figure 2.1.2). For group 'objects,' the locations were described as every-day objects; with respect to Figure 2.1.2 these were: 1 = Cooker, 2 = Table, 3 = Chair, 4 = Filing Cabinet. For half the participants in each of these groups, the start-point of the walk was described as from Cooker to Table (or 1-2 in Figure 2.1.2, whereas for the remaining half of participants, the start-point was described as Filing Cabinet to Chair (or 4-3 in Figure 2.1.2).

For group 'points,' and with the start-point described from '1' in Figure 2.1.2, the text read as follows:

> Imagine that you are standing in the room at Point 1. Twenty metres from where you are standing is Point 2. Imagine walking from Point 1 to Point 2. At Point 2 you turn to face 90 degrees to your left. Ten metres away is Point 3. You walk from Point 2 to Point 3, and at Point 3 you turn to face 90 degrees to your left. Eight metres away is Point 4. Imagine walking to Point 4.

For group 'objects' and with the start-point described as from '4' in Figure 2.1.2, the text read:

> Imagine that you are standing in the room next to a Filing Cabinet. Eight metres from where you are standing is a Chair. Imagine walking from the Filing Cabinet to the Chair. At the Chair, you turn to face 90 degrees to your right. Ten metres away is a Table. You walk from the Chair to the Table, and at the Table you turn to face 90 degrees to your right. Twenty metres away is a Filing Cabinet. Imagine walking to the Filing Cabinet.

Participants were tested in six groups of ten, and following preliminary instructions that described its purpose, the experiment was entirely presented in text-format, printed on two sides of a single A4 sheet. Copies of these sheets are included in Appendix A, labelled according to group (i.e. Points, 1-2, Points 4-3; Objects, 1- 2, Objects 4-3).

Participants were instructed to read the text description at least three times, and to "... try to imagine that you are actually walking between these (points/objects), visualising the journey as clearly as possible from a ground level perspective. When you have finished reading and you are sure that you have a really clear memory of the route... please turn this page over..."

Provided on the back of the same sheet were spaces for participants to indicate their age and sex, proceeded by the following instructions: "Without referring back to the description, draw a line diagram of your remembered route in the space below. Please label the diagram clearly with the (numbers of the points/names of the objects) and lines between them to show the route that you imagined walking."

Results and Discussion

An alpha level of $p < .05$ was adopted for all the analyses reported in this series.

The 60 line diagrams were divided into four categories reflecting the direction in which the first segment of the route that participants read was drawn: vertical from the bottom to the top of the page, vertical from the top to the bottom of the page, horizontal from left to right, or right to left across the page. The frequencies in each of these categories are illustrated in Figure 2.1.3.

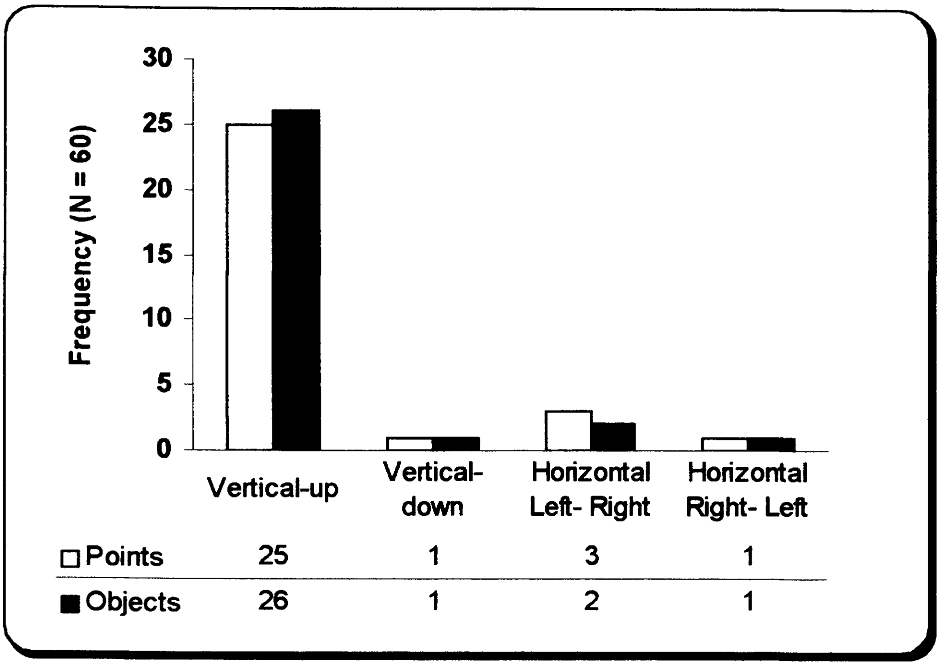


Figure 2.1.3. Experiment 1: Summary of the frequencies in which participants depicted the direction of the first segment of the path described in the text.

The overwhelming majority of participants (51 in total) drew the first segment of the path vertically, from the bottom to the top of the page. In view of the small number of responses for the remaining three categories, these were combined for between-group comparison, resulting in two overall categories: 'vertical up' and 'other directions.' No differences were found between the groups in the frequency of depiction of the first segment of the path (Fisher's exact probability = 1.0, two-tailed test). Chi-square analyses of the frequencies for each group separately found a statistically significant difference between the observed and expected frequencies for the four categories of path drawing in both groups: points ($A^2 = 54.80$, df = 3, $p < .001$); objects ($A^2 = 60.93$, df = 3, $p < .001$).

The results of Experiment 1 extend the findings of Palij et al. (1984, Experiment 1), in that, just as when learning is from directly walking a path, when asked to draw a map, participants apply forward-up equivalence in the construction of memories of a simple three-segment path learned from a text description. This finding held, irrespective of whether the description was of numbered points, or of a less abstract arrangement of common objects arranged on the floor of a room.

Important to note is that in the present experiment, participants were neither shown a diagram of a similar pathway to those described in text, nor was an initial orientation included in any of the descriptions used. The spatial memories derived from text descriptions were, in contrast to the results of Palij et al., characterized by a strong bias toward drawing of the initial segment of the path from the bottom to the top of the page. This orientation appears to be dominant in spatial memory, and implies that the mental representations of environments derived from text descriptions may be encoded with respect to the participant's body, and therefore share properties with the 'north-up' principle of cartographic map learning that is taught from early childhood (e.g. Boardman, 1990). This finding of a dominant and preferred orientation in spatial memory suggests that the mental representations derived from text descriptions appear to be organized within an egocentric reference system that works on the basis of a forward-up equivalent principle.

The evidence for egocentric encoding in Experiment 1 is consistent with the results of a large number of experiments in which participants have been presented with text descriptions of a single protagonist surrounded by a number of objects (Bryant, Tversky & Franklin, 1992; Franklin, Tversky & Coon, 1992; Tversky, Franklin, Taylor & Bryant, 1994). These authors have shown that readers preferentially adopt the perspective of the protagonist; that is, readers preferentially imagine their position and orientation with respect to the described configuration egocentrically, in the same way as these are described for the protagonist. However, an important difference between these experiments and the text-based experiments of Wilson et al. (1999), is that in the former, configurations of objects are described in relation to a stationary observer. In Wilson et al.'s experiments, once the protagonist starts to move along the route, and reorients by making left- or right-hand turns, egocentric position must be updated with respect to the configuration. Similarly, the readers' mental representation of themselves in relation to the configuration needs to be updated. If spatial memories are encoded within an egocentric reference system, this updating of position and orientation may incur high cognitive resources both during reading and when participants are given later tests of orientation based on their memories of the route.

One way in which the cognitive effort required for the updating of an egocentric mental representation could be reduced, is to introduce an allocentric frame of reference into the text (cf. Hörnig, Claus and Eyferth, 2000). The updating incurred by egocentric reorientation would not be required if locations are specified in relation to an allocentric reference frame because this frame is defined by stable features of an environment. In Wilson et al.'s (1999) experiments, a first perspective alignment effect may have consistently occurred from text because only the route itself was described; therefore, encoding could only be within an egocentric frame. By contrast, in the VE experiment reported by Wilson et al., features external to the route were visible, and the first-perspective effect was attenuated. Therefore, Experiment 2 provided an initial investigation of the influence on first-perspective encoding of including allocentric information in a text-route description.

Experiment 2

Allocentric frames of reference may play an important role in defining the alignment of spatial memories learned from text descriptions. Taylor and Tversky (1992) for example, developed descriptions of naturalistic environments written from what they described as either survey or route perspectives. Following reading, participants were provided with six statements about a location within the described environment relative to a suggested orientation that was not previously specified in the text. Three statements were true and the remaining three were false. These authors found that participants were able to make equally fast and accurate inferences from both described and inferred perspectives, irrespective of whether the text they had studied was a survey or procedural route description. This outcome contrasts to that of Wilson et al. (1999), who, in their orientation task, consistently found first-perspective alignment effects following participants' exposure to procedural route descriptions.

A possible reason for this inconsistency is the difference in text descriptions. Taylor and Tversky's (1992) route descriptions, in both the survey and procedural versions, provided allocentric information in describing the location of a fictitious town ('Etna') or a convention centre. For example, in one of the survey descriptions, 'Etna' was described as "...bordered by four major landmarks: the White Mountains, the White River, the River Highway, and Mountain Rd. The northern border is made up of the White Mountain Range..." (p.268). The text descriptions used by Wilson et al. (1999) did not provide landmark information, which may otherwise have facilitated allocentric encoding. Therefore, this factor may account for the difference in findings between participants who constructed memories that were preferentially aligned with the first part of the route description, and those of Taylor and Tversky (1992), whose participants were able to make accurate judgements even from inferred perspectives.

Landmarks are most commonly thought of as significant features of an environment that stand out from other aspects of that environment with respect to their size and overall prominence. In perceptual space, landmarks are central to how people organize information, and the ability to distinguish landmarks has been seen in children as young as six months (Acredolo & Evans, 1980; Rieser, 1975). In their theory of spatial knowledge acquisition, Siegel and White (1975) suggest that knowledge about spaces begins by forming and recognizing landmarks; by linking these together, knowledge about routes is acquired, and by processing route knowledge, survey knowledge can be developed. An array of landmarks can also provide at least three different sources of information that can help an individual to form a mental representation of an environment including non-spatial information such as colour, metric information (i.e. distance and orientation), and non-metric information such as proximity and relationships such as left-right and clockwise-anticlockwise (Waller, Loomis, Golledge & Beall, 2002). Landmarks can also help to anchor other spatial information within a coherent layout, for example in dividing a geographic area, or because their perceptual salience allows the description of other aspects of the same environment (e.g. streets, buildings) in relation to them (Golledge, 1999). Therefore, in Experiment 2, to investigate the role of allocentric frames of reference in defining the alignment of spatial memories derived from text, environmental information was provided in the form of four large, salient landmarks described as surrounding an internal route.

However, a major problem in introducing an allocentric frame of reference in text descriptions of a route is that the complexity of the information in the text could lead to an increase in intrinsic cognitive load. Even when using simple three-path routes with a distinctive building or object at each intersection, participants frequently report difficulty in learning; hence, substantially increasing the amount of to-be-remembered information in a single text description might obscure any important effects.

Rather than trying to reduce intrinsic cognitive load, an alternative approach, that of expanding working memory has been shown to facilitate learning (Baddeley, 1992; Pavio, 1990), and a number of experiments have demonstrated that presenting information via more than one medium can lead to enhanced learning (Jeung, Chandler & Sweller, 1997; Mousavi, Low & Sweller, 1995; Tindall-Ford, Chandler & Sweller, 1997). For example, Schelender, Peters and Weinhöfer (2002), have recently shown that participants were better able to navigate a virtual environment (VE) when additional cues (a map or textual information), were provided by comparison to when no additional cues were provided.

Following the rationale of expanding working memory described above, it was anticipated that the presentation of environmental information in a virtual environment could be used to establish an allocentric frame, which could subsequently be incorporated into text-based spatial information, without excessively increasing cognitive load. Experiment 2 was planned as a preliminary investigation of whether first-perspective effects are evident when an external frame of reference comprising large, salient landmarks is provided in a text description.

All participants initially explored a VE that comprised four large landmarks, and then answered five orientation test questions based on their memories of the VE. In a second learning phase, participants read a version of a text route description based on one of those used by Wilson et al. (1999), in which the route was described as surrounded by the environmental landmarks previously learned in the VE. Following completion of both learning phases, all participants were asked to make eight orientation judgements while they imagined themselves to be aligned and 180° with the first part of the internal route. To extend Wilson et al's earlier investigations, in which all the judgements were based on correct angles that were greater than 90°, data for judgements that were less than, and greater than 90° were separately recorded (i.e. front- and back-facing with respect to the imagined orientation at test). In addition, aligned and contra-aligned errors and latencies were examined separately on the first and last sections of the route. Should a first-perspective alignment effect be evident in the error and/or latency data from the first, but not the second part of the route, this alignment effect may share similarities with the well-known 'primacy' effect in list learning (e.g. Glanzer & Cunitz, 1966). If exploration of the routes used in the present experiment is encoded as a list of street views, similar to a list of words (e.g. in the right-hand panel of Figure 2.2.2 [p.32]: A-B, B-C, C-D, D-C, C-B, B-A), then participants may respond more accurately on A-B than B-A judgements because A-B was encountered first in the list (assuming that such an effect is not obscured by a recency effect). However, views C-D and D-C would be in the middle of this list, and should therefore not differ to a great extent.

To anticipate the results of the present experiment, with few exceptions, participants experienced difficulty in encoding the spatial information provided by the VE, and the experiment was subsequently modified (see Experiments 3 & 4). However, as the implications of this outcome are important with respect to learning about locations from both VEs and text descriptions, the methodology section, results, and their interpretation are reported below.

Method

Design

In a repeated-measures design, all participants initially explored a VE that comprised four large landmarks, and then answered five orientation test questions based on their memories of the VE. In a second learning phase, participants read a description of a return-walk around a symmetrical three-path route, in which all turns were 90°, with junctions marked by a distinctive building of the type usually found in a modern city; the text described this route as surrounded by the four environmental landmarks previously learned in the VE. Following completion of both learning phases, participants made two orientation judgements, one from an aligned and one from a contra-aligned perspective from each of the four building locations described on the internal route. The dependent variables of principal interest were: the absolute orientation errors in degrees, the accuracy of straight-line distance estimates between the imagined test location and the target location, and the time in seconds taken to make these judgements.

Participants

The participants were 15 female and 5 male undergraduates from the University of Leicester, UK who had a mean age of 20.3 years (range: 19 - 25 years). All received credit towards the fulfilment of a second-year practical course requirement.

Apparatus and Materials

The computer-simulated three-dimensional environment was created using the Superscape Virtual Reality Toolkit, and was presented on an Intel Pentium computer with SVGA graphics, presented on a 17-inch monitor. Movement was programmed at a fast walking pace so that a distance of 50m could be traversed in 25s; a 360° rotation was effected in 15s. The VE comprised four landmarks positioned at the corners of an invisible square, located within a flat, open space that continued to infinity. The sky was blue and the ground was light green.

Assuming average eye level to be approximately 170cm, the subjective length of each side of the invisible square was approximately 115m. In a clockwise order, the landmarks at the corners of the square were: a tower (height = 13.5m, width = 6.2m, depth = 6.2m), a large rock (height = 5.0m, width = 9.7m, depth = 5.7m), a tree (height = 13.5m, width = 7.5m, depth = 7.5m), and a pylon structure (height = 10.5m, width = 4.3m, depth = 4.3m). The diagonal of the square (i.e. rock to pylon structure and tower to tree) was 162m. Halfway along the diagonal (in the centre of the square) was a tree stump (height = 2.5m, width = 1.3m, depth = 1.3m), which was situated 81m from each landmark; the initial viewpoint was 1.8m from the tree stump. Screen captures from the VE are presented in Figure 2.2.1.

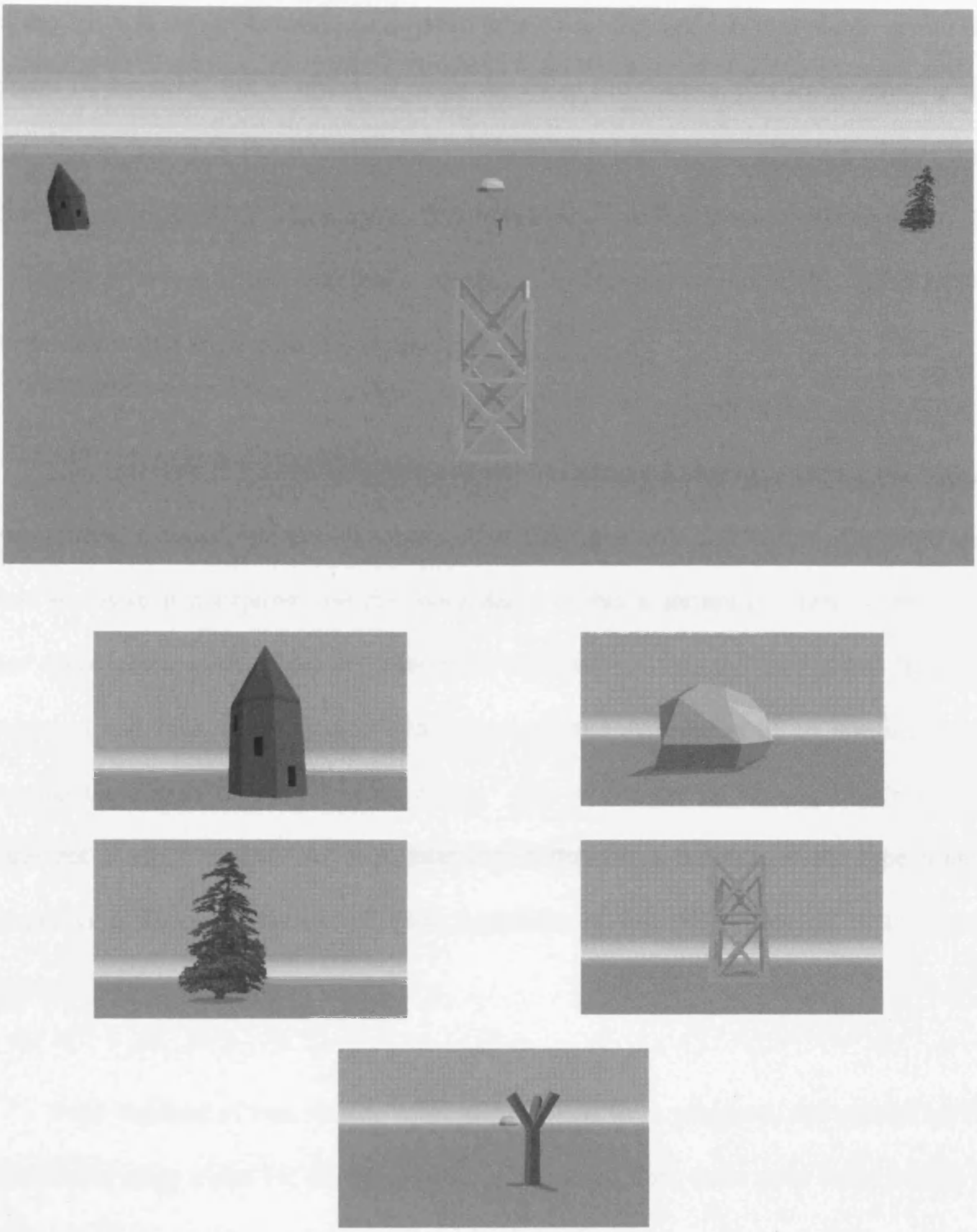


Figure 2.2.1. Grey-scale reproductions of colour screen captures from the virtual environment used in Experiment 2: overview of the array of landmarks (upper panel), individual captures of the four distal landmarks (tower, rock, tree, pylon) - centre panel, and the tree stump used as the centre point of the array (lower panel).

Written instructions that preceded participants' exploration of the VE described the purpose of the experiment, and provided the following information: "...Your position in the VE will be at the centre of an open area of countryside. A tree stump marks the centre of the area, and at equal 80 metre distances from where you are standing at the tree stump, are four large landmarks…" These instructions also informed participants that following their VE exploration, they would be "…asked some questions about the positions of some of the landmarks in relation to the tree stump at the centre of the environment and in relation to one another."

The instructions for the text-phase of the experiment included: "In this part of the experiment, I would like you to imagine that you have travelled back to the same area that you have just explored on the computer, and that a shopping centre development has taken place. All of the landmarks are still present, but the tree stump has been removed and built over. I shall hand you a printed description of an imagined walk around the streets of the shopping centre. The streets are of varying length, and all intersect at right angles. At each intersection there is a building of the type usually found in a shopping centre…" (See Appendix A for full copies of both sets of instructions).

Four versions of two written route descriptions were prepared, and printed on A4 size sheets using a size 16, double-spaced, emboldened font; these were based on one of the original descriptions used by Wilson et al. (1999), and as depicted in Figure 2.2.2, described a return-walk around an arrangement of streets and distinctive buildings arranged in an inverted U-shape; the buildings were described as a 'Bus Terminus,' 'McDonald's,' a 'Book Shop' and a 'Health Food Store.' While the names of the buildings remained constant across the two descriptions, these were counterbalanced according to the number of right and left turns, and which segment of the route (first or last) was the longer.

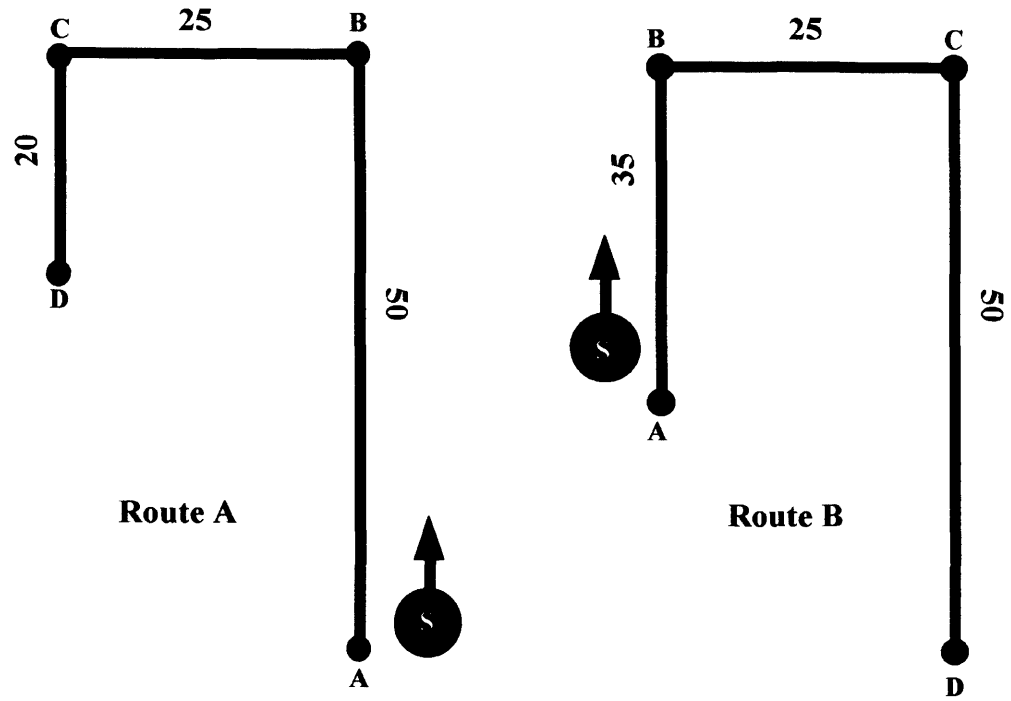


Figure 2.2.2: Plan diagrams (not to scale) of the two versions of the route used in Experiment 2. Illustrated are the positions of the target buildings (ABCD), the relative distances in metres between them, and the start position described in the text (large circle and arrow).

The four versions of each of the route descriptions differed according to the initial orientation that was described in the text as facing one of the landmarks previously explored in the VE (i.e. rock, tree, tower or pylon). For example, when initial orientation was aligned with the VE depiction of the rock, the 'Route A' description above read:

> Imagine that you have travelled back to the same area now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump first stood. Looking along the path from the Bus Terminus, you can see the large rock in the distance ahead. The tall fir tree is on your right-hand side, and when you turn, you see that the pylon is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends fifty metres in the direction of the large rock. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' The large rock is now on your right-hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second hand Book Shop. You turn left at the Book Shop and walk another twenty metres until you come to a Health Food Store. As you walk towards the Health Food Store you can see the castle tower in the distance ahead and to your right.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back towards the Book Shop. The castle tower is now on your left and slightly behind you. Imagine that you walk the twenty metres back to the Book Shop and turn right. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's and turn right so that you are now facing towards the Bus Terminus and the large rock is behind you.

Imagine that you walk the fifty metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the tall fir tree to your left and the pylon in the distance in front of you.

Each version of both descriptions similarly included egocentric information with respect to the landmarks explored in the VE that was adjusted according to the initial orientation described. Copies of all of the route descriptions can be found in Appendix B.

To make the angle estimates, participants rotated a black pointed arm around a 16cm diameter, white circular dial that was marked from 0 to 360 degrees in five-degree intervals. Response times were measured using a hand held stopwatch.

Procedure

Participants were tested individually, and all took part in both the VE and text phases of the experiment. Following clarification of the preliminary instructions where required, use of the 360° protractor to make orientation judgements was demonstrated.

The VE was presented with the view set at 1.8 m from the tree stump, and only one of the external landmarks was visible on the screen. The experimenter asked participants to freely explore the environment using the keyboard arrow keys, and to indicate when they had a clear representation of the arrangement of the landmarks and the relationships between them. Between participants, the order of presentation of the first perspective in the VE was counterbalanced according to the alignment between the tree stump and one of the four external landmarks. When participants indicated that they had completed their exploration of the test area, the experimenter asked them to return to their start point and to rotate the view through 360°. The computer screen was then made blank, and participants answered five orientation and distance test questions based on their memories of the VE; for ease of reference, the arrangement of the landmarks is illustrated in Figure 2.2.3.

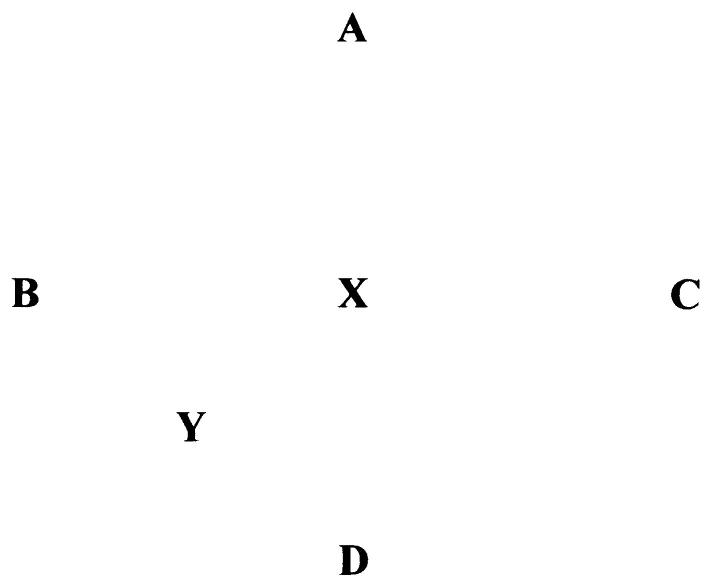


Figure 2.2.3. Plan diagram (not to scale) of the arrangement of landmarks used in the VE phase of Experiment 2, where ABCD represent the array of external landmarks, X represents the central point in the array, and Y represents the mid-point between B and D.

With respect to Figure 2.2.3, a practice question asked for angle and distance judgements when the imagined test location was at X, facing toward A, and the target, D was directly behind the imagined test location. The remaining four questions required orientation and distance estimates made from other imagined positions within the array of landmarks; for two of these questions, the target was to the left of participants' imagined location in the VE (i.e. at Y, facing X, point to A; at C, D behind, point to X). For the remaining two questions, the target was to the right of this position. (i.e. at X facing A, point to C; at B facing X, point to D). With the exception of the practice question, which was always presented first, the order of the test questions was counterbalanced between participants. For each direction judgement, participants were asked to imagine that the black dot in the centre of the 360° protractor indicated their imagined location, and the zero degree point illustrated imagined facing direction.

On completion of the VE learning phase, participants were handed the instructions for the text phase of the experiment. The two versions of the route (left and right turns) were presented between participants in a counterbalanced order. Participants were verbally instructed to read through the route description "… as many times as you like, but at least 3 times…" and to verbally indicate when they had a clear memory of the route. The names of the buildings encountered at each intersection on the described route were identical (i.e. outward journey: Bus Terminus – 'McDonald's' – Book Shop – Health Food Store; return journey: Health Food Store – Book Shop – 'McDonald's' – Bus Terminus); however, for half the participants, the route involved left-hand turns, whereas for the remaining half of participants, the route involved right-hand turns. Counterbalanced between participants, initial orientation was defined by the alignment of the first segment of the internal route with one of the landmarks previously learned in the VE (A, B, C or D in Figure 2.2.3.).

Immediately following each text description, participants answered eight alignment test questions based on their memories of the route (four aligned and four 180°contra-aligned with the first section of the route description). All questions asked participants to indicate the direction of one of the buildings described on the internal route while imagining themselves located at a second building; for example: "Imagine that you are at the Bus Terminus and that 'McDonald's' is in front of you. Point out the direction of the Book Shop." The test questions were counterbalanced for alignment (aligned, contra-aligned), facing orientation (the test locality being in front of or behind the imagined test location), and the section of the route (first or last) from which the judgement was made. The mean absolute correct angle (rounded to the nearest 5°) for the test questions was approximately 90°, with the means for front-facing aligned and contra-aligned questions, and back-facing aligned and contra-aligned questions being 25° and 145° respectively. The order of alignment test questions was arranged according to a Latin Square, which was counterbalanced across the above factors.

Following each orientation measure, participants were asked to estimate the straight-line distance, in metres, from their imagined building location to the target building. A complete list of the alignment and distance test questions for the VE and text phases of the experiment are included in Appendix C.

At the conclusion of testing, participants were asked to complete a questionnaire designed to reveal their experiences at the encoding (reading) and retrieval (alignment and distance judgements) stages of the experiment (see Appendix B); specifically whether they had (1) encoded and (2) retrieved the route from a ground level or overhead perspective. The response options for both questions were:

a) Visualised everything through my own eyes from a ground level, as though I was actually walking.

b) Visualised myself walking from a ground level perspective, but imagined this from outside myself.

c) Visualised myself walking along the streets as though I was looking from above.

d) Visualised just the streets and locations, not myself

e) I was not aware of any internal visual images

To ensure that any effects on the final (text) alignment test judgements were due to the inclusion of an allocentric frame of reference, it was important to establish that the arrangement of landmarks had been successfully encoded; therefore, it was planned that only the data from those participants who had recorded an overall error score of less than 35° following learning from the VE would be included in the final analyses. After testing the first 10 participants, the angle error data from the VE phase of the experiment were collated. It was apparent that participants experienced difficulty in encoding the array of landmarks in the VE; specifically, the locations of targets to their right and left with respect to their imagined orientation at test. For the next 10 participants, additional time was allocated to exploring the VE as follows: following the free-exploration of the VE described above, and when participants had indicated they had a clear memory of the arrangement of landmarks, the experimenter asked each participant to travel from the centre of the array to each landmark in turn (named by the experimenter in a counterbalanced order) and back to the centre point of the array. Participants were then asked to travel in a clockwise direction between the four external landmarks (ABCD in Figure 2.2.3) and return to the centre of the array, finally to repeat this latter exploration in an anti-clockwise direction before returning the centre of the array. The two sets of data (VE and text) from the first and second groups of 10 participants were then combined for subsequent analysis.

Results and Discussion

Raw data tables for Experiments 2-14 are included in Appendix D.

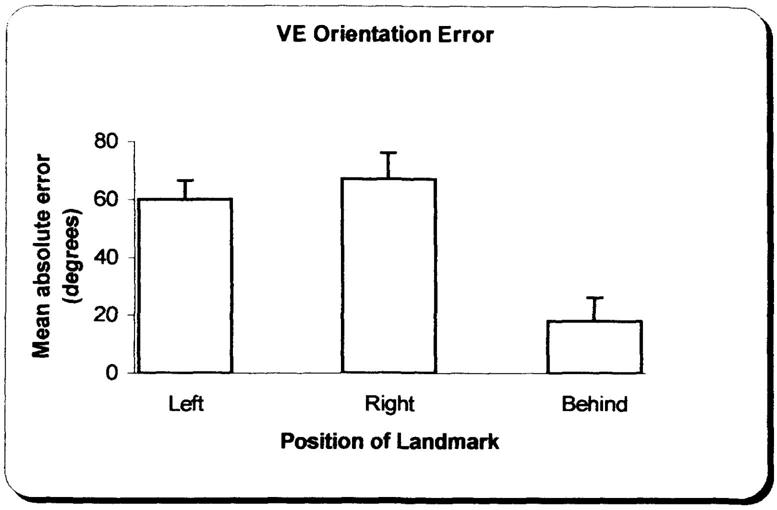
Sex was not included as a factor in any of the analyses below as there were too few men to make meaningful comparisons. In this, and all subsequent experiments, distance estimates were requested and analysed in both raw form and when converted to account for individual differences in baseline estimates. However, neither of these analyses, nor analysis of the latency to make distance judgements revealed a consistent or interesting pattern of effects; these data are therefore not reported or discussed in any experiment.

VE Data

Angle of error scores were derived from the participants' estimated angles by subtracting the estimates from the true angles and taking the unsigned value. Error data from the two left- and two right-facing orientation judgements for each participant were individually averaged for the following analyses, giving three judgement types: left, right and behind, with respect to the position of the target landmark in relation to participants' imagined facing direction within the VE at test. Descriptive statistics for these and the related latency data are presented below in Table 2.2.1; the respective means are illustrated in Figure 2.2.4.

Table 2.2.1
Descriptive Statistics for Orientation Judgements (tabled in degrees) to Targets that were to the Left, Right and Behind Participants' Imagined Facing Direction within the VE at Test, and the Times (tabled in seconds) taken to make these Judgements.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Orientation Error							
Left	20	20.00	100.00	60.00	29.58	46.16	73.84
Right	20	2.50	157.50	67.00	41.51	47.57	86.43
Behind	20	0.00	90.00	18.00	36.94	0.71	35.29
Orientation Latency							
Left	20	2.24	21.57	11.37	5.42	8.83	13.91
Right	20	1.71	26.12	8.87	7.23	5.49	12.25
Behind	20	1.27	20.18	6.86	4.70	4.66	9.06



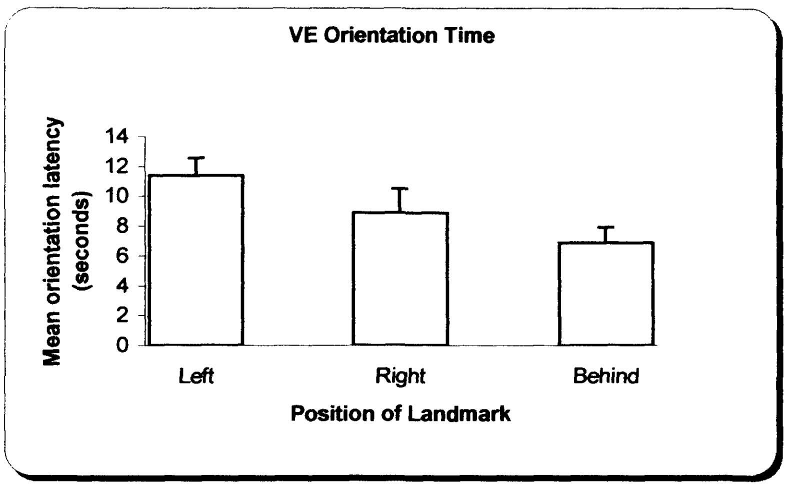


Figure 2.2.4. Experiment 2 (VE): Mean absolute error (upper panel) and latency (lower panel) scores for orientation judgements to target locations that were to the left, right and behind participants' imagined facing direction at test. Error bars represent one estimated standard error above the mean.

The mean absolute error scores for orientation judgements following learning from the VE, and the time taken to make these judgements were analysed individually using 2 x 3 mixed Analyses of Variance (ANOVA); in each case, the between-participants factor was exploration (free exploration, free exploration + guided exploration), and the within-participant factor was 'direction' (test locations that were either to the left, right or behind the imagined facing direction at test).

Analysis of the absolute orientation errors found statistically significant main effects of exploration, $F(1,18) = 4.64$, $MSE = 1315.26$, $p = .05$ (partial $\eta^2 = .21$), and direction, $F(2,36) = 11.61$, $MSE = 1219.12$ (Greenhouse-Geisser adjustment), $p < .001$ (partial $\eta^2 = .39$), however the interaction between these factors did not approach significance ($p > .4$). As can be seen in the upper panel of Figure 2.2.4, the direction effect reflects lower overall errors for targets that were behind participants' imagined facing direction at test ($M = 18°$) than targets to the left or right of their facing direction (Ms = 60 and 67° respectively); subsequent paired samples analyses (Bonferroni correction applied) revealed substantially large and significant differences between the means of left and behind judgements $t(19) = 3.67$, $SE = 11.44$, $p = .002$ ($\eta^2 = .42$) and right and behind judgements, $t(19) = 4.66$, $SE = 10.53$, $p < .001$, ($\eta^2 = .53$); no difference was found between the means of left and right judgements ($p > .5$). The exploration effect reflects lower overall errors when additional, guided exploration of the VE was included in the procedure compared to when participants explored the VE freely (Ms 38 and 58° respectively).

The analysis of the mean latencies to make VE orientation judgements (illustrated in the lower panel of Figure 2.2.4), detected a main effect of direction, $F(2, 27) = 5.50$, $MSE = 25.20$ (Greenhouse-Geisser adjustment), $p = .02$ (partial $\eta^2 = .23$) that reflects faster overall responses to targets that were behind (M = 7s) rather than to the left or right of participants imagined facing direction at test (Ms = 11 and 9s respectively). The analysis also found a statistically significant direction x exploration interaction, $F(2, 27) = 3.77$, $MSE = 95.06$ (Greenhouse-Geisser adjustment), $p = .05$ (partial $\eta^2 = .17$). The main effect of group was not significant ($p > .6$).

The significant interaction was examined by separately analysing the latencies for each 'exploration' sub-group separately. For the 'free exploration' group, no differences were apparent between the means for left, right and behind orientation judgements ($F < .15$); for the group who were provided with additional 'guided exploration' time during learning, the analysis found a significant effect for time, $F(2,16) = 7.08$, $MSE = 21.71$ (Greenhouse-Geisser adjustment), $p = .008$ (partial $\eta^2 = .44$). Paired samples analyses found a significant difference between the means of left and behind, $t(9) = 4.49$, $SE = 1.51$, $p = .002$ ($\eta^2 = .69$), and right and behind latencies $t(9) = 2.68$, $SE = 2.14$, $p = .03$ ($\eta^2 = .44$]); no difference was apparent between the means of right and left latencies ($p > .6$).

Interesting to note is the effect of additional training within the VE in the present experiment. When participants freely explored the VE, overall orientation errors were greater than when additional exploration guided by the experimenter was provided (*M*s 58 and 38° respectively). However, the direction x exploration interaction that was evident in the latency data indicated that the advantage for 'behind' judgements was only apparent when participants had undergone additional training within the VE. Taken together, these outcomes suggest that participants processed more information when additional VE training was provided; therefore, this factor was included in the following analyses of the text data.

Text Data

Descriptive statistics of the absolute error scores for orientation judgements following learning from the text-route description, and the time taken to make these judgements are presented in Table 2.2.2.

Table 2.2.2

Descriptive Statistics for Orientation Judgements (tabled in degrees) to Targets that were Aligned and 180° Contra-aligned with the First Part of the Route, and the Times (tabled in seconds) taken to make these Judgements.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Orientation Error							
Aligned	20	5.00	96.25	32.94	28.79	19.46	46.41
Contraaligned	20	10.00	145.00	65.56	44.47	44.75	86.37
Orientation Latency							
Aligned	20	2.20	26.28	7.65	6.38	4.66	10.63
Contraaligned	20	2.67	35.89	10.54	7.85	6.87	14.21

The orientation and latency data were analysed individually using 2 x 2 x 2 x 2 mixed ANOVA; in each case, the between-participants factor was exploration (free exploration of the VE, free exploration + guided exploration), and the within participant factors were: direction (test locations that were either in front or behind participants' imagined facing direction at test), alignment (aligned and contra-aligned with respect to the first part of the route), and route section (whether the test question asked for a judgement made from an imagined location on the first or last segment of the route).

Analysis of the absolute orientation errors detected a main effect of alignment, $F(1,18) = 11.05$, $MSE = 3854.10$, $p = .004$ (partial $\eta^2 = .38$). No other main effects and no interactions were significant (*p*s > .05). The alignment effect is illustrated in the upper panel of Figure 2.2.5, and reflects lower errors overall under the aligned than the contra-aligned condition (*M*s = 33 and 66° respectively).

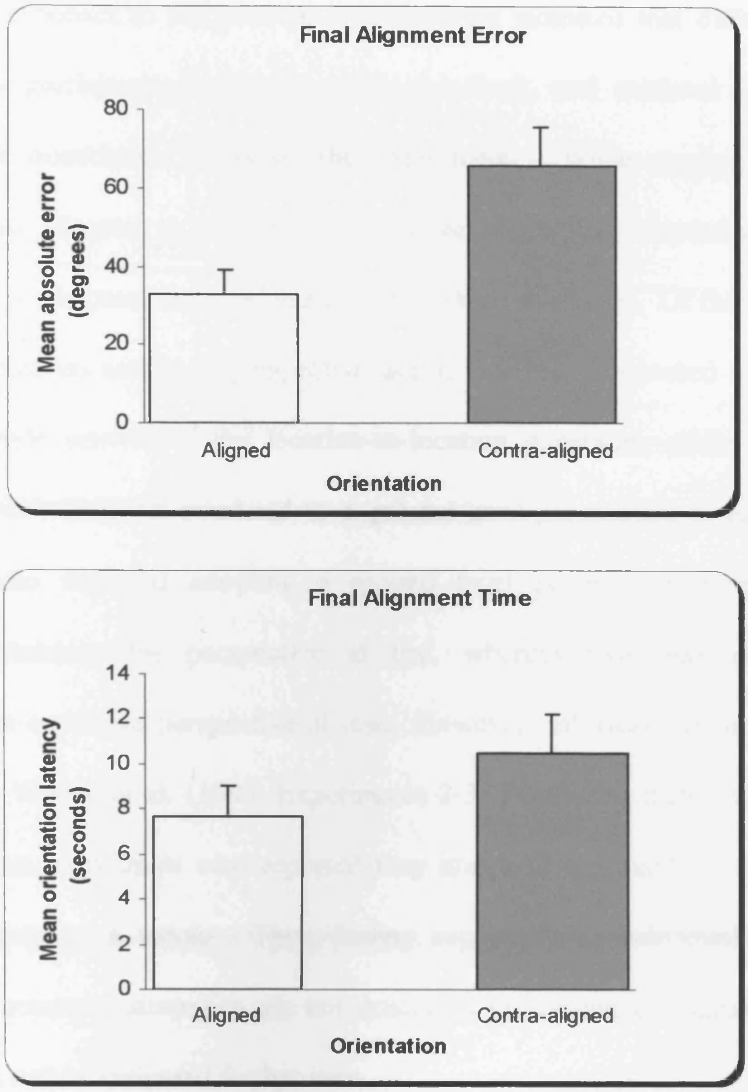


Figure 2.2.5. Experiment 2 (text): Mean absolute error (upper panel) and latency (lower panel) scores for orientation judgements to target locations that were aligned and 180° contra-aligned with the first part of the route description. Error bars represent one estimated standard error above the mean.

The mean latencies to make orientation judgements are illustrated in the lower panel of Figure 2.2.5. Analysis of these scores found a statistically significant main effect of alignment $F(1,18) = 6.46$, $MSE = 51.89$, $p = .02$ (partial $\eta^2 = .26$), that, in line with the orientation data, reflects overall faster judgements under the aligned than the contra-aligned condition (*M*s = 8 and 11s respectively). No other main effects or interactions were statistically significant (*p*s > .05).

Collated responses to the post-test questionnaire indicated that different strategies were used by participants at the encoding (reading), and retrieval (answering the alignment test questions) stages of the experiment. While reading the text, 12 participants had adopted an overhead perspective and 6 had adopted a ground level perspective; 2 participants reported using both of these strategies. Of the 12 participants who had adopted an overhead perspective during reading, 8 reported maintaining this perspective while answering the location-to-location questions, while 4 participants reported a switch from an overhead to a ground-level perspective at test. For the 6 participants who reported adopting a ground level perspective during reading, 4 reported maintaining this perspective at test, whereas two participants reported switching to an overhead perspective at test. However, following separate analyses of their text data Wilson et al. (1999, Experiments 2-3B) found no difference between the results for those individuals who reported they imagined a ground level walk and the participant group as a whole. Their finding suggests that individual differences in encoding and retrieval strategies are not crucial in promoting orientation effects, and this factor was not investigated further here.

That participants were able to encode the information provided by the VE only poorly in the present experiment was surprising, given the available literature on the effectiveness of this medium in learning the locations of landmarks within an environment (e.g. Pèruch Vercher & Gauthier, 1995; Regian, Shebilske & Monk, 1992; Rossano & Moak, 1998; Tlauka & Wilson, 1994; Waller et al., 2002). The orientation error and latency data suggest that participants encoded the array of landmarks within an egocentric spatial framework defined by natural bodily axes (i.e. front-back and left-right), in the manner predicted by the spatial framework model (Franklin & Tversky, 1990). As access to landmarks to the left and right was slower and more error prone than access to the landmark that was directly behind participants' imagined orientation at test, spatial learning from the present VE appears consistent with the outcomes of a large number of studies that have involved learning scenes from text (e.g. Bryant, 1992; Bryant et al., 1992; Carr & Roskos-Ewoldsen, 1998; Franklin & Tversky, 1990; Franklin et al., 1992), and from real-world experience (Bryant, Tversky & Lanca, 2001), which have supported a memory advantage for locations in the 180° direction when this is directly opposite to the imagined facing direction.

In Experiment 2, it was anticipated that the presentation of environmental information in a VE that was processed prior to participants reading about a route described as internal to that information should facilitate the encoding of an allocentric frame of reference in memory without increasing cognitive load. In contrast to this expectation, it appears that the abstract nature of the VE used in this experiment did not allow participants to accurately encode the relationships between the external landmarks. If incorrect encoding of these relationships conflicted with the correct arrangement of these landmarks when they were re-presented in text, it is possible that cognitive load may have been increased, rather than decreased, either by the presentation of the to-be-learned information via two different media, or by the use of four landmarks.

However, the same external information presented in the VE was re-presented in the text descriptions with respect to each of the segments of the internal route as these were encountered during reading. Experiment 2 therefore provides an important replication of the first-perspective alignment effect using a group of participants who learned a text description of a route surrounded by an array of external landmarks. Both overall errors and the time taken to complete the final alignment test suggested better performance when participants made spatial judgements that were aligned with the orientation of the first part of the route description. This outcome extends the findings of Wilson et al. (1999) in that when additional allocentric information is provided in a text description, participants continue to preferentially encode the space egocentrically, on the basis of the first aligned perspective described in the text. However, two related points merit consideration. First, because the alignment task used in this series requires an egocentric response, the present results should not be interpreted as an indication that allocentric information has not been encoded (see Experiments 3 & 4 for contradictory outcomes). Second, to ensure a similar between-participant learning period during the crucial text phase of the present experiment, individuals were asked to read the route description "at least three times..." A potential outcome of this instruction is that repeated readings might serve to affect the nature of the resultant representation. In their original experiments (in which allocentric information was not included), Wilson et al. (1999) found no difference in the magnitude of the first-perspective effect after participants had been asked to read the route descriptions 3 times (Experiment 3A), to that found following a single reading (Experiment 2). However, under circumstances in which allocentric cues are available, related lines of research suggest that for both animal and human navigation, repeating a route appears to strengthen an action based egocentric response rather than an allocentric place response. For example, Packard and McGaugh (1996) showed that rats trained to approach a consistently baited arm in a cross-maze from the same start box over a 14 day period (4 trials per day) made the same turning response during training when placed in a start box opposite to that used in training. Comparably, using human participants who explored a VE version of an 8-arm radial maze with a central starting location, Iaria, Petrides, Dagher, Pike and Bohbot (2003), found that of 46% of participants who spontaneously adopted a spatial strategy during navigation (reliance on the relationships between environmental landmarks in the VE), 39% switched to a non-spatial strategy (counting the arms of the maze and ignoring the array of environmental landmarks), following multiple trials for an object location task. Future experiments could therefore investigate the generality of this effect with respect to text-route descriptions by varying the number of times participants are asked to read descriptions of similar content to those used in the present experiment, and the effect of this manipulation on the magnitude of the first-perspective alignment effect.

With respect to other potential accounts of the first-perspective alignment effect currently under investigation, the error and latency data in the present experiment do not offer support for the hypothesis that this alignment effect may share similarities with the primacy effect found in serial list learning (e.g. Glanzer & Cunitz, 1996). With reference to the upper panel of Figure 2.2.2, participants responded more accurately and faster on A-B judgements (M = 32°) than B-A (M = 62°); this outcome is consistent with a list learning account because A-B was encountered first in a possible 'list of views.' However, an alignment effect of similar magnitude was found for D-C (M = 34°) and C-D (M = 69°) judgements. This pattern was also evident in the latency data: for A-B and B-A judgements, the mean latencies were 9 and 11s respectively; for D-C and C-D judgements, the mean latencies were 7 and 10s respectively. Had the route been remembered as a series of views, a serial list account predicts little difference in accuracy and/or latencies for C-D and D-C judgements because these views were encountered in the middle of the list.

When considered alongside participants' subjective reports of their imagined perspectives during reading and at test, the similar patterns of aligned (A-B and D-C in Figure 2.2.2) and contra-aligned (B-A and C-D in Figure 2) error and latency data observed for orientation judgements on the first and last parts of the route, are more compatible with encoding of the entire representation in the same orientation than serial list learning. That is, and consistent with the outcome of Experiment 1, an orientation in which the first segment of the route was egocentrically encoded on the basis of forward-up-north-equivalence, with the remainder of the route encoded in relation to that first segment. Also interesting, is that an advantage to targets in front than behind participants' imagined orientation at test would be anticipated from egocentric recall (Franklin & Tversky, 1990). However, in the present experiment there was no main effect of direction in either the error or latency data, nor were there any interactions between this and any other factor.

This outcome is in contrast to Taylor and Tversky's (1992) experiment, in which the provision of allocentric information may have aided or influenced recall at test. What appears to be the case in the present experiment, is that when environmental information serves to increase cognitive load, the first-perspective alignment effect may occur as a consequence of encoding via a default spatial learning mechanism, in which 'ego' corresponds to a conceptual 'north.' This theory is investigated in Experiments 3 and 4.

Experiment 3

The outcome of Experiment 2 suggests that when allocentric information is provided in a text description, participants continue to preferentially encode the space using an egocentric frame of reference that is defined by forward-up-north-equivalence. However, due to possible conflict between VE and text learning, and/or increased cognitive load incurred by including additional information in the text-phase of that experiment, the results are not conclusive. It remains possible that first-perspective alignment encoding and recall may be 'over-ridden' when salient environmental cues make allocentric encoding more efficient (Taylor & Tversky, 1992).

In Experiment 3, using an entirely text-based procedure, participants were presented with a 3-path route described in relation to one, distinct external landmark. It was anticipated that by including only one landmark, intrinsic cognitive load would be kept to a minimum. The design of Experiment 2 was extended, so that each participant served in two conditions; in one condition, the text referred to a single landmark described as positioned either in the distance beyond, or opposite to the direction of the first part of the route; in a second, control condition, the landmark information was not included. To avoid evoking a 'conceptual north,' initial orientation in both conditions was described in the text as "the direction that you plan to walk" rather than "ahead" (cf. Wilson et al., 1999). It was anticipated that under the control condition, the first-perspective alignment effect found by Wilson et al. would be replicated. In the experimental condition, when the landmark was described as in front of the start point of the route, a strong first-perspective alignment effect was predicted because the additional allocentric information provided should enhance the salience of this already dominant, north-equivalent perspective in spatial memory. In contrast, when the landmark was described as behind the first perspective direction, it was hypothesized that creating a 'new' conceptual north, which was oriented in the opposite direction to the first-perspective, might attenuate the first-perspective alignment effect.

Method

Design

In a mixed design, participants read two text descriptions of different three-path routes through city streets, with the initial orientation for both routes described as "the direction that you plan to walk," and 90° turns counterbalanced as left- and right-hand. The within-participant independent variable was whether the text described a large external landmark ('landmark'), or whether no landmark information was provided ('no landmark'). The between-participants variable under the 'landmark' condition was the described position of the landmark (i.e. in the distance beyond or behind the start-direction of the route). As for Experiment 2, the dependent variables were orientation and distance estimates and the times taken to make these judgements.

Participants

Thirty-two participants from the University of Leicester, UK took part in the experiment, and of these, 5 were male. They had a mean age of 19.4 years (range: 18-40 years), and all received credit towards the fulfilment of a first- or second-year practical course requirement.

Materials

Preliminary written instructions included the following information: "This experiment is designed to investigate the properties of mental images. You will be asked to imagine yourself making two short journeys on foot. It is important that you try to visualise the routes as clearly as possible from a ground level perspective. I would like you to imagine that you have travelled to a large, modern city. The streets, which are all of varying length, are arranged in a grid pattern, and all intersect at right angles. At each intersection there is a building of the type usually found in a modern city. For example, cinema, bank, garage and so on. Please read the descriptions carefully and imagine yourself walking along the pathways described as clearly as you can…" A complete copy of these instructions is included in Appendix A.

Two route descriptions similar to those used in Experiment 2 were produced, in which the number of right and left turns, and which segment of the route (first or last) was the longer were counterbalanced. However, in contrast to Experiment 2, each of these routes depicted differently named buildings, and the overall dimensions of both routes were increased. With reference to the plan diagrams in Figure 2.2.2, for Route A the building locations were: A = 'Bus Terminus,' B = 'McDonald's,' C = 'Book Shop,' D = 'Health Food Store;' the distances between each of these buildings were described as: A-B = 200 metres, B-C = 100 metres, C-D = 80 metres. For Route B, the building locations were: A = 'Tube Station,' B = 'Job Centre,' C = 'Concert Hall,' D = 'Pub,' and the respective distances were: A-B = 110 metres, B-C = 100 metres, C-D = 200 metres.

For each of these routes, three descriptions were prepared, all with the initial orientation described as "the direction you plan to walk;" one description did not include landmarks, and two described the position of a large external landmark (Route A, cathedral spire; Route B, tall block of flats), as located either in the distance beyond or behind the first segment of the route. For example, when the landmark was not described, the opening sentences for Route A read:

> Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. As you start walking along your

planned path, you see a sign for 'McDonald's,' which is situated at the first junction...

In condition 'landmark', and when the landmark was described as beyond the start point, the same section read:

> Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. In the distance, in the same direction is a cathedral spire that towers over the city. As you start walking along your planned path you see a sign for 'McDonald's,' which is situated at the first junction...

Finally, when the landmark was described as behind the start point, the text read:

> Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. In the distance, in the opposite direction is a cathedral spire that towers over the city. As you start walking along your planned path you see a sign for 'McDonald',' which is situated at the first junction...

Throughout each route description, as in Experiment 2, the text described the position of the single external landmark in relation to each segment of the route, and with respect to the left- and right-hand turns described. Copies of all of the route descriptions are in included in Appendix B

Procedure

Participants were tested individually in a quiet room, and all took part in both the no landmark and landmark conditions in a counterbalanced order. Immediately following each text description, eight alignment test questions were presented (four aligned and four 180° contra-aligned with the first section of the route description). The alignment test questions were counterbalanced to include the factors of target location, alignment and part of route in the same way as for Experiment 2, and required participants to indicate the direction of one of the buildings described on the route while imagining themselves to be located at a second building. The alignment test questions for Route A were identical to those used in Experiment 2; for Route B, the mean absolute correct angle for the test questions was approximately 90°, with the mean for front-facing aligned and contra-aligned judgements being 30°, and behind-facing aligned and contra-aligned judgements 140°. To carry out the judgement task, participants used the 360° pointing device described for Experiment 2, and following each orientation measure, were asked to estimate the straight-line distance, in metres, from their imagined location to the target building. The alignment and distance test questions for both routes are included in Appendix C.

After testing had been completed in both conditions, participants were asked to complete questions 1 and 2 of the written questionnaire used in Experiment 2. A third question referred to the route that described the landmark, and asked participants to indicate the direction that they imagined themselves facing at the start of their 'journey' by drawing an arrow outwards from the centre of a pre-marked 'X' in the centre of a blank area of the questionnaire; also to write the letter 'L' in relation to the cross and arrow to indicate the position of the landmark in the description they had read (see Appendix B for a copy of this questionnaire).

Results and Discussion

As any effects of the additional between-participant factor included in the landmark condition (position of landmark) could not be addressed in overall comparisons when no landmark was described, the error and latency data for orientation judgements were analysed separately for each condition. Sex was not included as a factor in any of these analyses as there were too few men to make meaningful comparisons; however, the order of testing the two conditions was entered into the analyses.

Descriptive statistics for the absolute error scores in the 'landmark' and 'no landmark' conditions are presented in Table 2.3.1; the means for both conditions are illustrated in Figure 2.3.1.

Table 2.3.1
Descriptive Statistics (tabled in degrees) for Aligned and 180° Contra-aligned Absolute Orientation Error Scores under the 'Landmark' and 'No Landmark' Conditions.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Landmark							
Aligned	32	6.25	107.50	40.08	29.92	29.29	50.87
Contraaligned	32	8.75	170.00	71.84	44.79	55.68	87.98
No Landmark							
Aligned	32	2.50	105.00	39.02	29.64	28.33	49.71
Contraaligned	32	11.25	168.75	75.98	43.22	60.39	91.56

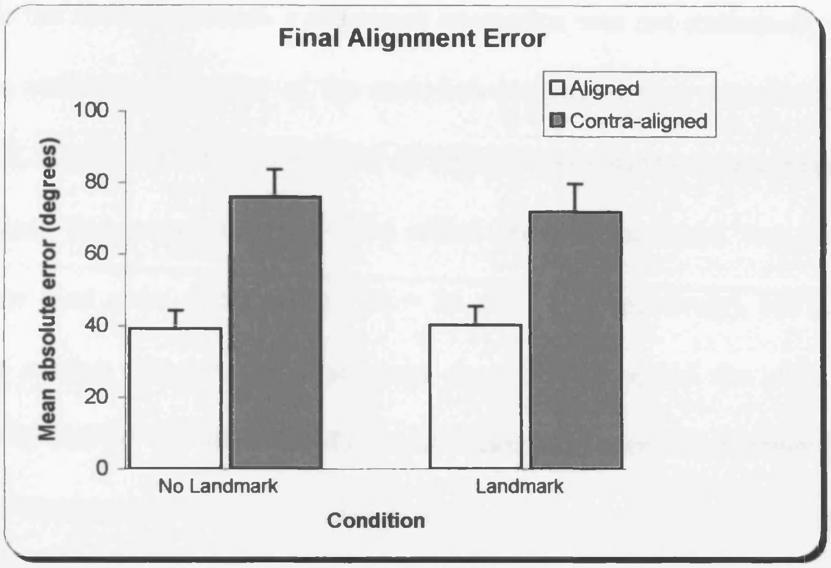


Figure 2.3.1. Experiment 3: Mean absolute error scores under the no landmark and landmark conditions for aligned and 180° contra-aligned orientation judgements. Error bars represent one estimated standard error above the mean.

The mean absolute angle errors for the landmark condition were analysed using a 2 x 2 x 2 x 2 x 2 mixed ANOVA with order (whether the landmark condition was tested first or second) and position (whether the landmark was described as in front of or behind the start point of the route) as between participants factors, and direction (test locations that were either in front or behind participants' imagined facing direction at test), alignment (aligned and 180° contra-aligned with respect to the first part of the route) and route section (whether the test question asked for a judgement made from an imagined location on the first or last segment of the route) as within participant factors. This analysis found a statistically significant main effect of alignment, $F(1,28) = 18.85$, $MSE = 3424.29$, $p < .001$ (partial $\eta^2 = .40$), reflecting lower errors overall for aligned ($M = 40°$) than contra-aligned ($M = 72°$) judgements. No other main effects or interactions were significant (*ps* > .06).

While the order x position x alignment interaction was not statistically significant in the above analysis, inspection of the raw data suggested that numerically, and when tested first, the data showed a pattern of aligned and contra-aligned errors consistent with a strong first-perspective alignment effect when the landmark was described as in front of the start point of the route (*M*s = 36 and 71° respectively), but the effect was much less evident when the landmark was described as behind the start point of the route (*M*s 45 and 60° for aligned and contra-aligned judgements respectively).

The absolute error data for condition no landmark were analysed using a 2 x 2 x 2 x 2 mixed ANOVA with order (whether this condition was tested first or second) as the between-participants factor, and target direction, alignment and route section as within-participant factors. As anticipated from Figure 2.3.1, this analysis found a statistically significant main effect of alignment, $F(1,30) = 21.71$, $MSE = 4026.45$, $p < .001$ (partial $\eta^2 = .42$), reflecting lower overall errors for aligned ($M = 39°$) than contra-aligned ($M = 76°$) judgements when no initial orientation was described in the text. Also statistically significant were main effects of order, $F(1, 30) = 6.84$, $MSE = 3975.39$, $p = .014$ (partial $\eta^2 = .19$), and direction, $F(1, 30) = 8.42$, $MSE = 1604.21$, $p = .007$ (partial $\eta^2 = .22$). A complex order x direction x alignment x route section interaction, $F(1, 30) = 4.57$, $MSE = 1251.39$, $p = .04$, (partial $\eta^2 = .13$]) was also apparent, but does not reflect a consistent pattern, and is not discussed in detail. No other main effects or interactions were significant (*p*s > .1). The main effect of order represents greater overall errors when the no landmark condition was tested first ($M = 71°$) than when tested following the landmark condition ($M = 45°$), and the direction effect reflects greater overall errors for judgements to targets that were in front of ($M = 65°$) than behind ($M = 50°$) participants' imagined facing orientation at test.

Descriptive statistics for the orientation latency data in the no landmark and landmark conditions and the means for both conditions are presented in Table 2.3.2 and Figure 2.3.2 respectively.

Table 2.3.2
Descriptive Statistics (tabled in seconds) for Aligned and 180° Contra-aligned Orientation Latency Scores under the 'Landmark' and 'No Landmark' Conditions

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Landmark							
Aligned	32	2.75	25.69	8.79	5.81	6.68	10.87
Contraaligned	32	3.47	42.34	11.11	7.27	8.49	13.74
No Landmark							
Aligned	32	3.07	34.97	9.70	7.56	6.97	12.42
Contraaligned	32	4.07	62.47	13.23	12.98	8.55	17.91

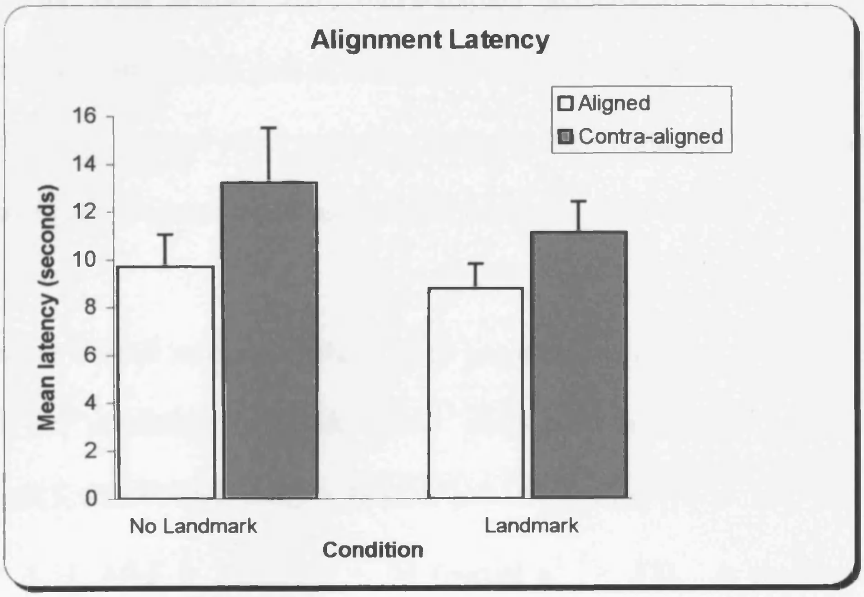


Figure 2.3.2. Experiment 3: Mean latency scores under the no landmark and landmark conditions for aligned and contra-aligned orientation judgements. Error bars represent one estimated standard error above the mean.

The orientation latency scores for condition landmark were analysed in the same way as the relevant orientation error data; the analysis found significant alignment x part of route, $F(1, 28) = 7.39$, $MSE = 40.18$ $p = .01$ (partial $\eta^2 = .21$) and order x alignment x part of route, $F(1, 28) = 7.64$, $MSE = 40.18$, $p = .01$ (partial $\eta^2 = .21$) interactions. No other main effects or interactions were significant ($ps > .1$). The alignment x route section interaction reflects faster overall responses for aligned ($M = 8$s) than contra-aligned ($M = 12$s) judgements when the test question asked for a judgement made from an imagined orientation on the first part of the route, whereas latencies were equivalent for aligned and contra-aligned judgements ($Ms = 10$ s) when the test orientation was on the last part of the route. The order x alignment x route section interaction indicates that the above pattern of latencies was apparent when the landmark condition was tested first ($Ms = 7$ and 15s) for aligned and contra-aligned judgements respectively when test orientations were on the first part of the route, and the means for both aligned and contra-aligned judgements were 11s, when test orientations were on the last part of the route. However, when the landmark condition was tested second, an equivalent pattern of latencies was found ($M = 9$s for both aligned and contra-aligned judgements on the first and last parts of the route).

A similar overall analysis of the latency scores for condition no landmark to that conducted for condition landmark found statistically significant main effects of alignment, $F(1, 30) = 4.89$, $MSE = 163.24$, p = .04 (partial $\eta^2 = .14$), and direction, $F(1,30) = 4.54$, $MSE = 172.99$, $p = .04$ (partial $\eta^2 = .13$). A significant order x direction x alignment was also apparent, $F(1, 30) = 4.81$, $MSE = 68.69$, $p = .04$ (partial $\eta^2 = .14$). As indicated in Figure 2.3.2, and consistent with the error data, the alignment effect reflects faster overall responses for orientation judgements under the aligned ($M = 10$s) than the contra-aligned ($M = 13$s) condition. Contrary to the error data analysis, the direction effect represents faster overall responses for judgements to targets that were in front of (M = 10 seconds) than behind (M = 13 seconds) participants' imagined facing orientation at test.

The significant interaction involving order of testing was examined by separately examining the results for whether condition no landmark was tested first or second, but revealed no interesting effects related to alignment.

In answer to the question that asked participants to indicate their experiences while reading the text, 20 of the 32 participants reported being able to adopt a ground-level perspective (either 'as though actually walking' [15 participants] or from an 'external' perspective [5 participants]), and 9 participants reported adopting an overhead perspective. The remaining 3 participants reported 'visualising just the streets and locations, not myself.' Of the participants who had adopted a ground-level perspective while reading, 12 maintained this perspective while answering the orientation test questions, and 8 participants switched to an overhead perspective. For the 9 participants who reported adopting an overhead perspective while reading, 6 reported a switch to a ground-level perspective at test, while 3 maintained an overhead perspective.

When asked to draw an arrow on a blank part of the questionnaire to indicate their imagined facing direction at the start point of the route, 28 participants drew vertically from the bottom to the top of the page, 3 drew horizontally across the page from right to left, and one drew left to right. All 32 participants correctly indicated the position of the large, external landmark (by drawing the letter 'X' in relation to the arrow) as either in front of or behind the start point of the route. This latter outcome is important, and unlike the results of Experiment 2, indicates that participants had successfully encoded the location of the landmark with respect to the internal route.

For condition no landmark, in which no initial orientation was described, the error and latency data were generally consistent with the previous patterns of data obtained by Wilson et al. (1999), and those reported in Experiment 2. Overall, the error and latency data were indicative of first-perspective alignment encoding and recall. The trade-off observed between the error and latency data for front- and back-facing orientation judgements suggests that this factor does not exert a consistent influence over this outcome. By contrast, the crucial orientation error data from the landmark condition provide a hint of first-perspective alignment attenuation, under a condition in which the landmark was described as in the opposite orientation to the first perspective, but only when the landmark condition was tested first. This suggests that in the present experiment, the order of testing the two conditions may be masking important effects; hence, in Experiment 4, an additional 32 participants were recruited, all of whom took part in a single (landmark) condition that was identical to that described in the present experiment.

Experiment 4

The results of Experiment 3 provide a suggestion of attenuation of the first-perspective alignment effect when a salient environmental cue was described as in the distance behind rather than in front of the start direction of the route, but only when the crucial conditions are run first. To investigate this further, Experiment 4 tested the prediction that when only the 'landmark' condition is included in a single experiment (effectively running this condition first for all participants), the first-perspective alignment effect should be found in the 'in front' condition, but in comparison, it should be reduced in the 'behind' condition.

Method

Participants

The 32 participants were a mixture of first-year psychology undergraduates from the University of Leicester, UK and third-year undergraduates from the Leicester Warwick Medical School; they had a mean age of 20 years (range: 18-26 years), and 8 participants were male. In return for taking part in the experiment, participants either received credit towards the fulfilment of a practical course requirement or the reimbursement of travel costs.

Materials

Each participant was presented with an A4-size instruction sheet that comprised the same information as for Experiment 3, with the exception that participants were informed that they would be asked to read a single route description (see Appendix A). Two versions of a description of a tour around two routes were used, and these were identical to those employed in the landmark condition of Experiment 3 (see Appendix B).

Procedure

The procedure was the same as in Experiment 3, but only the landmark condition was run. Whether the position of a large external landmark was described in the text as in the distance in front of or behind the start direction of the route was varied between participants. Immediately after reading this description, participants were presented with eight alignment and distance test questions counterbalanced in the same way as described for Experiment 3 (see Appendix C); participants were also asked to complete the same post-test questionnaire used in that Experiment (see Appendix B).

Results and Discussion

Due to the small number of men compared to women who took part in the current experiment, sex was not included as a factor in the following analyses of the orientation error and latency data.

Descriptive statistics of the absolute error scores for orientation judgements following learning from the single 'landmark' route description, and the times taken to make these judgements are presented in Tables 2.4.1 and 2.4.2 respectively.

Table 2.4.1

Descriptive Statistics (tabled in degrees) for Aligned and 180° Contra-aligned Absolute Orientation Error Scores for Groups 'In front' and 'Behind.'

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Landmark in front							
Aligned	16	5.00	63.75	20.16	18.15	10.48	29.83
Contraaligned	16	5.00	136.25	44.69	37.67	24.61	64.76
Landmark behind							
Aligned	16	8.75	71.25	25.08	18.81	15.06	35.10
Contraaligned	16	8.75	168.75	59.53	54.91	30.27	88.79

Table 2.4.2

Descriptive Statistics (tabled in seconds) for Aligned and 180° Contra-aligned Absolute Orientation Latency Scores for Groups 'In front' and 'Behind.'

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Landmark in front							
Aligned	16	3.25	27.77	8.01	6.23	4.69	11.33
Contraaligned	16	3.69	44.20	12.72	9.99	7.39	18.05
Landmark behind							
Aligned	16	1.90	14.99	7.19	3.69	5.22	9.16
Contraaligned	16	2.38	32.49	8.84	7.11	5.05	12.64

Overall analyses of the means for the orientation and latency data were conducted separately using 2 x 2 x 2 x 2 mixed ANOVAs, with position (whether the landmark was described as in front of or behind the start point of the route) as the between-participants factor, and direction (test locations that were either in front of or behind participants' imagined facing direction at test), alignment (aligned and 180° contra-aligned with respect to the first part of the route) and route section (whether the test question asked for a judgement made from an imagined location on the first or last segment of the route) as within participant factors. As suggested in the upper panel of Figure 2.4.1, analysis of the error data found a statistically significant main effect of alignment, $F(1,30) = 14.69$, $MSE = 3815.38$, $p = .001$ (partial $\eta^2 = .33$), that reflects lower errors overall for aligned ($M = 23°$) than contra-aligned ($M = 52°$) judgements. No other main effects or interactions were significant ($ps > .1$).

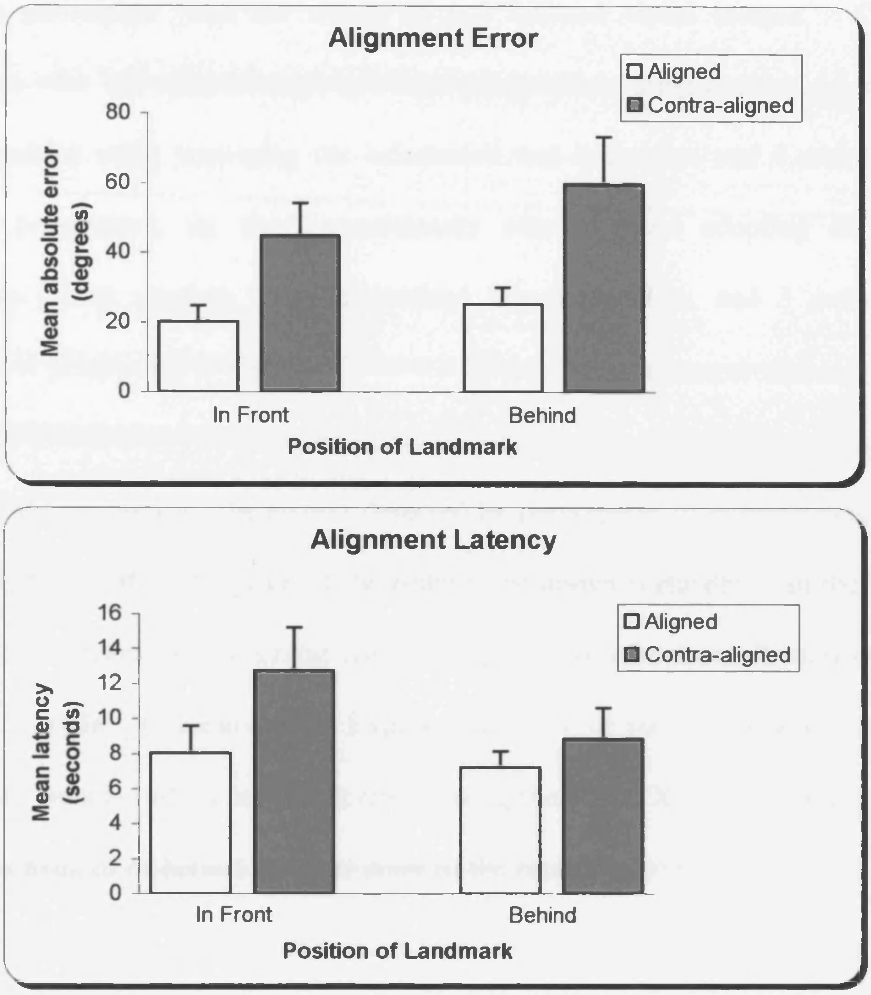


Figure 2.4.1. Experiment 4: Mean absolute error (upper panel) and latency (lower panel) scores under the 'in front' and 'behind' conditions for aligned and 180° contra-aligned judgements. Error bars represent one estimated standard error above the mean.

Consistent with the error data, overall analysis of the latency data revealed a significant main effect of alignment, $F(1,30) = 7.36$, $MSE = 88.1$, $p = .01$ (partial $\eta^2 = .20$); no other main effects and no interactions were significant (ps > .16).

While reading the text, 19 of the 32 participants reported being able to adopt a ground-level perspective, either 'as though actually walking' (14 participants) or from an 'external' perspective (15 participants), and 6 participants reported adopting an overhead perspective; one participant reported adopting both of these strategies. Four participants reported 'visualising just the streets and locations, not myself,' and the remaining participant 'was not aware of any internal visual images.' Of the 19 participants who had adopted a ground-level perspective during reading, 15 maintained this perspective while answering the orientation test questions, and 4 switched to an overhead perspective; for the 6 participants who reported adopting an overhead perspective during reading, three maintained this perspective, and 3 switched to a ground-level perspective at test.

With two exceptions, the arrows depicted by participants to indicate their imagined facing direction at the start point of the route were drawn vertically from the bottom to the top of the page; the remaining two participants drew horizontally across the page from left to right. Comparable to Experiment 3, 31 of the 32 participants correctly encoded the position of the landmark (by drawing the letter 'X' in relation to the arrow) as either in front of or behind the start point of the route.

Contrary to the experimental hypothesis, analyses of the error and latency data in Experiment 4 revealed evidence for first-perspective alignment effects, irrespective of whether the landmark was described as in front of or behind the start point of the route. As was the case in Experiments 2 and 3, alignment effects of similar magnitude were evident in the error data of the present experiment, whether the test question required an imagined location on the first or last section of the route (first: aligned $M = 27°$, contra-aligned $M = 50°$; last: aligned $M = 18°$, contra-aligned $M = 54°$); a similar pattern was apparent in the time scores (first: aligned $M = 8$s, contra-aligned $M = 12$s; last: aligned $M = 7$s, contra-aligned $M = 10$s). Taken together, these findings suggest: first, additional support for the hypothesis that the text first-perspective alignment effect may occur as a consequence of participants encoding the first section of the route on the basis of forward-up-north-equivalence, with the remainder of the route encoded in relation to that first segment. Second, because the inclusion of landmark information in the text failed to attenuate the first-perspective alignment effect, the data imply that this form of egocentric encoding may represent a primary form of encoding spatial information when learning is from text descriptions. However, as noted in Experiments 2 and 3, the advantage for judgements to targets in front of rather than behind participants' imagined orientation at test that might be anticipated from pure egocentric encoding was not apparent in either the error (*M*s = 37° for both front- and back-facing targets) or latency (*M*s = 9s for both front- and back-facing targets) data of the present experiment.

The landmark information used in the text descriptions of Experiment 4 did not appear to engender a directional allocentric reference frame. This may be because the landmarks lacked salience when presented in the context of many new spatial relationships. In Experiments 5 and 6, an allocentric frame of reference was provided by the cardinal terms north, south, east and west. This reference system is so familiar and so well learned that it should be automatically invoked. To the extent that the mental representations of environments learned from text descriptions are egocentrically encoded on the basis of what appears to be a default, north-ahead equivalent frame, should the initial orientation be described as 'north-facing,' no change in the pattern of data would be anticipated from that observed by Wilson et al. (1999) or that found in the 'landmark ahead' condition of Experiments 3 and 4. However, because cardinal terms are implicit in the memories of adults, when the default north-ahead and allocentric frames of reference are maximally misaligned, that is, when the initial orientation is described as 'south-facing,' the egocentric frame may not predominate.

Experiment 5

The allocentric reference system that comprises the cardinal directions north, south, east and west is commonly used in everyday discourse (Taylor & Tversky, 1996), and as suggested by the outcome of Experiment 1, may affect the way in which spatial information learned from text is mentally represented.

It is well-documented that the mental representations of environments acquired from cartographic maps typically have a picture-like 'north-up' orientation facilitated by the way in which the map is structured (e.g. Palij et al., 1984), and that map learning seems to influence the development of other aspects of spatial cognition (e.g. Liben & Downs, 1989, 1991; Uttal, 2000). However, studies that have investigated the role of cardinal directions in the accessibility of spatial information while varied, are generally confined to comparisons between the spatial information derived from real-world navigation and map learning (e.g. Sholl, 1987, 1999; Werner & Schmidt, 1999, Experiment 2). Related experiments have investigated the role of environmental geometry in real-world, cardinally defined orientation accuracy (Sholl, Acacio, Makar & Leon, 2000; Werner & Schmidt, 1999, Experiments 1 & 3), while others have addressed the relationship between sex and orientation ability derived from cardinal information (Lawton, 1994; Sholl et al., 2000). To the knowledge of this author, no published study has systematically investigated the role of cardinal terms in defining the alignment of spatial memories derived from text descriptions.

Experiment 5 provided an initial investigation of the influence on first-perspective encoding of employing cardinal terms in the text descriptions used in Experiments 2-4. Two hypotheses were investigated: First, that if the mental representations derived from text descriptions are, by default, based on a forward-north-up-equivalent frame of reference, when the first part of the route is described as north-facing, no change would be anticipated in the data patterns from that those observed by Wilson et al. (1999), and in the 'landmark ahead' conditions of Experiments 3 and 4 (present chapter). However, if the first part of the route is described as south-facing and as such, cardinally and conceptually opposite to north, conflict between the default egocentric and allocentric reference frames should require additional processing, to bring the two reference frames into alignment in order to carry out the alignment task. The prediction is that the first-perspective alignment effect should be attenuated in the south-facing description. The second hypothesis is that if cardinal terms provide a systematic frame of reference, descriptions with east or west as the initially described orientation should lead to a pattern of data that falls between that of north- and south-facing. If the first-perspective alignment effect does not depend on a default reference frame that is founded upon forward-north-up-equivalence, there should be no systematic effect of introducing cardinal terms into the route descriptions.

Experiment 5 was a preliminary investigation that took advantage of a University practical class in which undergraduates acted as experimenters and recruited an opportunity sample of participants. In a simplified procedure based on that described for Experiments 3 and 4, four groups of these participants were asked to read one of the route descriptions used in Experiments 2-4 (Route A); with the modification that the initial orientation described in the text differed between groups, as either north, south, east or west facing.

Method

Design

The between-participants independent variable was the initial cardinal direction (i.e. north, south, east or west), specified in the text description. The within- participant variable was a direction estimating task carried out from an imagined perspective that was either aligned or contra-aligned with the initial heading, from two test locations within the environment. The dependent variable was the orientation error, in degrees, between participants' direction estimates and the true angle of the test locations.

Participants

These were an opportunity sample of 42 males and 54 females (n = 96), recruited by 24 Social Science undergraduates from Nottingham Trent University UK, as part of a first year directed practical course requirement. Participants had a mean age of 26.3 years (range 17-71 years), and were allocated to four equal sized experimental groups.

Materials

Preliminary written instructions were similar to those used for Experiments 2-4 (see Appendix A). Four written descriptions of the route were prepared and printed on A4 size sheets using a size 16, double-spaced, emboldened font. Route descriptions differed in wording only with respect to their initially described cardinal orientation.

For example, the description for group North read as follows:

> Imagine that on leaving the Bus Terminus, you see a path which extends two hundred metres northwards. As you start walking along this path, you see a sign for 'McDonald's' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face west. Imagine that you walk a further one hundred metres to the next junction, at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face south, and walk another eighty metres until you come to a Health Food Store.

Imagine that you are at the Health Food Store and that you turn 180 degrees to face north, back towards the Book Shop. Imagine that you walk the eighty metres back towards the Book Shop, and turn right to face east. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing south towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

The descriptions for the remaining groups were identical except that the word "north" was replaced in the first and seventh sentences with "south," "east" or "west" throughout the text, and the remaining cardinal terms were adjusted accordingly (see Appendix B).

Illustrations were prepared of a 360° protractor comprising a nine-centimetre diameter circle marked in 5-degree intervals. These were presented on a separate A4 sized sheet for direction estimation training, and were reproduced on question sheets that asked for direction estimates (see procedure). A copy of these materials can be found in Appendix B.

Procedure

Twenty-four experimenters each recruited and tested four participants under quiet conditions. As preliminary training for the participants, experimenters illustrated how to make direction judgements using the 360° protractor illustration. Participants were presented with a diagram of a triangle with its angles marked A-C and asked to imagine themselves standing at one angle facing another angle; they were asked to illustrate the relative direction of the third point of the triangle by marking the outer perimeter of the protractor diagram with a single line. They were told that their imagined location should correspond with the centre point on the protractor, while zero degrees represented their facing direction. The point on the protractor's edge that indicated the appropriate direction was pre-marked on an example diagram, and the experimenters explained the correspondence between this mark and the angle judgement. Participants were then asked to make an independent judgement involving a second set of points on the triangle. If the participant made a reasonably accurate direction judgment, the experimenter proceeded with the main part of the experiment. If the participant's judgement was not less than 25°, further training was provided.

Following this preliminary training, each participant was handed a printed verbal description of the route; they were asked the read the description at least twice, and more times if necessary, until they had formed a clear mental representation of the route.

When participants confirmed they had a clear memory of the route, the test questions were presented. Two questions were printed on a single sheet, below each of which was an illustration of the 360° protractor. For each direction judgement, participants were asked to imagine that the black dot in the centre of the protractor indicated their imagined location, and the zero degree point illustrated imagined facing direction. All questions were of the form (for example): "Imagine that you are at the Bus Terminus and that 'McDonald's' is in front of you. Score a line through the outer edge of the protractor diagram to illustrate the direction of the Book Shop." Each participant made two judgements: one aligned with the first section of the route (e.g. from the Bus Terminus to 'McDonald's'), and one contra-aligned to this perspective (e.g. from the Book Shop to the Health Food Store). Counterbalanced across participants was whether the direction of the target location was in front of or behind participants' imagined facing location at test. The order of alignment test questions (aligned, contra-aligned with respect to the first perspective) was arranged according to a Latin Square, counterbalanced across the factors of alignment and direction; a list of these questions is included in Appendix C. On completion of the two alignment test judgements, participants were asked to draw a sketch-map depicting their route on a blank sheet of paper; no explicit instructions were provided as to how this should be done.

Results and Discussion

Absolute orientation error scores for each group were derived in the same way as described for Experiments 2-4. Descriptive statistics of aligned and contra-aligned judgements for the four groups are presented in Table 2.5.1; the means are illustrated in Figure 2.5.1.

Table 2.5.1
Descriptive Statistics (tabled in degrees) for Aligned, and 180° Contra-aligned Absolute Orientation Error Scores for Groups North, South, East and West

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval Lower	95% Confidence Interval Upper
Group North							
Aligned	24	5.00	150.00	55.21	46.87	35.42	74.99
Contraaligned	24	.00	180.00	95.83	55.71	72.31	119.36
Group South							
Aligned	24	.00	180.00	87.08	55.07	63.83	110.37
Contraaligned	24	.00	150.00	67.71	42.01	50.00	85.45
Group East							
Aligned	24	.00	130.00	63.16	43.71	44.69	81.58
Contraaligned	24	.00	155.00	65.63	47.85	45.42	85.83
Group West							
Aligned	24	.00	140.00	59.38	40.04	42.47	76.28
Contraaligned	24	.00	175.00	70.62	49.70	49.68	91.61

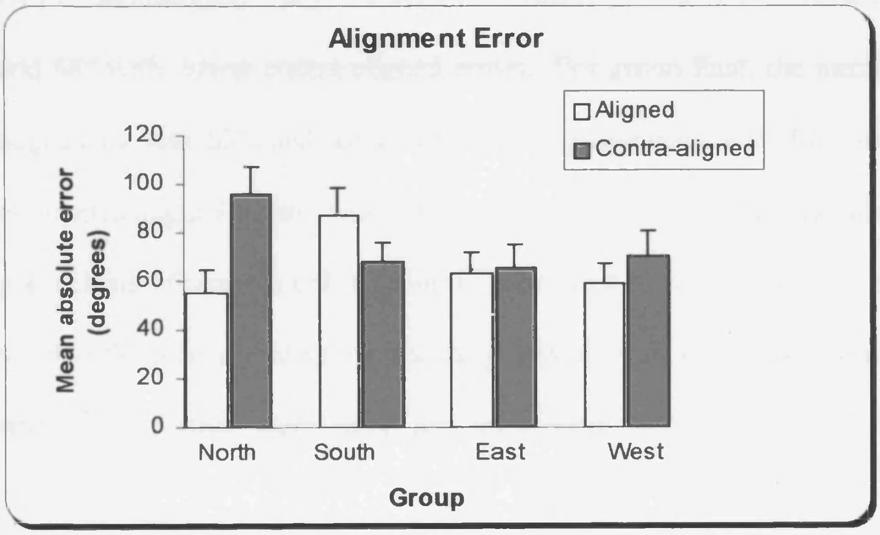


Figure 2.5.1. Experiment 5: Mean absolute error scores for aligned and 180°contra-aligned judgements in groups North, South, East and West. Error bars represent one standard error above the mean.

It is apparent that group North produced an alignment effect similar to that reported by Wilson et al. (1999), with aligned judgements being more accurate than contra-aligned judgements. By contrast, group South produced an alignment effect but in the opposite direction, while groups East and West did not differ in the accuracy of their aligned and contra-aligned judgements. This picture was confirmed by statistical analysis.

The data were entered into a 4 x 2 x 2 mixed ANOVA with group (North, South, East, West) and sex as between-participant factors, and alignment (aligned, 180° contra-aligned) as the within-participant factor. The analysis revealed a statistically significant interaction between group and alignment, $F(3,88) = 4.04$, $MSE = 1703.37$, $p = .01$ (partial $\eta^2 = .12$); no other interactions or main effects were significant ($ps > .1$). Planned comparisons on the interaction between group and alignment using paired samples *t*-tests found that the difference between aligned and contra-aligned conditions was significant for group North, $t(23) = 2.58$, $SE = 15.73$, $p = .017$ ($\eta^2 = .22$), means 55 and 96° respectively; while the alignment condition effect in group South just failed to reach statistical significance, $t(23) = 1.90$, $SE = 10.20$, $p = .07$ ($\eta^2 = .14$); the means were 87 and 68° with lower contra-aligned errors. For group East, the mean error for aligned judgements was 63°, and for contra-aligned judgements 65°; for group West, aligned and contra-aligned means were 59 and 71° respectively. The alignment effect did not approach significance in either group East or West ($ps > .2$). Worthy of note, is that no overall difference in orientation accuracy between men and women was apparent in this experiment, neither were there any interactions between sex and any other factors.

Accurate (relative to the order of the described building locations) sketch maps of the imagined routes were drawn by 16 participants in group North, 18 in group South, 24 in group East and 20 in group West. However, the cardinal direction in the text descriptions influenced map drawing systematically. Of participants who drew accurate maps, all 16 participants in group North drew a map that depicted their 'start point' at the bottom of the page with the first pathway drawn vertically towards the top of the page. For group South, 10 participants depicted their start point at the top of the page with the first pathway drawn vertically down the page, 7 participants drew as described for group North, and one participant drew the first pathway horizontally left to right across the page. Of group East participants, 21 participants drew the first pathway horizontally from left to right across the page, and the remaining 3 participants drew their maps from the bottom, vertically up. Finally, for group West, fourteen participants drew the first pathway horizontally from right to left; 5 participants drew their maps from the bottom, vertically up, and one drew left to right.

One prediction that can be derived from the depicted orientations of these map drawings is that individual participants might perform preferentially well for whichever orientation they drew 'up' (from the bottom to the top of the page), and that 'north=ahead=up' and the first-described perspective might compete for this orientation dominance. For example, the first-perspective alignment effect might be stronger for those participants in group South who drew 'south-up' maps than for those who drew 'south-down' maps. This is because in the 'south-up' case, people equate south = ahead = up, and there is no conflict between a possible tendency to perform preferentially well for the orientation drawn as 'up,' and the first described perspective. In contrast, for the 'south-down' case, there is conflict between better performance for an orientation preferentially drawn as 'up' and the first described perspective, because the latter faces 'down' the page. To test this hypothesis, the error data for group South were collated according to the orientation of map drawings (south-up [n = 7], south-down [n = 10]), and analysed using a 2 x 2 mixed ANOVA with map-orientation ('south' depicted as upward or downward on the page), and alignment (aligned, contra-aligned) as factors. Neither of the main effects nor the interaction between main effects were significant (*p*s

> .2). However, with such small numbers of participants and a very variable response measure, any effect would not be anticipated to be strong.

Overall, the use of cardinal terms in the text produced systematic changes in the data pattern across the four groups: when the first part of the route description was described as north-facing, the first-perspective alignment effect reported by Wilson et al. (1999), and in the 'landmark ahead' conditions of Experiments 3 and 4 was replicated; the effect was attenuated in groups East and West, but when the first part of the route description was described as south-facing, the alignment effect was numerically, although not quite statistically, reversed. Map drawing appeared to reflect a joint influence of first-perspective alignment encoding and the cardinal directions included in the text. Of those who drew accurate maps, all of the participants in group North drew a 'forward-up' map; whereas over half of the participants in group South drew a 'forward-down' map, however, map drawing in this group did not provide evidence for the hypothesis that individual participants might perform preferentially well when maps were drawn 'south-up' in comparison to 'south-down.' Approximately half of the participants in groups East and West drew the first segment of the route with respect to the first cardinal term described; the remaining half drew their maps with the first part of the route depicted vertically up the page.

The results of this preliminary investigation suggest that cardinal terms provide an allocentric reference system that either opposes the default forward-up-north equivalent frame, or encourages orientation-free learning; to investigate these possibilities, a better controlled replication was conducted in Experiment 6.

Experiment 6

Experiment 6 addressed the design and procedural limitations of Experiment 5 in a number of ways. First, all participants were tested by a single experimenter, to assure uniformity to the procedure, and the method of measuring orientation judgements used by Wilson et al. (1999), and in Experiments 2-4 was employed. In a similar design to that used for Experiment 3, two descriptions were used in order to counterbalance the direction of imagined turns and the relative lengths of the first and second segments of the route. In addition to the orientation judgements reported in Experiment 5, participants were also asked to make distance estimates, and latency data were recorded for both orientation and distance measures. Given the different direction of alignment effects found in the groups of Experiment 5, it was important to replicate these effects alongside the first-perspective alignment effect reported by Wilson et al., in which initial orientation was described as 'ahead' and Experiments 3 and 4 of the present chapter, in which initial orientation was described as 'the direction you plan to walk;' therefore, each participant served in two conditions: in one condition the text contained cardinal terms, and in the other, no cardinal terms were used and initial orientation was always described as 'ahead.'

It was hypothesized that under the 'no cardinal' condition, the first-perspective alignment effect found by Wilson et al. (1999), and in Experiments 3 and 4 would be replicated. Where cardinal terms were introduced, a replication of the effects found in Experiment 5 was hypothesized; of particular interest was whether the suggestion of a reversal of the alignment effect in group South found in that experiment would also be replicated.

Method

Design

In a mixed design, participants read two text descriptions of different three-path routes through city streets. The within-participant independent variable was whether the text contained cardinal directions ('cardinal'), or whether no cardinal directions were included ('no cardinal'), with the initial orientation described as "ahead" and 90° turns described as left- and right-hand. In the cardinal condition, the text descriptions included cardinal terms that differed between sub-groups, as in Experiment 5. After reading each passage of text, participants made two orientation judgements, one from an aligned and one from a contra-aligned perspective from each of the four building locations described in the text. The eight test questions were counterbalanced for alignment (aligned, contra-aligned), facing orientation (the test locality being in front of or behind the imagined test orientation), and the part of the route from which the judgement was made (first or last segment of the route). The dependent variables were as described for Experiments 2, 3 and 4.

Participants

The participants were 64 first- or second-year undergraduates from the University of Leicester, UK, and all received credit towards the fulfilment of a practical course requirement. They had a mean age of 20.3 years (range: 18-55), and 14 participants were men.

Apparatus

Preliminary written instructions were identical to those used in Experiment 3 (see Appendix A), as were the two routes upon which the descriptions were based; for ease of reference, plan diagrams of these routes are re-presented in Figure 2.6.1.

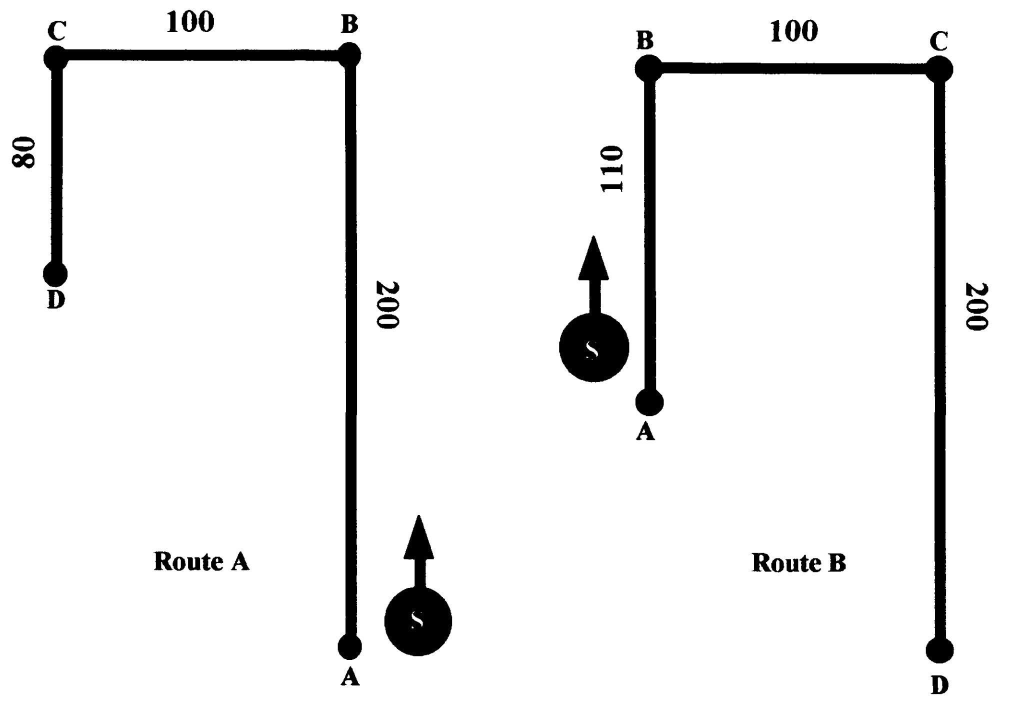


Figure 2.6.1: Plan diagrams (not to scale) of the two routes used in Experiment 6. Illustrated are the positions of the target buildings (ABCD), the relative distances in metres between them, and the start position described in the text (large circle and arrow).

For each of these routes, five descriptions were prepared: one with the initial orientation described as "ahead," and four that described the initial orientation as either north- south- east- or west-facing, as in Experiment 5 (see Appendix C). To make the angle estimates, participants used the white circular dial that was employed in Experiments 2-4; reaction times were measured using a hand-held stopwatch.

Procedure

Participants were tested individually in a quiet room by one experimenter, and all took part in both the cardinal and the no cardinal condition, in a counterbalanced order.

The two versions of the route (left and right turns) were presented in a counterbalanced order across the cardinal and no cardinal conditions. Immediately following each text description, eight alignment test questions were presented (four aligned and four 180° contra-aligned with the first section of the route description). The alignment test questions were counterbalanced to include the factors of alignment, facing direction and route section and, as for Experiments 2-5, required participants to indicate the direction of one of the buildings described in the text while imagining themselves located at a second building. Following each orientation measure, participants were asked to estimate the straight-line distance, in metres, from their imagined location to the target building. The alignment and distance test questions for the two routes were identical to those used in Experiment 3 (see Appendix C). .

After testing had been completed in both conditions, all participants were asked to draw line diagrams of their imagined cardinally described route; a randomly selected 40 participants from the 'no cardinal' condition were then asked to draw line diagrams of the route described as "ahead." Participants were also asked to complete questions 1 and 2 of the written questionnaire used in Experiment 2.

Results and Discussion

Because the number of men was too small to make meaningful between-group comparisons, sex was not included as a factor in the following analyses.

The data of primary interest are the absolute orientation errors in the alignment tests for the 'cardinal' and 'no cardinal conditions.' To establish the effects of the additional between-participants factor in condition cardinal, the error and latency data for orientation judgements were analysed separately for each condition. Also included as a factor in all of these analyses was whether each condition was tested first or second in the repeated measures procedure.

The orientation error scores were derived in the same way as for Experiments 2-4, and descriptive statistics for the cardinal and no cardinal conditions are presented in Tables 2.6.1 and 2.6.2 respectively.

Table 2.6.1

Descriptive Statistics (tabled in degrees) for Aligned and 180° Contra-aligned Absolute Orientation Error Scores for Groups North, South, East and West in the Cardinal Condition.

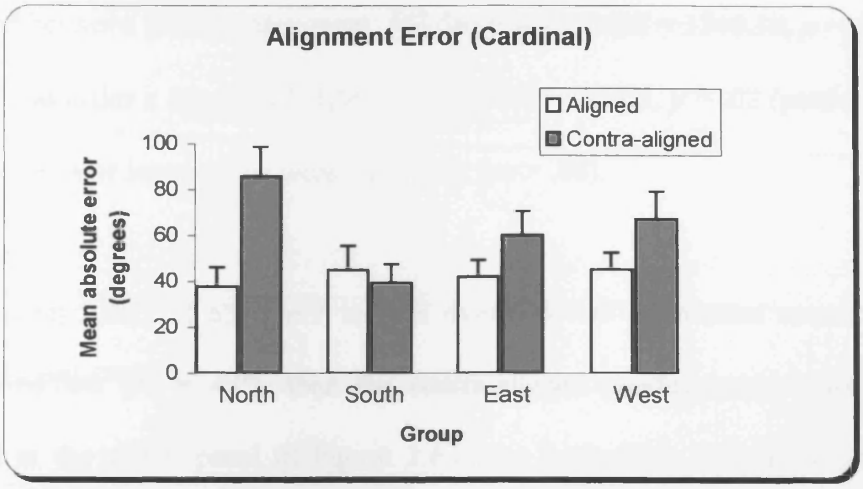
	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Group North							
Aligned	16	6.25	125.00	37.34	34.60	18.91	55.78
Contraaligned	16	3.75	171.25	85.78	51.00	58.61	113.00
Group South							
Aligned	16	6.25	136.25	44.61	43.40	21.48	67.74
Contraaligned	16	3.75	115.00	39.06	33.90	21.00	57.12
Group East							
Aligned	16	5.00	78.75	41.88	29.57	26.19	57.63
Contraaligned	16	11.25	143.75	60.16	42.37	37.58	82.73
Group West							
Aligned	16	6.25	116.25	45.00	30.55	28.72	61.28
Contraaligned	16	3.75	127.50	67.20	48.37	41.52	93.00

Table 2.6.2.

Descriptive Statistics (tabled in degrees) for Aligned and 180° Contra-aligned Absolute Orientation Error Scores for Groups North, South, East and West in the 'No Cardinal' Condition

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Group North							
Aligned	16	8.75	93.75	43.13	28.95	27.70	58.55
Contraaligned	16	8.75	167.50	84.77	53.44	56.29	113.24
Group South							
Aligned	16	6.25	78.75	25.15	22.76	13.03	37.29
Contraaligned	16	1.25	133.75	48.75	43.26	25.70	71.80
Group East							
Aligned	16	7.50	76.25	28.20	21.70	16.64	39.77
Contraaligned	16	10.00	156.25	58.28	41.47	36.18	80.38
Group West							
Aligned	16	8.75	110.00	35.08	32.88	17.56	62.60
Contraaligned	16	13.75	176.25	73.52	45.17	49.45	97.58

The mean absolute angle errors for the 'cardinal' condition are illustrated in the upper panel of Figure 2.6.2.



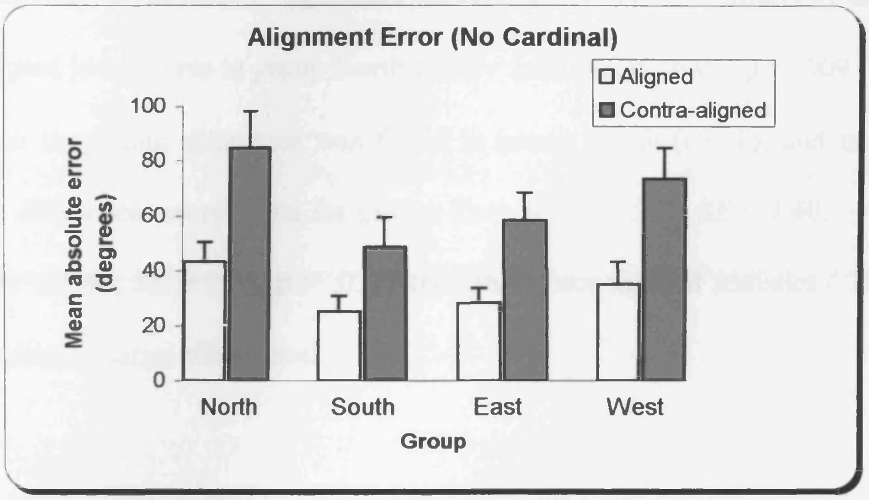


Figure 2.6.2. Experiment 6: Mean absolute error scores under the cardinal (upper panel) and no cardinal (lower panel) conditions for aligned and contra-aligned judgements in groups North, South, East and West. Error bars represent one estimated standard error above the mean.

The 'cardinal' condition orientation error data were entered into a 2 x 4 x 2 x 2 x 2 mixed ANOVA with order (whether this condition was run first or second) and group (North, South, East, West) as between-participant factors; direction (test locations that were either in front or behind participants' imagined orientation at test), alignment (aligned, contra-aligned), and route section (first or last segment of the route), served as within-participant factors. This analysis found statistically significant main effects of alignment, $F(1,56) = 14.84$, $MSE = 3746.18$, $p < .001$ (partial $\eta^2 = .21$), and order, $F(1,56) = 17.70$, $MSE = 122357.86$, $p < .001$ (partial $\eta^2 = .24$). Significant interactions were found between group x alignment, $F(3,56) = 4.18$, $MSE = 3746.18$, $p = .01$ (partial $\eta^2 = .18$), and order x direction $F(1,56) = 6.23$, $MSE = 858.5$, $p = .02$ (partial $\eta^2 = .10$). No other effects or interactions were significant (*ps* > .08).

The main effect of alignment reflects overall lower orientation errors under the aligned condition ($M = 42°$), than the contra-aligned condition ($M = 63°$). As is suggested in the upper panel of Figure 2.6.2, the interaction between alignment and group represents a statistically significant difference between the means of aligned and contra-aligned judgements in group North $t(15) = 3.02$, $SE = 16.03$, $p = .009$ ($\eta^2 = .38$), whereas no significant difference was found in group South ($t < 1$), and intermediate significant differences were found for groups East, $t(15) = 2.47$, $SE = 7.40$, $p = .03$ and West $t(15) = 2.46$, $SE = 9.03$, $p = .03$, although the eta squared statistics (.29 for both groups) indicated large effect sizes.

The order effect reflects overall lower errors when the cardinal condition was run second ($M = 37°$), in comparison to when undertaken before the no cardinal condition ($M = 68°$); however, the difference between aligned and contra-aligned judgements in group North, and the lack of this alignment effect in group South, occurred irrespective of whether condition 'cardinal' was tested first or second, see Table 2.6.3 below.

Table 2.6.3
Mean Absolute Aligned and 180° Contra-aligned Orientation Error Scores for Groups North and South by Order of Testing the Cardinal Condition.

	N	Mean Absolute Error	
		Aligned	Contra-aligned
Tested First			
Group North	8	55.63	82.81
Group South	8	59.22	50.63
Tested Second			
Group North	8	19.06	88.75
Group South	8	30.00	27.50

The interaction between order of testing and direction results from lower overall errors for targets that were behind (M = 63°) rather than in front of (M = 74°) participants' imagined facing orientation at test when the 'cardinal' condition was undertaken first. When this condition was undertaken second, errors were reduced, and were of similar magnitude (Ms = 36 and 38° for front and behind judgements respectively).

The mean absolute angle errors for condition 'no cardinal' are illustrated in the lower panel of Figure 2.6.2. A similar analysis to that conducted for the 'cardinal' condition error data found a significant main effect of alignment, $F(1, 56) = 32.32$, $MSE = 4427.46$, $p < .001$ (partial $\eta^2 = .37$), and a significant order x group x alignment x route section interaction $F(3, 56) = 2.72$, $MSE = 1399.77$, $p = .05$ (partial $\eta^2 = .13$). No other main or interaction effects were significant (ps > .05). The main effect of alignment reflects lower overall orientation errors under the aligned (M = 33°) than the contra-aligned condition (M = 66°). Individual planned comparisons of the alignment effect for each group separately found the effect to be significant in all cases: for group North, $t(15) = 3.20$, $SE = 13.01$, $p = .005$; for group South, $t(15) = 2.21$, $SE = 10.68$, $p =$

.043; for group East, $t(15) = 2.93$, $SE = 10.25$, $p = .01$; and for group West, $t(15) = 2.93$, $SE = 13.08$, $p = .01$. The eta squared statistics for groups North, South, East and West (.41, .25, .36 and .37 respectively) indicate large effects, with substantial differences between the means of aligned and contra-aligned scores in all cases. Further analysis of the four-way interaction did not reveal any consistent effects relevant to alignment.

Descriptive statistics for the latency data in the 'cardinal' and 'no cardinal' conditions are presented in Tables 2.6.4 and 2.6.5 respectively; the mean latencies for both conditions are illustrated in Figure 2.6.3.

Table 2.6.4

Descriptive Statistics (tabled in seconds) for Aligned and 180° Contra-aligned Orientation Latency Data for Groups North, South, East and West under the Cardinal Condition.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Group North							
Aligned	16	1.75	18.15	6.79	3.78	4.78	8.80
Contraaligned	16	4.00	14.60	9.21	3.47	7.36	11.06
Group South							
Aligned	16	3.75	25.40	10.02	6.04	6.80	13.23
Contraaligned	16	3.50	28.54	13.53	7.39	9.62	17.44
Group East							
Aligned	16	2.69	20.13	7.07	4.90	4.46	9.68
Contraaligned	16	2.75	13.43	13.53	7.64	5.80	9.50
Group West							
Aligned	16	3.28	23.50	9.68	5.56	6.72	12.64
Contraaligned	16	3.25	37.7	11.78	9.05	6.96	16.61

Table 2.6.5

Descriptive Statistics (tabled in seconds) for Aligned and 180° Contra-aligned Orientation Latency Data for Groups North, South, East and West in the No Cardinal Condition.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Group North							
Aligned	16	2.79	16.50	7.94	3.99	5.81	10.07
Contraaligned	16	3.75	13.96	9.18	3.29	7.42	10.93
Group South							
Aligned	16	2.91	16.75	8.13	3.86	6.08	10.19
Contraaligned	16	3.71	31.50	12.80	7.00	9.07	16.53
Group East							
Aligned	16	1.81	17.25	6.01	4.90	3.76	8.27
Contraaligned	16	4.00	24.25	8.83	5.47	6.92	12.75
Group West							
Aligned	16	3.25	22.75	7.24	5.28	4.43	10.06
Contraaligned	16	3.83	22.47	9.57	5.26	6.77	12.37

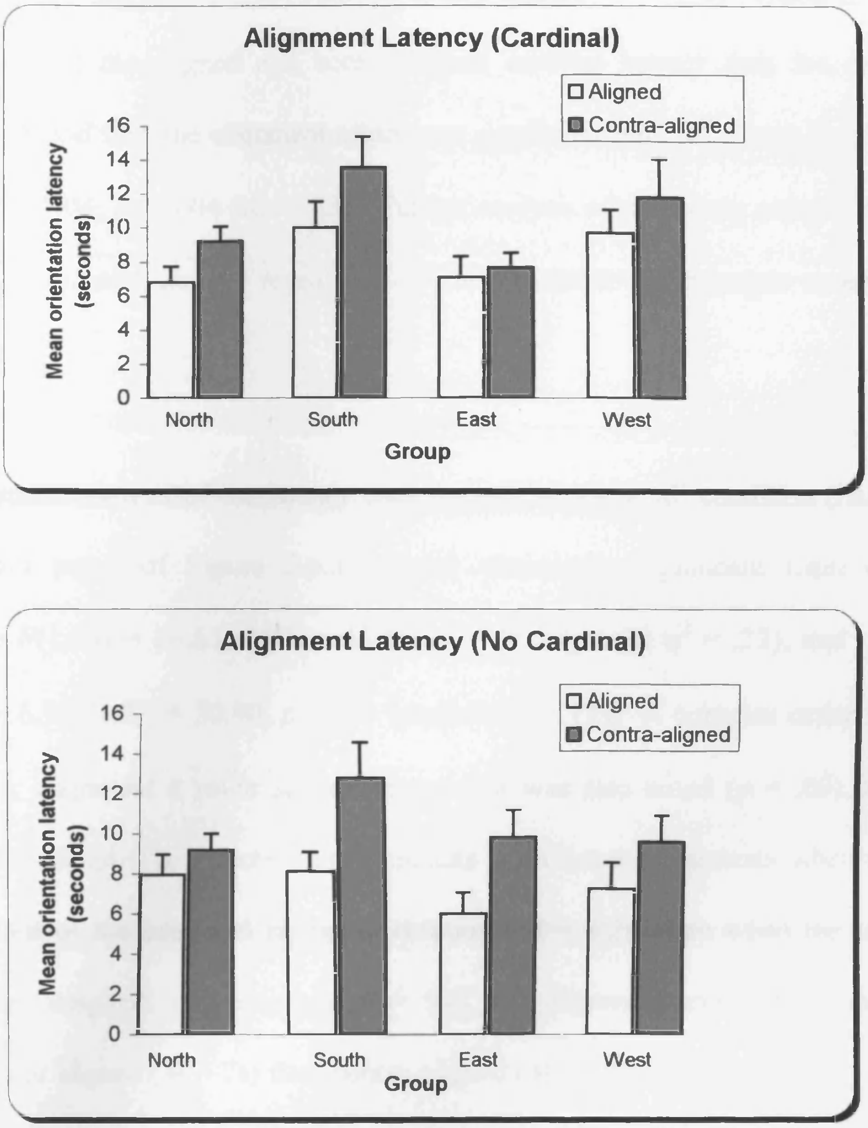


Figure 2.6.3. Experiment 6: Mean orientation latency scores under the cardinal (upper panel) and no cardinal (lower panel) conditions for aligned and contra-aligned judgements in groups North, South, East and West. Error bars represent one estimated standard error above the mean.

The orientation latency data were analysed in the same way as the absolute angle error data. The analysis of condition 'cardinal' found a significant main effect of alignment, $F(1,56) = 10.32$, $MSE = 57.25$, $p = .002$ (partial $\eta^2 = .16$), and a significant order X direction X alignment interaction $F(1,56) = 5.57$, $MSE = 40.78$, $p = .022$ (partial $\eta^2 = .16$). No other effects or interactions were significant (ps > .05). As illustrated in the top panel of Figure 2.6.3, the alignment effects reflects lower overall latencies in the aligned (*M* = 8s) than the contra-aligned (*M* = 11s) condition. Planned comparisons of the aligned and contra-aligned cardinal latency data for each group separately found that the alignment effect was significant only for group South, $t(15) = 3.39$), $SE = 1.04$, $p = .004$ ($\eta^2 = .43$). Further analysis of the 3-way order x direction x alignment interaction did not reveal any effects relevant to the principle variables under investigation.

A similar analysis of the latency data for the 'no cardinal' condition (illustrated in the bottom panel of Figure 2.6.3), found statistically significant main effects of alignment $F(1,56) = 26.65$, $MSE = 43.57$, $p < .001$ (partial $\eta^2 = .32$), and direction $F(1,56) = 6.93$, $MSE = 30.90$, $p = .01$ (partial $\eta^2 = .11$). A complex order x group x direction x alignment x route section interaction was also noted ($p = .03$), but is not discussed in detail. The direction effect results from faster judgements when the target was in front of the imagined facing orientation (*M* = 8.2s) than when the target was behind the imagined orientation (*M* = 9s); the alignment effect represents faster responses for aligned (*M* = 7s) than contra-aligned (*M* = 10s) judgements.

In the 'cardinal' condition, all participants drew procedurally accurate line diagrams of their imagined routes, and the cardinal directions mentioned in the text systematically influenced drawing. With one exception, all participants in group North drew a diagram that depicted their 'start' point at the bottom of the page with the first pathway drawn vertically towards to the top of the page; the remaining participant drew vertically from the top to the bottom of the page. In group South, 7 participants depicted their start point at the top of the page with the first pathway drawn vertically down the page, and 9 participants drew the path as described for the majority of group North. For group East, 13 participants drew the first pathway horizontally from left to right, and one drew horizontally right to left; one participant depicted the start point at the bottom of the page with the first pathway drawn vertically towards the top of the page, and one drew vertically from the top to the bottom of the page. Finally, for group West, 12 participants drew the first pathway horizontally from right to left, one drew horizontally from left to right, and 3 drew vertically up from the bottom to the top of the page. For the 'no cardinal' condition, route diagrams were collected from 40 participants, all of whom drew procedurally accurate diagrams. Of these, 37 participants depicted the first pathway vertically from the bottom to the top of the page; one drew vertically from the top to the bottom of the page, and 2 drew horizontally from right to left. As for Experiment 5, to test the prediction that individual participants might perform preferentially well for whichever orientation they drew 'up' (from the bottom to the top of the page), and that 'north=ahead=up' and the first-described perspective might compete for this orientation dominance, the error and latency data for group South were collated separately according to the orientation of map drawings. The error data (south=up [n = 9], south=down [n = 7), were analysed using a 2 x 2 mixed ANOVA with map-orientation ('South' depicted as up or down the page), and alignment (aligned, contra-aligned) as factors. Consistent with the outcome of Experiment 5, neither of the main effects nor the interaction between main effects were significant (*F*s < 1). A similar analysis of the orientation latency data found a main effect of alignment, $F(1, 14) = 11.36$, $MSE = 8.97$, $p = .005$ (partial $\eta^2 = .49$) that reflects lower overall latencies for aligned (M = 10s) than contra-aligned (M = 14s) judgements. However, the interaction between this factor and map-orientation was not significant ($p = .09$).

When asked to indicate their experiences while reading the text, one participant reported not being aware of any internal visual images, 29 reported being able to envisage a ground-level perspective, either 'as though actually walking' 22 participants or from an 'external' perspective (7 participants), 7 participants reported envisaging an overhead perspective, and 27 participants reported 'visualising just the streets and locations, not myself.' Of the 29 participants who had envisaged a ground-level perspective while reading, 19 maintained this perspective while answering the orientation test questions, six switched to an overhead perspective, and 4 imagined 'just the streets and locations.' For the 7 participants who reported adopting an overhead perspective while reading, 4 maintained this perspective at test, 2 switched to a ground-level perspective, and the remaining 2 participants imagined 'just the streets and locations.' Finally, of the 27 participants who imagined 'just the streets and locations' during reading, 17 participants maintained this representation, 5 switched to an overhead perspective, and 5 switched to a ground level perspective. In summary, just under half the participants (29) in the current experiment were able to imagine a ground level perspective while reading, and more than half of these (19) were able to maintain this perspective at test. Quite striking in this experiment is that a similar number of participants (27) reported imagining 'just the streets and locations' during reading; presumably from a fixed perspective 'outside' the described scene (Taylor & Tversky, 1996).

Consistent with the experimental hypothesis, the pattern of data for the orientation errors in condition 'no cardinal' was similar to that found by Wilson et al., (1999) and in Experiments 3 and 4 (present chapter), irrespective of whether this condition was run first or second. In the 'cardinal' condition, although overall errors were attenuated when this condition was run second, by comparison to when run first, the pattern of orientation errors was similar to that found in Experiment 5. In group North the data conformed to a first-perspective alignment effect with greater errors for judgements that were contra-aligned rather than aligned with the first part of the route description; in groups East and West the first-perspective alignment effect was less evident than in group North; and in group South, similar aligned and contra-aligned errors were found; this latter outcome for group South held, irrespective of whether condition cardinal was tested first or second under the repeated measures conditions. Clearly, the introduction of cardinal terms in the text route descriptions had a systematic effect on orientation accuracy.

The borderline significant reversal of the alignment effect in group South that was noted in Experiment 5 was not replicated in Experiment 6. Instead, the data appear to reflect orientation-free learning for that group, in that aligned and contra-aligned judgements were both at approximately the same level of accuracy as those in the aligned condition of group North, and they were more accurate than the contra-aligned judgements in group North. Given the more uniform procedure and complete counterbalancing in the present experiment, it seems reasonable to afford more weight to what appears to be an orientation-free pattern of learning found here than the reversal pattern in Experiment 5.

While the latency data in the 'no cardinal' condition generally conform to the pattern for the relevant orientation error data, in the 'cardinal condition,' the latency data from group South do not conform to the orientation error pattern for that group; the cardinal orientation error data for this group are consistent with orientation-free learning, whereas the time data indicate that the first-perspective alignment effect is still present for this group. However, this picture is complicated by the overall trade off between accuracy and latency; as is apparent in the upper chart in Figure 2.6.3, group

South took longer overall to make their orientation judgements than group North, and this could account for the greater accuracy of their judgements overall.

To summarize the crucial north-south data: the latency data suggest, first, that overall, group South found it more difficult to orient themselves at test than did group North; and second, that group South found making judgements that were contra-aligned with the first part of the route more difficult than making judgements that were aligned with the first part of the route. The error data revealed that group South were equally accurate in making aligned and contra-aligned judgements. Taken together, the orientation and latency data for group South do not suggest an orientation-free memory, but do lend support to the hypothesis that group South processed more information than group North while making their orientation judgements. It appears that because north and south are cardinally and conceptually, opposite, conflict between a default forward-up-north-equivalent frame of reference and a south-facing allocentric frame may have incurred additional processing (and hence, better learning), to bring the two reference frames into alignment in order to carry out the orientation task, resulting in the lack of a first-perspective alignment effect in group South and intermediate effects in groups East and West.

The data on front- and back-facing judgements hint at different processing under the cardinal and no cardinal conditions. In the cardinal condition, and when tested first, back-facing orientation errors were slightly lower than front-facing; by contrast, there was no effect of this factor in the no cardinal condition error data. No direction effect was apparent in the cardinal latency data, but in the no cardinal condition, front-facing judgements were made faster than back-facing judgements.

In neither condition was there a main effect of 'route section' apparent in the analyses of the orientation error and latency data and with one exception (a complex 5-way interaction between order x group x direction x alignment x part of route in the latency data for condition 'no cardinal'), there were no significant interactions involving this factor. Therefore, consistent with the results of Experiments 2-4, but at odds with an explanation of the first-perspective alignment effect in terms of learning the routes as a series of views, there appear to be little or no differences in the this type of alignment effect depending on whether the imagined test location is on the first or last part of the route.

Chapter 2: Summary

The results of a map-drawing task in Experiment 1 provide evidence that, just as when learning is from maps (Levine, 1982), or from directly walking a path (Palij, Levine & Kahan, 1984), participants apply forward-up equivalence in the construction of memories of a simple three-segment path learned from a text description. Even though no initial orientation was described in the text, maps were depicted with the second point or object described on the route as above the first point or object; that is, participants had a bias toward drawing the *initial* segment of the first pathway vertically, from the bottom to the top of the page. This important finding of a preferred orientation in spatial memory suggests that the mental representations derived from text descriptions appear to be organized within an egocentric reference system that works on the basis of 'forward-up equivalence,' and as such, may share properties with the 'north-up' principle of cartographic map learning. On the basis of this outcome, it was hypothesized that one way to reduce the cognitive effort required for the necessary updating of orientation and position which egocentric encoding necessarily incurs, would be to introduce an allocentric frame of reference into the text.

In Experiment 2, participants had difficulty in learning the spatial arrangement of an array of external landmarks explored in a VE, which were later described in text as surrounding an internal route. As a large number of experiments have demonstrated successful route learning and knowledge acquisition about locations from VEs (e.g. Pèruch et al., 1995, Rossano & Moak, 1998; Tlauka & Wilson, 1994; Wilson et al., 1999), it was anticipated that prior learning from a VE might establish an allocentric frame of reference which could be subsequently incorporated into text-based spatial information without excessively increasing cognitive load (Sweller, 1998, 1994).

However, participants were poor at encoding the information provided by the VE, and subsequent tests of orientation based on text descriptions that incorporated the same distal landmarks as those explored resulted in a strong first-perspective alignment effect.

In a modified procedure from that used in Experiment 2, participants in Experiment 3 read a route description that provided external landmark information, but the experiment was entirely text-based, and the number of external landmarks was reduced from four to one. Participants took part in two conditions. In one, the text-route description referred to a large external landmark positioned either in front of or behind the start orientation of the route; it was anticipated that the first-perspective alignment effect might be attenuated in the latter case by increasing the salience of an allocentric perspective in opposition to the first perspective. In a second condition, no landmark information was included. Initial orientation was described as "the direction you plan to walk" in both conditions. Under the condition where no landmark information was provided, and no initial orientation was described in the text, the overall patterns of orientation error and latency data were similar to those found by Wilson et al. (1999), when initial orientation was described as "ahead." This pattern held, irrespective of whether this condition was tested prior to, or following the 'landmark' condition, and provides further evidence for encoding within a preferred orientation in which people appear to equate the direction of the first path as heading 'north.'

Overall, the data under condition 'landmark' suggested a similar pattern of errors and latencies to that described for the 'no landmark' case. However, the order of testing this condition and the position of the landmark described in the text affected subsequent patterns of orientation error and latency data. When tested first, and when the landmark was described as oriented in front of the first path direction, the error data were consistent with a first-perspective alignment effect; in contrast, when the landmark was described as oriented behind the first path, the first-perspective alignment effect was less evident. As the order of testing the two conditions appeared to be masking important effects, in Experiment 4, an additional 32 participants were tested under a single (landmark) condition.

Contrary to expectation, overall analyses of the error and latency data in Experiment 4 revealed evidence for first-perspective alignment encoding and recall, irrespective of whether the landmark was described as oriented in front of or behind the first path. The outcomes of Experiments 3 and 4, firstly, lend further support for the hypothesis that the text first-perspective alignment effect may occur as a consequence of participants egocentrically encoding the first section of the route on the basis of forward-up-north-equivalence, with the remainder of the route encoded in relation to that first segment. Second, because the environmental information in Experiments 3 and 4 failed to over-ride the egocentric reference system, it appears that the egocentric frame may represent a dominant or preferred form of encoding and recall in comparison with an allocentric frame when learning is from verbal descriptions.

However, in Experiments 5 and 6, the introduction of an allocentric frame of reference conveyed in already familiar cardinal terms systematically affected the text first-perspective alignment effect. In Experiment 5, when participants were asked to imagine that the first part of the route was north-facing, the pattern of error data did not differ from that found by Wilson et al. (1999), who described initial orientation as "ahead," or that observed in Experiments 3 and 4 (present Chapter), in which initial orientation was described as "the direction you plan to walk." When the first part of the route was described as east- or west-facing, the first-perspective alignment effect was less evident than when described as facing north, and the effect was attenuated when the first part of the route was described as south-facing. In Experiment 6, this latter outcome was replicated, irrespective of whether the condition that included cardinal terms was tested first or second under the repeated measures procedure. However, analysis of the latency data from Experiment 6 found that participants in the south-facing cardinal condition were slower to make judgements that were contra-aligned to the first part of the route (consistent with a first-perspective alignment effect), and were slower overall to make aligned and contra-aligned judgements than groups North, East and West. Together, the orientation and latency data do not suggest that the inclusion of cardinal terms in a text description engenders orientation-free learning; rather, that two frames of reference appear to systematically influence the pattern of results.

Before developing a reference frame account of the data from Experiments 1-6, it is worth addressing two alternative accounts of why the text first-perspective alignment effect occurs. The first possibility is that this alignment effect may share similarities with the 'primacy effect' found following serial list learning (e.g. Craik, 1970; Glanzer & Cunitz, 1966). To briefly recapitulate: this account holds that the exploration of the streets that comprised the return journeys used in the present experiments is remembered in the same way as a list of words; for example, in the right hand-panel of Figure 2.6.1: A-B, B-C, C-D, D-C, C-B. B-A. If this were the case, participants may have responded more accurately on A-B than B-A (first section of the route) judgements because A-B was encountered first in the 'list.' If the routes were remembered as a series of views, a serial list account predicts little difference in accuracy and/or latencies for C-D and D-C (last section of the route) judgements because these views would be encountered in the middle of the list. However, analyses of the error and time data in

Experiments 2-4 and 6, found little evidence to support this explanation: the main effect of route section was not found to be significant in any analysis in all four experiments; with two exceptions (a stronger alignment effect on A-B judgements than D-C judgements in the latency data of the cardinal condition [first test] of Experiment 3, and a complex 5-way interaction involving 'route section' under the 'no cardinal' condition in Experiment 6), there were no significant interactions involving this factor. Therefore, there appear to be no consistent differences in this type of alignment effect, depending on whether the imagined test location is on the first or last part of the route. However, given that the first-perspective alignment effect depends, by definition, on the first experienced perspective defining the alignment of orientation judgements, a primacy effect may well play a role in producing the effect; however, there is no reason to believe that the present results should be explained in the same way as serial order free-recall tasks.

The similar patterns of aligned (A-B and D-C in figure 2.6.1), and contra-aligned (B-A and C-D in Figure 2.6.1) error and latency data observed for orientation judgements on the first and last parts of the route suggest a second explanation of the outcomes of Experiments 2-4 and 6; that, participants may have encoded and/or retrieved the entire representation in the same orientation, as has been shown when learning is from maps (e.g. Levine, 1982). If participants adopted a map-like perspective at test, their mental representations would lead to data that resemble those depicted in Figure 2.6.1. The first-perspective alignment effect would be similar to the typical map effect, with judgements from contra-aligned perspectives being less accurate and/or slower than when aligned with this orientation (e.g. Levine, Jankovik & Palij, 1982). For some participants, and as reported by Wilson et al. (1999), this explanation appears to be a possibility. However, the statistically equivalent patterns of aligned and contra-aligned errors for group South in Experiments 5 and 6 are not easily explained in terms of map-like encoding or retrieval; had this been the case, the errors for group South should have been similar to those found for Experiments 2-4, with greater contra-aligned than aligned errors. Further, many participants reported having switched from a ground level to an overhead perspective (or vice-versa) between reading and recall in a manner that was not consistent either within or between experiments.

Neither of the above explanations can fully account for the cumulative patterns of orientation error and latency data presented in the current Chapter. To account for all of the present results, a hypothesis can be formulated that builds on the consistent finding of Wilson et al. (1999), of first-perspective alignment encoding and/or retrieval, when learning is from text descriptions; this account also considers the importance of the cognitive demand incurred in the present orientation task.

Encoding a space in a particular alignment may engender less cognitive resources than constructing a representation that includes multiple orientations, or is orientation-free. The repeated demonstration of the first-perspective alignment effect in Experiments 2 - 6 suggests that there is a strong tendency for people to encode a text route description egocentrically, using the start location as a primary reference point. Golledge (1978; 1984) suggests that such primary reference or psychological 'anchor points' within an environment are used as a basis from which other spatial information can be derived. The first direction of travel from this primary anchor point determines the alignment encoding of the entire route on the basis of a forward-up north equivalent principle. The similar alignment effect on the first and last sections of the route is compatible with this hypothesis, or possibly with the hypothesis that at the end of the route, where the text describes turning through 180°, a second anchor point may be established at the start of the return journey. Thus, both the first section of the route and the first return section may be encoded as 'ahead' or 'north.' The implications of this idea are investigated further in Chapters 3 and 4.

Introducing salient landmarks external to the route into the text descriptions might be expected to attenuate egocentric encoding by providing an allocentric reference frame. Contrary to the experimental predictions, introducing multiple (Experiment 2), or single (Experiments 3 and 4) distal landmarks did not appear to have a significant influence on route encoding from text descriptions - possibly because the landmarks used in these experiments either lacked salience when presented in the context of a number of new spatial relationships, and/or served to increase cognitive demand during learning. However, when a well-established, cardinal allocentric reference frame was invoked, the pattern of effects was found to be consistent with the influence of both egocentric and allocentric encoding. There are two suggestions in the data from group South in Experiment 6 that are compatible with the use of two reference frames: First, slower overall processing in the cardinal condition; and secondly, the contrast between the first-perspective alignment effect found in the orientation latency data and the lack of this effect in the orientation error data, with equal and very accurate aligned and contra-aligned judgements. Overall, the data suggest that egocentric encoding is the primary or default form of alignment encoding when learning is from text descriptions, but that allocentric encoding can have an influence.

However, with respect to perceptual learning, allocentric information may be more salient than when described in text, for example with respect to colour, size or proximity. Based on the absence in their experiments of first-perspective alignment encoding when learning was from VEs, and the similarity between this outcome and the orientation-free patterns of errors observed in studies of real-world perceptual learning (Evans & Pezdek, 1980; Thorndyke & Hayes-Roth, 1982), Wilson et al. (1999) hypothesized that it may be the visual and self-guided nature of VE exploration that results in learning that is closer to real-world learning than is the case when learning is from text (p. 676), and therefore proposed a graded rather than absolute distinction between spatial learning from perceptual experience and that derived from secondary learning media. The environmental surroundings included in Wilson et al.'s VEs, in contrast to the lack of allocentric information in their text descriptions may have provided different frames of reference in which the space could be encoded. If, as Wilson et al. suggested, learning from a VE is more similar to real world learning than is learning from text, then in their VE experiments, participants may have preferentially encoded the space allocentrically. This suggestion is important because the experiments included in the present chapter suggest that the first-perspective alignment effect represents the default form of encoding for text descriptions, whereas for perceptual spatial learning, allocentric encoding may be the dominant form. Experiments 7 and 8 in Chapter 3 provide an investigation of this hypothesis with respect to spatial learning from VEs; in Experiment 9, the findings from these VE experiments are extended to text descriptions.

CHAPTER 3

First-Perspective Alignment Effects in Desk-Top Virtual Environments and Text Descriptions: The Role of 'Active' Spatial Processing

Desktop VE technology can create a visual, three-dimensional representation of an environment that can be explored in real time. Although individual differences have been reported in spatial learning from VEs (e.g. Waller, 2000), this medium is useful for investigating spatial knowledge acquisition. First, because the interface preserves a number of the visual-spatial characteristics that are experienced during real-world exploration; secondly, because all participants can participate under precisely controlled conditions (Bülthoff & van Veen, 1999; see Péruch & Gaunet, 1998; Wilson, 1997 for reviews).

Many experiments have demonstrated evidence for successful route learning and knowledge acquisition about locations in a VE (Péruch, Vercher & Gauthier, 1995; Regian, Shebilske & Monk, 1992; Rossano & Moak, 1998; Tlauka & Wilson, 1994; Wilson, Foreman, Gillett & Stanton, 1997; Wilson, Tlauka & Wildbur, 1999). The information acquired from virtual exploration can be effectively transferred to real-world equivalent environments such as buildings (O'Neil, 1992; Ruddle, Payne & Jones, 1997; 1998; Wilson, Foreman & Tlauka, 1997), and other multi-location environments (Waller, Hunt & Knapp, 1998; Witmer, Bailey, Knerr & Parsons, 1996). The level of spatial knowledge acquisition from VEs is also a good predictor of spatial performance in real-world settings (Richardson, Montello & Hegarty, 1999; Waller, 2000).

However, with respect to orientation effects following VE learning, studies have recorded different outcomes. For example, in an object location task, Tlauka and Wilson (1996) compared the performance of participants who had either actively explored a VE that comprised a central building surrounded by eight objects by actively navigating through it, or who had learned a map-like plan of the same environment. Response latencies suggested that the VE group had encoded the environment from multiple perspectives, whereas the map group had formed an orientation-dependent representation. Consistent with this pattern, Wilson et al. (1999, Experiment 3C) found little evidence for orientation-dependent effects following their participants' exploration of a computer-simulated street scene, even though strong first-perspective alignment effects had been repeatedly established when participants read descriptions of environments which had similar relative dimensions as those explored in the VE. As Wilson et al. tentatively concluded, this difference in patterns of orientation errors between their text and VE conditions suggested that learning from text descriptions is not isomorphic to perceptual learning.

In contrast, in a between group comparison of map, VE and direct learning, Rossano, West, Robertson, Wayne & Chase (1999) reported significantly lower errors for judgements that were aligned to the first part of the route than contra-aligned, which they termed a "first view priority" (p.113). In this study, the participants observed a pre-recorded tour through a VE-simulated section of a University campus. A similar effect was recorded for the map group, whereas participants who learned by exploring the real-world equivalent environment did not show a first-perspective alignment effect. A major procedural difference between the studies of Rossano et al. and Wilson et al. (1999), is that in the latter, participants actively explored the VE, whereas in the former, participants passively viewed a pre-recorded route through the environment. The evidence for superior spatial knowledge acquisition from VEs under 'active control' conditions is mixed (e.g. Christou & Bülthoff, 1997; Pèruch, Vercher & Gauthier, 1995; Larish & Andersen, 1995 for affirming outcomes, but see Wilson, 1993, 1999; Wilson, Foreman, Gillett & Stanton, 1997; Wilson & Pèruch, 2002 for contradictory findings). However, the active nature of VE exploration in Wilson et al.'s (1999) study, in comparison to the passive learning experienced by Rossano et al.'s participants may have, at least in part, influenced the different outcomes.

In a more directly comparable experiment to that of Wilson et al. (1999), Richardson, Montello and Hegarty (1999) asked their participants to learn three corridors arranged in an 'H' shape on two floors of a University campus building, either by studying a map, interactively exploring a desk-top simulation of the building, or by learning through direct exploration of the real building. In a subsequent orientation test that asked them to make between- and within-floor orientation judgements from their memory, an alignment effect was apparent in the map group, and a small but non-significant difference was recorded for those participants who had explored the real building. For the VE group, not only did these participants show the poorest learning of all three groups, but also, their mental representations were encoded with respect to the first segment of the explored route; mean errors for orientation judgements aligned with the start direction were approximately 48° by comparison to approximately 69° for judgements that were misaligned with this direction.

At first glance, the difference in first-perspective alignment outcomes in VEs found by Richardson et al. (1999) and Wilson et al. (1999) is striking, although inspection of Wilson et al.'s VE error and latency data reveals a small numeric difference between the means of both data sets in the direction of a first-perspective alignment effect.

Excluding data from an atypical version of their VE (see Wilson et al., Experiment 3C), mean absolute orientation errors for contra-aligned judgements were 39 and 45° respectively, with mean latencies to make these judgements 10.2 and 11.7 seconds respectively. The two studies were similar in a number of respects: Each used similar numbers of male and female participants (with no differences reported between the sexes in either experiment); methodologically, participants were 'active' in their VE exploration; and in both studies, the VEs depicted pathways arranged so that all intersections were at right angles. There were, however, a number of differences between the VEs and the procedures involved that may have contributed to the different study outcomes. For example, the VE used by Richardson et al. was more complex than that of Wilson et al. The latter comprised a specially constructed, ground-level, three pathway street scene arranged in a U-shape, whereas the VE used by Richardson et al. depicted the interior corridors on two storeys of a six-storey, real-world university building. Each corridor was arranged in an H-shape, and access between corridors was achieved by traversing a flight of stairs that involved eight 90° turns. There were also procedural differences. For each of four simulated street scenes, Wilson et al.'s participants travelled a return-journey from the start to the end point of the route on three successive occasions, then answered orientation questions concerning four designated landmarks; whereas in Richardson et al.'s study, participants were asked to travel the route (i.e. both floors of the tiered environment) from beginning to end, on one occasion only, then to answer orientation test questions on eight designated landmarks – four on each floor. Finally, in Wilson et al.'s VE, the streets adjacent to those that were explored continued into the visible (on screen) distance, creating an 'open' environment, which may have facilitated allocentric encoding, whereas Richardson et al.'s VE comprised an 'enclosed' building interior. As appears to be the case in text descriptions (Chapter 2, Experiments 2-6), it is conceivable that different environmental surroundings may lead to encoding via different frames of reference in VEs.

Experiment 7 employed a within-participant comparison between two versions of a three street VE based on the text descriptions used in Experiments 2 - 6 (Chapter 2), and essentially replicated the general methodology and procedure of Wilson et al.'s original VE study (1999, Experiment 3C). More participants were tested in the present experiment than by Wilson et al., either to make a null result more convincing, or to see whether the small difference between aligned and contra-aligned orientation error and latency scores in that study would exceed chance probability.

Two main research questions were addressed. The first was whether open or enclosed versions of the VE would affect first-perspective alignment encoding. To investigate this question, as in Wilson et al. (1999), for one VE the surroundings were 'open' in that the area surrounding the test route extended outwards from the to-be-explored area; in the other VE, to resemble the simulated corridors explored by Richardson et al.'s (1999) participants, the study area was enclosed by high walls. While no firm predictions were made about the direction of any effects between VEs, it was considered plausible that, consistent with the findings of Richardson et al., the enclosed version of the VE might facilitate first-perspective alignment encoding. The second question was whether the degree of misalignment from the first ahead-north-equivalent frame would systematically affect orientation errors as had been found for text descriptions that employed cardinal terms (Experiments 5 & 6, Chapter 2).

In Wilson et al.'s (1999) study, orientation judgements were made from an aligned (defined as congruent with the first experienced view) perspective, and 180° contra-aligned to that perspective, and the correct orientation judgements were all greater than 90° (i.e. back-facing with respect to participants' imagined orientation at test). Richardson et al. defined alignment similarly, and measured orientations misaligned to the first experienced perspective; by implication, these authors included a mixture of less than (front-facing), and greater than (back-facing), 90° angles. In Experiment 7, alignment was strictly defined with respect to the first, front-facing perspective of the first street that participants explored in the VE, and tests of alignment and distance were carried out while participants imagined themselves aligned, 90° left- and right-misaligned, and 180° contra-aligned with this perspective.

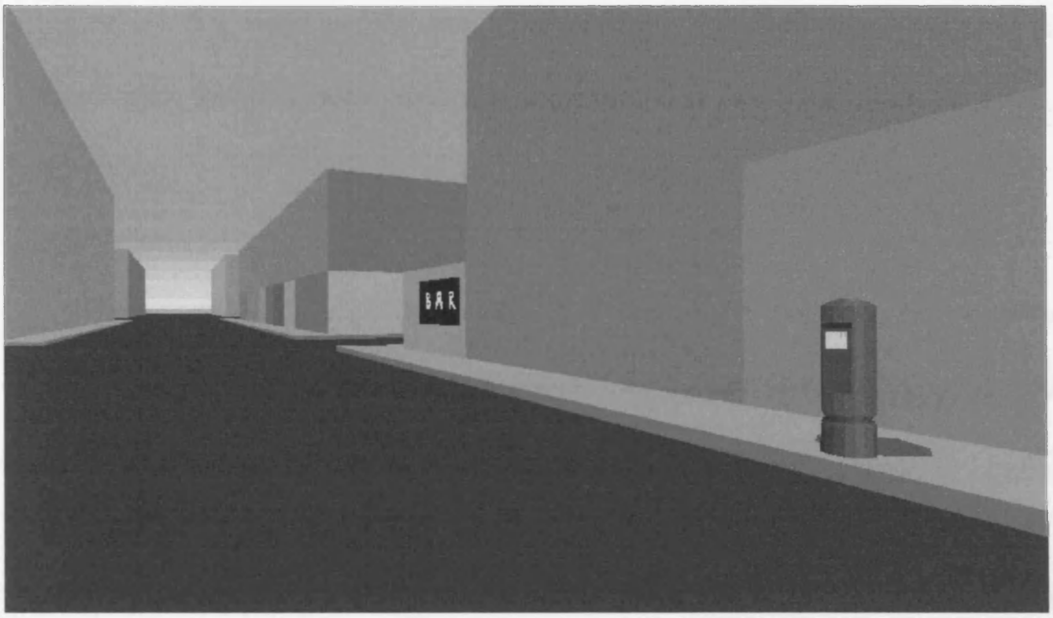
Experiment 7

Method

Design

Participants explored two desk-top VEs that comprised a small part of a city in which the streets intersected at right angles. As illustrated in the top panel of Figure 3.7.1, in condition 'open' the sky was bright blue, and each street continued beyond the end points of the area to be explored, but invisible barriers prevented access beyond the experimental area. In condition 'enclosed' the sky was dark blue, and the area of the city to be explored was separated from the remainder by high, dark grey walls that provided a corridor-like appearance.

(a)



(b)

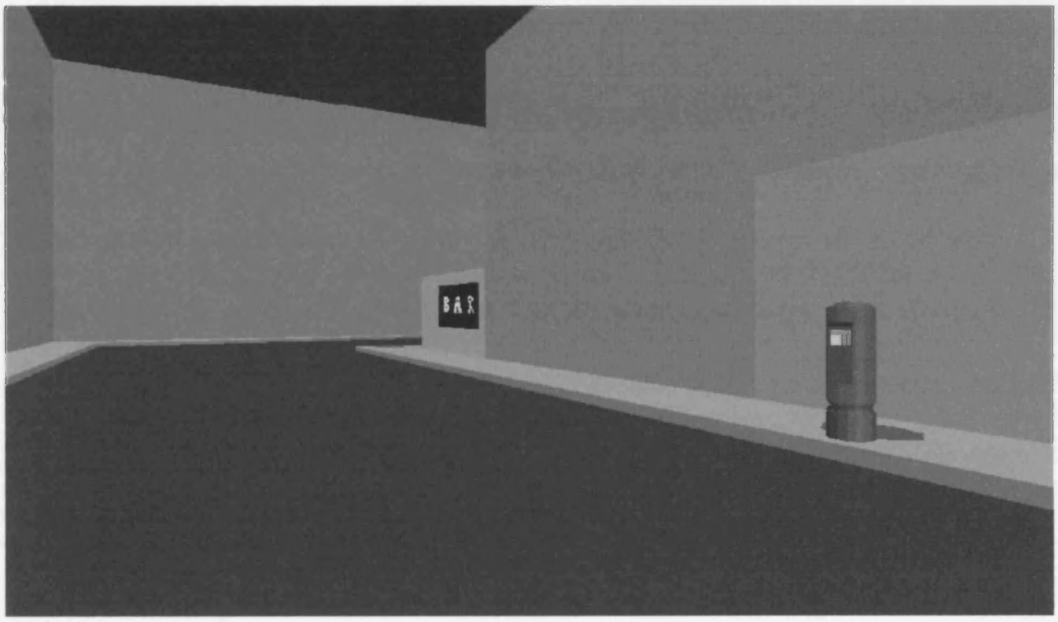


Figure 3.7.1. Grey-scale reproductions of colour screen captures from an 'open' (a) and 'enclosed' (b) version of the same virtual street environment used in Experiment 7.

The dependent variables were angle and distance estimates from imagined perspectives that were aligned, 90° left-misaligned, 90° right-misaligned, and contra-aligned with the first street that was explored, and the time taken to make these judgements.

Participants

These were 48 undergraduates from the University of Leicester, UK, of whom 41 were female, and who received credit towards the fulfilment of a first- or second-year practical course requirement. They had a mean age of 19.6 years (range: 18 - 27 years).

Apparatus

For the main experiment, an open and an enclosed version of two simulated environments were created using the Superscape Virtual Reality Toolkit software; these were presented on an Intel Pentium computer with SVGA graphics, displayed on a 17-inch monitor, and were modelled on two of the environments used by Wilson et al. (1999, Experiment 3C). The open versions of Environment 1 and Environment 2 were visually continuous within a surrounding city environment, whereas high walls to create a corridor-like appearance surrounded the enclosed versions of Environment 1 and Environment 2. Other than whether the environments were open or enclosed, and whether the sky was bright blue (open) or dark blue (enclosed), the open and enclosed versions of VEs open-1 and enclosed-1 were identical, as were VEs open-2 and enclosed-2.

As illustrated in both panels of Figure 3.7.2, each environment comprised a rectangular block of plain coloured buildings at three adjacent corners (labelled B, C and D). For the open and enclosed versions of Environment 1 (left panel of Figure 3.7.2), these were one distinctive object (Post Box), positioned at location A, two detailed buildings (Bar, Bank), positioned at locations B and C respectively, with a fourth landmark (Red Car) positioned at location D. For both versions of Environment 2 (right panel of Figure 3.7.2), the targets were three well-known types of motor vehicle (Tank, Lorry, Land Rover) positioned at locations B, C and D respectively), with a telephone box positioned at location A.

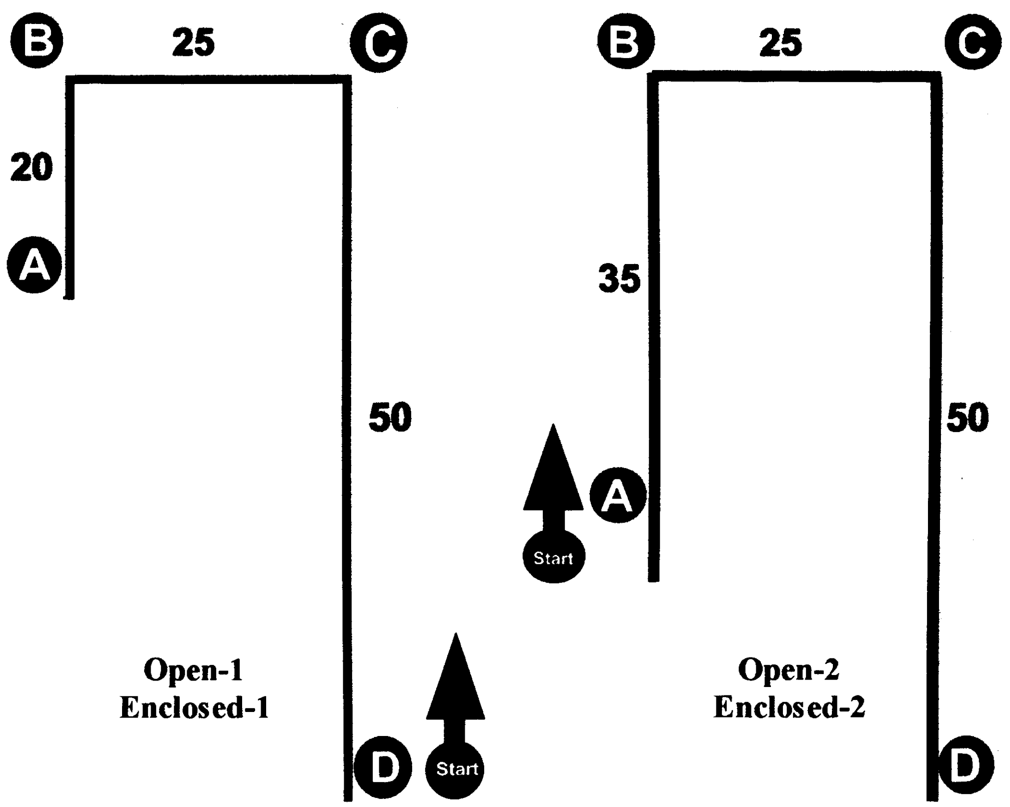


Figure 3.7.2. Experiment 7: Plan diagrams (not to scale) of the four versions of the VE street routes used in the main experiment. Illustrated are the positions of the target locations (labelled ABCD), the relative distances in 'virtual metres' between them, starting position and initial facing direction (circle and arrow respectively).

As illustrated, assuming average eye level to be approximately 170 cm, the real-world equivalent dimensions of the streets in all of the VEs translates to BC = 25m and CD = 50m; for Environment 1, the distance AB was 20m (left panel of Figure 3.7.2), and for Environment 2, the distance AB was 35m (right panel of Figure 3.7.2). For reference when making judgements, the position of each of the target buildings or objects was marked on the inner pavement by an adjacent blue, circular dot. Movement through the VE was effected by pressing the up and down arrow keys to move the view forward and backward, and the left and right arrow keys to effect left and right rotations. Movement was set to a fast walking pace so that a distance of 50m could be travelled in 25 seconds, with a 360° rotation effected in 15 seconds.

A 'pre-training' environment was also created that comprised a 60 metre square compound with 5m high, grey coloured walls. Within the compound were six internal walls (4 x 2 x 0.4m) that were evenly distanced from, and set at odd angles to one another. On each of four of these inner walls, on the opposite side of the wall to that which could be see from the mid-point of the maze, was a distinctive patch, coloured either yellow, red, pink or blue.

Angle estimates in the main experiment were made using the 360°protractor used in Experiments 2-4 and 6. Response latencies to complete these and target distance judgements were made in seconds using a hand held stopwatch.

Procedure

All participants were seated approximately .5m from the centre of the computer screen, and were individually tested in the same room.

For the preliminary training, the pre-training compound VE was presented with the view set in the centre of the compound so that none of the coloured patches on the walls could be seen. Participants read an instructions sheet (see Appendix A), which explained that the purpose of the preliminary phase of the experiment was for them to become accustomed to the keyboard controls; specifically, that they would be asked to explore the environment using the arrow keys while avoiding collision with any of the internal walls, while locating and remembering the positions of the four coloured patches on the far side (from the centre) of the internal walls for a subsequent memory test. A minimum of five minutes per participant was allocated for this exploration, during which, if a participant collided with an interior wall they were returned to the start position and exploration recommenced. At the end of five minutes, participants were offered additional exploration time if required; no-one accepted this offer, and none of the participants reported or were observed to experience any difficulty in manoeuvring through the VE.

For the memory test, the view was set to a location near the centre of the compound where none of the coloured patches could be seen directly, and translation movement using the forward and backward keys was disabled. Using only rotation movements that were effected by pressing the left and right keys, participants were asked to indicate the locations of each of the four coloured patches in turn in a counterbalanced order, by aligning crosshairs in the centre of the computer screen with the wall they considered to bear the coloured target named by the experimenter. Correct and incorrect responses were recorded but not analysed.

On completion of the preliminary training phase, participants were presented with an A4-size instruction sheet (see Appendix A), which informed them that the purpose of the experiment was to investigate memories for scenes, and that they would be asked to explore two VEs, one at a time, that comprised a small part of a city. Participants were informed that each environment contained a number of distinctive buildings or objects that each had its location marked by a large blue dot on the adjacent pavement, and that they would be asked to make judgements from their memories about the location of each of these landmarks from the location of a second landmark, using the blue dots as reference points. Following any clarification of these instructions, the experimenter demonstrated how to use the 360° protractor.

Each participant explored two VEs, one open and one enclosed, and answered eight alignment and distance questions immediately following each exploration. Counterbalancing included first, the arrangement of whether participants initially explored then answered test questions about an open or enclosed version of Environment 1 or 2; second, in order to counterbalance the number of right and left turns and which segment of the route (initial or final) was the longer, in VEs open-1 and enclosed-1, the initial viewpoint (labelled 'Start' in Figure 3.7.2) was set close to landmark D, facing towards landmark C; in environments open-2 and enclosed-2, the initial viewpoint was set close to landmark A facing toward landmark B.

During the initial exploration of each route, and to provide a sense of scale, participants were informed of the real-world equivalent distance between the two buildings or objects that comprised the middle segment of the route (i.e. BC in Figure 3.7.2). Also, the experimenter pointed out the blue dots on the pavement adjacent to each object or building location. When each location had been encountered and named aloud by the participant the experimenter asked him or her to rotate the view through 180° and to return to the start point. Participants were asked to repeat the return-journey on two subsequent occasions, following which they were asked if they had formed a clear memory of the route and landmarks. After participants had explored the first VE, the computer screen was made blank, and participants turned from the screen to face the experimenter while answering eight alignment test questions. This same procedure was repeated for the second street VE.

Alignment was defined with respect to the first, front-facing perspective that participants experienced on their exposure to the VEs. With reference to Figure 3.7.2, 'aligned' was congruent with the direction of the arrow above the 'Start' point for both VEs, with subsequent test questions either aligned, 90° left- or right- misaligned, or 180° contra-aligned with this orientation.

All of the alignment and distance test questions were constructed in the same way as described for the text experiments reported in Chapter 2. Congruent with the orientation of the first experienced perspective depicted in Figure 3.7.2, eight alignment questions were prepared for each of the VEs (see Appendix C): two questions asked participants to imagine themselves aligned with the direction above the 'Start' point (e.g. "Imagine that you are at D, facing C, what is the direction to A?), two to imagine themselves each of 90° right- or left- misaligned with this direction (e.g. "Imagine that you are at B facing C, what is the direction to D?), and two to imagine themselves contra-aligned with this direction (e.g. "Imagine you are at C, facing D, what is the direction to A?). In every pair of alignment questions (2 aligned, 2 left-misaligned, 2 right-misaligned, and 2 contra-aligned) one question asked for a judgement that was 'front-facing' (i.e. the correct judgement was less than 90° left or right), and the other question asked for a judgement to which the correct answer was 'back-facing' (i.e. greater than 90° left or right). The order in which left and right judgements were presented, and whether the judgement was front- or back-facing was counterbalanced. The order of the alignment test questions (aligned, left- and right-misaligned, or contra-aligned with the first perspective) was arranged according to a Latin Square, counterbalanced across the above factors. Between participants and across the front- and back-facing judgements, half of the aligned questions and half of the contra-aligned questions described participants' imagined location on the first segment of the route (i.e.

in Figure 3.7.2: DC in open-1 and enclosed-1; and AB in open-2 and enclosed-2, and the remaining questions described imagined locations on the final segment of the route (i.e. in Figure 3.7.2: AB in open-1 and enclosed-1, and CD in open-2 and enclosed-2).

With respect to the presentation of the test questions, and use of the 360° protractor to make orientation judgements, the remainder of the procedure was identical to that used in Experiments 2-4 and 6 (Chapter 2). On completion of the experiment, participants were asked to describe in their own words, the method they used to complete the alignment tests.

Results and Discussion

As for the experiments reported in Chapter 2, the distance error data for the experiments reported in the present Chapter were analysed in both raw form and when converted to account for individual differences in baseline distance estimates. Again, neither of these analyses, nor analysis of the distance time data proved to be sensitive to any of the variables under investigation, and are not reported. Sex was excluded as a factor in the analyses of the orientation error and latency data reported below due to the relatively small number of men compared to women who took part in the experiment.

The left- and right- facing misaligned judgement data for each participant were averaged for all of the following analyses, and are reported as 'misaligned.' As in the text experiments reported in Chapter 2, orientation errors were derived by subtracting the participant's estimated angles of the direction to test locations from the true angles and taking the unsigned value. Descriptive statistics for these data and the time taken to make orientation judgements are presented in Tables 3.7.1 and 3.7.2 respectively.

Table 3.7.1
Descriptive Statistics (tabled in degrees) for Aligned, 90° Misaligned, and 180° Contra-aligned Absolute Error Scores under the 'Open' and 'Enclosed' Conditions

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Open							
Aligned	48	2.50	162.50	38.80	38.63	27.59	50.02
Misaligned	48	5.00	132.50	42.66	31.75	33.05	51.48
Contraaligned	48	5.00	172.50	43.07	44.78	30.07	56.06
Enclosed							
Aligned	48	.00	142.50	37.03	33.60	27.27	46.79
Misaligned	48	5.00	136.25	48.91	34.78	38.81	59.01
Contraaligned	48	2.50	170.00	48.54	43.76	35.84	61.25

Table 3.7.2
Descriptive Statistics (tabled in seconds) for Aligned, 90° Misaligned, and 180° Contra-aligned Latencies under the 'Open' and 'Enclosed' Conditions.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Open							
Aligned	48	2.50	25.50	7.26	4.60	5.92	8.60
Misaligned	48	3.25	34.00	11.20	6.49	9.31	13.08
Contraaligned	48	2.00	36.00	8.54	6.62	6.62	10.46
Enclosed							
Aligned	48	3.00	44.50	8.39	7.31	6.26	10.51
Misaligned	48	2.75	31.25	10.65	6.28	8.83	12.48
Contraaligned	48	3.00	28.00	8.69	6.00	6.94	10.43

The orientation and latency data were analysed individually using 2 x 2 x 2 x 3 mixed ANOVAs. In each case; the between-participants factor was 'order' (of testing the two environments), and the within-participant factors were VE (open or enclosed environment), 'direction' (test locations that were either in front of or behind the imagined facing direction at test), and 'alignment' (aligned, misaligned and contra-aligned with respect to the first part of the route).

Analysis of the absolute orientation errors found a statistically significant order of testing x VE x direction interaction, $F(1, 46) = 7.16$, $MSE = 556.37$, $p = .01$ (partial $\eta^2 = .14$). No main effects and no other interactions were significant (*p*s >.08). Therefore, the data for the VEs that were tested first and second were analysed separately using 2 x 2 x 3 mixed ANOVA analyses, with VE (open or enclosed for half the participants) as the between-participant factor, and direction and alignment as within-participant factors. The mean orientation errors for the VEs that were tested first and second are presented in the upper and lower panels of Figure 3.7.3 respectively. As differences in alignment effects were not found to be consistently related to whether the explored VEs were open or enclosed, the data from both conditions are averaged for illustration.

Analysis of the mean orientation errors for the condition that was tested first found a significant main effect of alignment $F(2, 76) = 4.17$, $MSE = 1969.21$ (Greenhouse-Geisser adjustment) $p = .02$ (partial $\eta^2 = .08$), that reflects lower overall errors in the aligned condition than under the 90° misaligned $t(47) = 2.60$, $SE = 4.94$, $p = .01$ ($\eta^2 = .13$), and contra-aligned conditions $t(47) = 2.28$, $SE = 6.96$, $p = .03$ ($\eta^2 = .10$), which did not differ ($t < 1$). No other main effects or interactions between main effects were statistically significant (*p*s > .07).

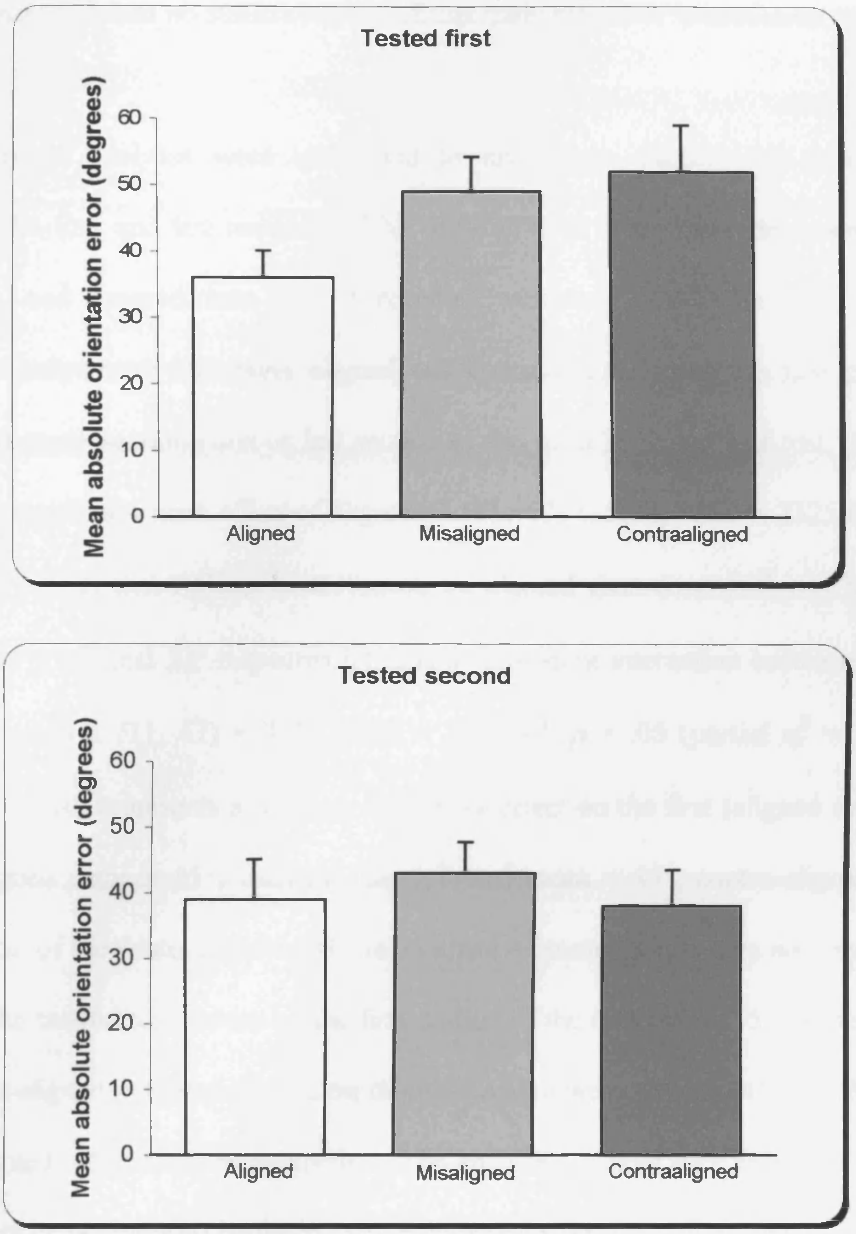


Figure 3.7.3. Experiment 7: Mean absolute errors for aligned, 90° misaligned and 180° contra-aligned orientation judgements averaged over the open and enclosed VEs following learning in the first (upper panel), and second (lower panel) VEs. Error bars represent one estimated standard error above the mean.

As is apparent in the lower panel of Figure 3.7.3, by comparison with the VEs tested first, the misaligned and contra-aligned errors were reduced on the second test;

this picture was confirmed by analysing the data in the same way as those from the first test; the analysis found no statistically significant main effects or interactions (*p*s > .1).

Additional analyses were conducted to investigate aligned and contra-aligned errors on the first and last sections of the route in both tests; these data were collated separately, and entered into 2 x 2 repeated measures ANOVAs with factors of alignment (judgements that were aligned and contra-aligned with the first path of the route), and route section (first or last section of the route). In the first test, the analysis detected a significant main effect of alignment $F(1, 47) = 5.18$, $MSE = 2325.09$, $p = .03$ (partial $\eta^2 = .10$) that reflects lower errors on aligned than contra-aligned judgements overall (*M*s = 37° and 52° respectively), and a significant interaction between alignment and route section $F(1, 47) = 4.25$, $MSE = 1274.87$, $p = .05$ (partial $\eta^2 = .08$). The interaction effect represents a stronger alignment effect on the first (aligned mean = 28°, contra-aligned mean = 55°) than the last (aligned mean = 45°, contra-aligned mean = 50°) section of the route; however the main effect of route section was not significant ($p > 1$). In the second test, errors on the first section of the route were 35° for both aligned and contra-aligned judgements, and on the last section were 44° and 41° for aligned and contra-aligned judgements respectively. The analysis of these data found no significant main effects or interactions between main effects (*p*s > .1).

The mean latencies to make orientation judgements are illustrated in the upper and lower panels of Figure 3.7.4, and as for the error data, are presented separately for the VEs tested first and second.

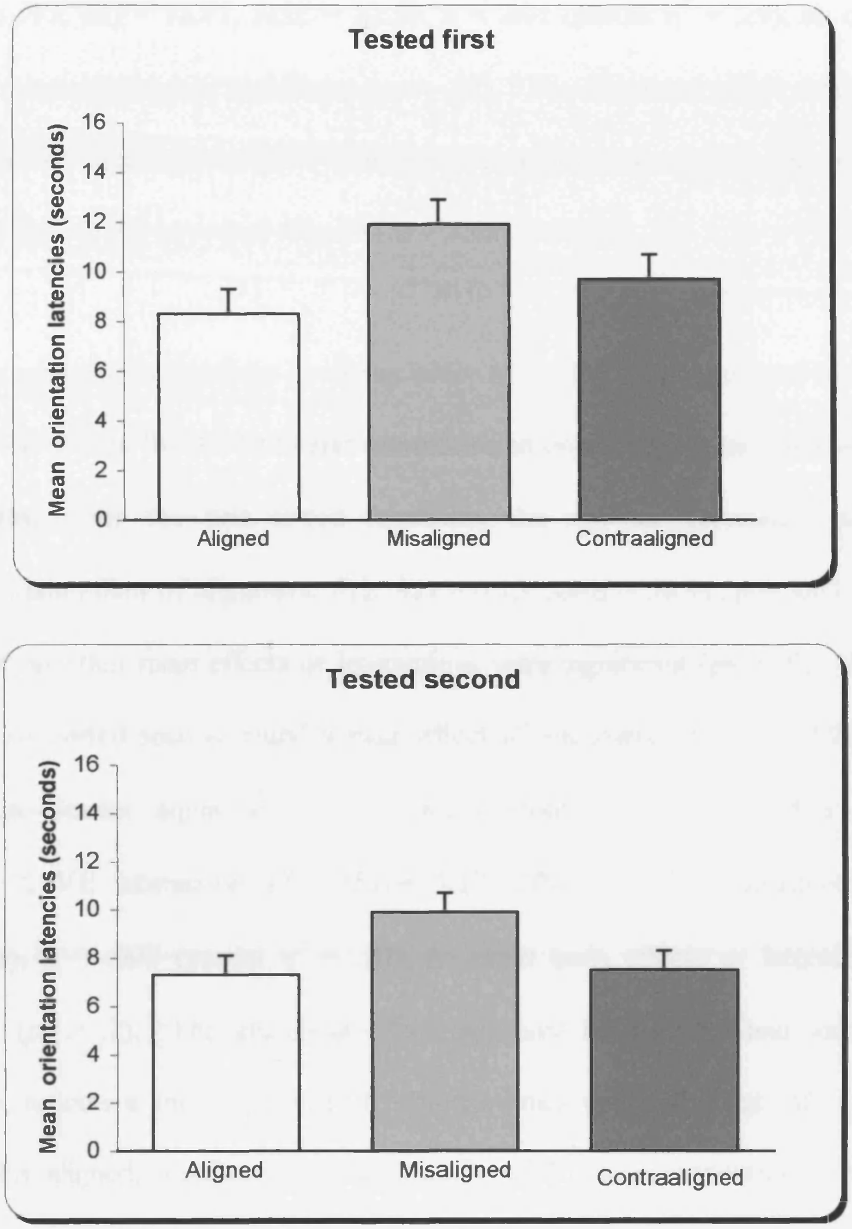


Figure 3.7.4. Experiment 7: Mean latencies for aligned, 90° misaligned and 180° contra-aligned orientation judgements averaged over the open and enclosed VEs following learning in the first (upper panel), and second (lower panel) VEs. Error bars represent one estimated standard error above the mean.

As for the orientation data, the latency scores were entered into a 2 x 2 x 2 x 3 mixed ANOVA. This analysis found a statistically significant main effect of alignment $F(2, 92) = 17.45$, $MSE = 28.58$, $p < .001$ (partial $\eta^2 = .28$), an order x alignment interaction $F(2, 92) = MSE = 3.36$, $p = .04$ (partial $\eta^2 = .07$), and an order x VE interaction $F(1, 46) = 18.71$, $MSE = 22.59$, $p < .001$ (partial $\eta^2 = .29$); no other main effects or interactions were significant (*p*s > .07). The alignment effect reflects slower overall response times under the 90° misaligned condition ($M = 10.9$s) than under either the aligned ($M = 7.8$s) or contra-aligned ($M = 8.6$s) condition.

The significant interactions involving order of testing were examined by separately analysing the results for the first- and second-tested conditions in the same way as the error scores. For the first tested condition, the analysis detected a statistically significant main effect of alignment, $F(2, 92) = 6.15$, $MSE = 50.91$, $p = .003$ (partial $\eta^2 = .12$), but no other main effects or interactions were significant (*p*s > .5). Analysis of the condition tested second found a main effect of alignment, $F(2, 75)$, $MSE = 27.75$ (Greenhouse-Geisser adjustment), $p < .001$ (partial $\eta^2 = .16$), and a significant alignment X VE interaction $F(2, 75) = 5.17$, $MSE = 27.75$ (Greenhouse-Geisser adjustment), $p = .007$ (partial $\eta^2 = .10$); no other main effects or interactions were significant (*p*s > .2). The alignment effect, apparent for the first and second tested conditions, reflects a similar pattern of response times under the first (*M*s = 8.3, 11.9 and 9.7s for aligned, misaligned and contra-aligned latencies respectively) and second (*M*s = 7.31, 9.9 and 7.5s) tested conditions; responses were slower under the 90° misaligned condition than under the aligned or contra-aligned conditions which were similar. The alignment x VE interaction under the second tested condition reflects a similar pattern of slower response times in the open condition for 90° misaligned judgements to those reported above (*M*s = 6.6, 11.4 and 7.6s for aligned, misaligned and contra-aligned respectively), but no alignment differences in the enclosed condition (*M*s = 8.0, 8.4 and 7.4s for aligned, misaligned and contra-aligned respectively).

As for the error data, alignment effects in latencies on the first and last sections of the route in both tests were examined; the data from the first and second tests were entered into 2 x 2 repeated measures ANOVAs with alignment (judgements that were aligned and contra-aligned with the first path of the route), and route section (first or last section of the route) as factors. In the first test, mean latencies on the first section of the route were 8.2 and 11s for aligned and contra-aligned judgements respectively, and on the last section, the mean latencies were 8.5 and 8.3s for aligned and contra-aligned judgements respectively. Neither of the main effects were significant ($ps > .2$), but the analysis detected a significant interaction between alignment and route section $F(1, 47) = 4.07$, $MSE = 27.30$, $p = .05$ (partial $\eta^2 = .08$). This interaction represents an alignment effect (slower response times for judgements contra-aligned with the first path on the route) that was not apparent on the last path on the route. In the second test, mean latencies on the first section of the path were 7.7 and 8.9s, and on the last section were 6.9 and 6.2s for aligned and contra-aligned judgements respectively. A similar 2 x 2 analysis of these data revealed a significant main effect of route section $F(1, 47) = 5.15$, $MSE = 27.2$, $p = .03$ (partial $\eta^2 = .1$), that reflects higher latencies on the first than the last section; the main effect of alignment and the interaction between main effects was not significant ($ps > .1$).

Five of the 48 records of participants' responses to the open question asking them to describe the method they had used to answer the alignment test questions were lost due to a computer failure. Of the remaining 43 responses, 6 participants (of whom 2 described attempting mathematical deductions) did not mention a subjective perspective, 4 described themselves as imagining the routes from above, but the remaining 33 participants reported having imagined themselves within the VE, and described perceptual features from this perspective.

Following exploration of two computer-simulated VEs that depicted small sections of a city described in text by Wilson et al. (1999) and in Experiments 2-6 (Chapter 2), the overall orientation errors from the VE tested first suggest evidence for a first-perspective alignment effect (see upper panel of Figure 3.7.3); orientation judgements that were aligned with the first part of the route were overall more accurate than those that were misaligned or contra-aligned with that perspective, and the effect was more evident on the first than the last section of the route. No support (but see below) was provided for the speculation that the degree of misalignment from the first aligned perspective would systematically affect orientation errors as in the case of text descriptions that employed cardinal terms (Chapter 2, Experiments 5 & 6). The latency data do not suggest a trade-off between accuracy and the time taken to make orientation judgements, but do indicate that misaligned judgements required more time to make than either aligned or contra-aligned judgements. Consistent with the error data, and with respect to the aligned and contra-aligned latencies on the first and last parts of the route, much lower latencies were apparent for aligned judgements on the first section of the route. Whether the VE was 'open' or 'enclosed' did not systematically affect these outcomes; therefore, it appears that differences in the VEs used by Wilson et al. (1999) and Richardson et al. (1999) in this respect were not crucial to encoding from multiple perspectives.

However, the first-perspective alignment effect was not apparent in the orientation or latency data from the VEs that were tested second, neither with respect to the overall analysis nor the separate analysis of the first and last sections of the route. Overall (see Figure 3.7.3), aligned errors were of similar magnitude in the first and second test, but in the second test, the 90° misaligned and contra-aligned errors were reduced to the level of the aligned errors.

Although misaligned and contra-aligned errors were reduced from the first to the second test, in both tests, the 90° misaligned judgements took longer to make than either aligned or contra-aligned judgements (see Figure 3.7.4). In line with other studies that have noted an advantage for contra-aligned compared to other types of misaligned judgements (e.g. Diwadkar and McNamara, 1997; Carr & Roskos-Ewoldsen, 1998; Experiment 2, Chapter 2), this outcome could be interpreted to suggest a 'special status' in spatial memory for locations in the 180° direction when this is directly opposite to imagined facing direction. However, examination of the alignment test questions employed in the present experiment suggests a procedural difference between the 90° misaligned and the aligned and contra-aligned judgements that could account for this pattern. Due to the structure of the route and the counterbalancing arrangement of an equal number of judgements to targets that were either in front of or behind and to the left or right of participants' imagined location at test, sometimes the 90° misaligned questions required an initial imagined orientation with respect to a location described to the left or right. For example, with reference to the right-hand panel of Figure 3.7.2 the only possible 'right-misaligned' question for a judgement that was to the left and in front of an imagined test location was: "Imagine that you are at A, B is to your left, point out the direction of C." Therefore, as was apparent in the VE-learning phase of Experiment 2 (Chapter 2), it may be that the longer latencies on misaligned judgements reflect a difficulty in spatial memory of orienting with respect to left and right locations rather than to ahead or back (cf. Franklin & Tversky, 1990).

The finding that exploration and testing in a first VE should attenuate the first-perspective alignment effect in a second VE test, is surprising because if this type of alignment effect is a general phenomenon of spatial learning from secondary sources, it should have been equally apparent in the tests that followed exploration of both VEs.

The present data suggest a change in participants' spatial encoding or retrieval processes between the first and second tests that led to an overall improvement in accuracy from the first to the second test. Such improvement does not appear to be a simple practice effect because the aligned errors were not reduced in the second test; the change in the data pattern reflects a reduction in errors in the misaligned and contra-aligned conditions in the second test, and suggests a change from encoding with respect to the first aligned perspective to encoding from multiple perspectives. This finding is further explored in Experiment 8.

Experiment 8

Two aspects of the procedure of Experiment 7 may have been primarily responsible for attenuating the first-perspective alignment effect from the first to the second VE. First, the layouts of the routes in both VEs were very similar; therefore practice in exploring the first VE could have simply made memorizing the second layout much easier. Alternatively, because participants answered alignment test questions following exploration of the first VE, they may have been more prepared for the alignment test questions that followed exploration of the second VE. More attention may have been paid to the relationships between the key locations and turns while exploring the second route; specifically, to perspectives that they anticipated might be required in the second test. With better processed mental representations of the likely perspectives to be tested, less cognitive effort would have been required to make the second set of orientation judgements.

To test whether the change from encoding based on the first experienced perspective to encoding from multiple perspectives in Experiment 7 was due to experience of exploring the first VE, or prior experience of making orientation judgements, participants in Experiment 8 were asked to explore two VEs as in Experiment 7, but the alignment test questions following exploration of the first VE were omitted. If the factor most responsible for the change in encoding in Experiment 7 was previous experience of a previously explored VE, a change to encoding from multiple perspectives should still be evident. In contrast, if the crucial factor that brought about this change was prior experience of the first alignment test, no change from encoding from the first experienced perspective would be anticipated following exploration of the second VE. However, while omitting the first VE test should reflect on the importance of this factor in attenuating first-perspective alignment effects, the results would not reveal whether testing that was specific to the first VE was the crucial factor, or whether non-specific factors associated with any spatial memory test exert an effect. Therefore, following exploration of the first street VE in Experiment 8, participants completed a spatial orientation test that was not related to the first VE. The procedure followed that of Experiment 7, but after exploring the practice environment, the memory test for the coloured blocks on four of the inner walls of the compound was omitted, and participants proceeded to immediately explore the first open or enclosed street VE. The memory test for the coloured blocks was administered following this exploration in place of the alignment test that followed the first street VE exploration in Experiment 7. Exploration of the second VE, and subsequent alignment tests related to that VE were carried out in the same way as in Experiment 7.

Method

Design

After exploring the practice VE used in Experiment 7, participants explored two VEs that comprised a small part of a city in which the streets intersected at right angles. As in Experiment 7, two conditions, open and enclosed were employed. The design and procedure was identical to that of Experiment 7, with the exception that the alignment test that followed exploration of the first 'street' VE was replaced with the memory test that in Experiment 7, followed exploration of the practice environment. The dependent variables were orientation and distance judgements from imagined perspectives that were aligned, 90° misaligned, and contra-aligned to the first part of the route in the second VE only, and the time taken to make these judgements.

Participants

Participants were 48 participants with the same characteristics as those in Experiment 7. They had a mean age of 19.3 years (range: 18-36 years), and 39 were women.

Apparatus and Procedure

The apparatus was identical to that used in Experiment 7. Participants were allocated to two sub-groups (N = 24), who explored either one open or one enclosed environment first. As in Experiment 7, if the first VE explored was open, the second was enclosed, and vice-versa. The experiment consisted of 5 phases: first, participants underwent preliminary training in the practice VE; second, the first of two route environments was explored; third, the memory test used in Experiment 7 for the locations explored in the preliminary training environment was administered; fourth, participants explored the second route environment; finally, participants answered eight alignment test questions based on their memories of the second route VE.

Following exploration of the preliminary training environment, participants immediately explored the first (open or enclosed) route VE, then were returned to the preliminary training environment and asked to 'point' towards the locations of each of the four coloured blocks in turn in a counterbalanced order. On completion of this test, participants were asked to explore the second (open or enclosed) route VE, then completed the same tests of alignment that were administered to participants in Experiment 7 following exploration of each of the route VEs. All procedural details not specified were identical to those described for Experiment 7.

Results and Discussion

Sex was not included as a factor in the analyses reported below due to the relatively small number of men who took part in the experiment. Descriptive statistics for the orientation error and latency data that followed exploration of the second VE under the open and enclosed conditions are presented in Tables 3.8.1 and 3.8.2.

Table 3.8.1

Descriptive Statistics (tabled in degrees) for Aligned, 90° Misaligned, and 180° Contra-aligned Absolute Error Scores under the 'Open' and 'Enclosed' Conditions

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Open							
Aligned	24	5.00	142.50	33.13	33.35	19.04	47.21
Misaligned	24	11.25	142.50	47.03	29.09	34.75	59.32
Contraaligned	24	5.00	125.00	46.15	30.31	33.35	58.94
Enclosed							
Aligned	24	5.00	110.00	31.25	25.86	20.33	42.17
Misaligned	24	11.25	115.00	41.72	28.60	29.64	53.79
Contraaligned	24	2.50	155.00	40.94	44.24	22.26	59.62

Table 3.8.2

Descriptive Statistics (tabled in seconds) for Aligned, 90° Misaligned, and 180° Contra-aligned Latencies under the 'Open' and 'Enclosed' Conditions

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Open							
Aligned	24	1.57	23.77	7.25	4.64	5.29	9.21
Misaligned	24	4.62	28.33	12.13	6.32	9.47	14.80
Contraaligned	24	2.91	26.93	10.07	6.26	7.42	12.71
Enclosed							
Aligned	24	2.91	16.90	9.27	4.30	7.45	11.09
Misaligned	24	5.11	24.19	11.82	5.61	9.43	14.17
Contraaligned	24	2.22	19.16	8.49	4.79	6.47	10.51

These data were collated in the same way as the separate data from the first and second alignment tests in Experiment 7. The absolute error scores for orientation estimates and the time taken to make these judgements were entered into separate 2 x 2 x 3 mixed ANOVA analyses. In each case, the between-participants factor was 'VE' (open or enclosed for half the participants), with 'direction' (test locations that were either in front of or behind the imagined facing direction at test), and 'alignment' (aligned, misaligned and contra-aligned, with respect to the first part of the route).

Mean absolute orientation error scores, averaged across the open and enclosed conditions, are illustrated in the top panel of Figure 3.8.1. Analysis of these data found a statistically significant main effect of alignment, $F(2, 80) = 4.90$, $MSE = 1137.6$ (Greenhouse-Geisser adjustment), $p = .01$ (partial $\eta^2 = .09$), that reflects overall lower errors for aligned ($M = 32°$) than misaligned ($M = 44°$) or contra-aligned ($M = 44°$) judgements, which did not differ. No other effects or interactions were significant ($ps > .05$).

As in Experiment 7, additional analyses were undertaken to examine the alignment effect on the first and last segments of the route. Errors on the first section were, Ms = 31 and 45°, for aligned and contra-aligned judgements respectively; and on the last section were, Ms = 37 and 52° for aligned and contra-aligned judgements respectively. The error scores were analysed using a 2 x 2 repeated measures ANOVA with alignment (judgements that were aligned and contra-aligned with the first path of the route), and route section (first or last section of the route) as factors. The main effect of alignment was statistically significant, $F(1, 47) = 5.48$, $MSE = 1128.45$, $p = .02$ (partial $\eta^2 = .10$), reflecting greater errors on contra-aligned judgements overall, but neither the main effect of route section, nor the interaction between main effects were significant ($ps > .1$).

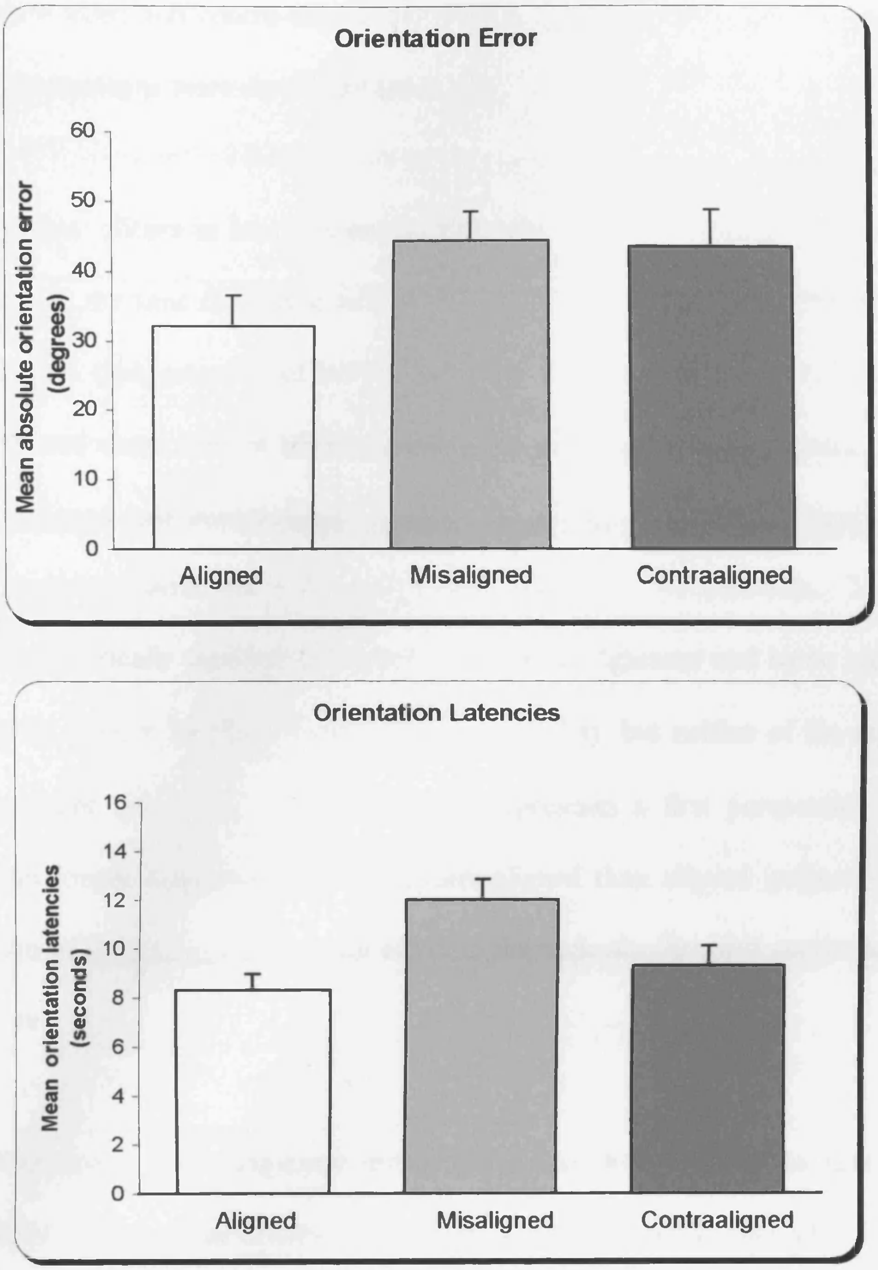


Figure 3.8.1. Experiment 8: Mean absolute errors (upper panel) and latencies (lower panel) for aligned, 90° misaligned and contra-aligned orientation judgements averaged over the open and enclosed VEs in the single test in Experiment 8. Error bars represent one estimated standard error above the mean.

Mean latencies to make orientation judgements are illustrated in the lower panel of Figure 3.8.1. Analysis of these scores in the same way as for the error data, found a main effect of alignment, $F(2, 80) = 13.64$, $MSE = 29.64$, $p < .001$ (partial $\eta^2 = .23$), which reflects significant differences overall between misaligned (M = 12s), and both aligned (M = 8.3s) and contra-aligned (M = 9.3s), which did not differ. No other main effects or interactions were significant ($ps > .05$).

Alignment effects in latencies on the first and last sections of the route were also examined, and the time data were subject to 2 x 2 repeated measures ANOVA analysis with alignment (judgements that were aligned and contra-aligned with the first path of the route), and route section (first or last section of the route) as factors. Response times for aligned and contra-aligned judgements on the first and last sections of the route respectively were: Ms = 7.4 and 10.4s, and MS = 9.2 and 8.2s. The analysis detected a statistically significant interaction between alignment and route section, $F(1, 47) = 10.45$, $MSE = 18.52$, $p = .002$ (partial $\eta^2 = .18$), but neither of the main effects were significant ($ps > .1$). The interaction represents a first perspective alignment effect, with longer response times for contra-aligned than aligned judgements on the first section of the route, with a small effect in the opposite direction on the last section of the route.

In Experiment 8, the alignment test that followed exploration of the first route VE was replaced with a spatial orientation test that was not related to that VE. The pattern of error data on the alignment tests that followed exploration of the second VE conformed closely to that found following the first, but not the second alignment test in Experiment 7. Absolute orientation errors were lower for judgements that were aligned rather than 90° misaligned or contra-aligned with the first experienced perspective in the VE. However, in contrast to Experiment 7, where the first-perspective alignment effect was primarily evident on the first section of the route, the pattern of judgement errors was similar in Experiment 8, with lower errors for aligned than contra-aligned judgements on both sections. The latency data were similar to those from both tests in

Experiment 7, but consistent with the error data, were in closer agreement with the first than the second test in that experiment. Overall, the results of Experiment 8 strongly support the hypothesis that in Experiment 7, it was experience of the first VE alignment *test*, rather than exploring routes of a similar layout, which changed the encoding of the second VE from aligned with the first experienced perspective to aligned with multiple perspectives.

Before considering an account of why this change occurred, it is important to reflect on possible explanations of why the orientation error scores reflected an orientation-dependent representation in the first tested VE in Experiment 7. As in the case of text descriptions, a first possibility is that the effect depends on participants adopting a map-like perspective at test; if this were the case, judgements from perspectives misaligned or contra-aligned to this perspective would be less accurate and/or slower than when aligned to this orientation (e.g. Levine et al., 1982).

One prediction that can be derived from adopting a map-like perspective at test is that both the first and final paths of the route should be equally accessible for recall in the same orientation. With reference to Figure 3.7.2, alignment effects should be equivalent whether the imagined test orientation was on path AB or CD. While the error data in Experiment 8 conform to this prediction, the latency data do not. Moreover, in the first test of Experiment 7, the alignment effect was significantly stronger on the first part of the route (*M*s 28° and 55° for aligned and contra-aligned judgements respectively) than on the second part of the route (*M*s = 45° and 50° for aligned and contra-aligned judgements respectively), and the latency measures conformed to this overall pattern. Further, less than 10% of participants in Experiment 7 reported adopting a map-like strategy at test in which they imagined looking down on the route 'from above', and approximately three quarters of participants made comments consistent with their having adopted a ground-level perspective as they made their orientation judgements. For example, "...imagined myself to be actually in the scene..." "...standing where you said...," "...was actually there..." Finally, even if participants had adopted a map-like image, and taking this perspective was responsible for the pattern of orientation errors found in the first VE test, this explanation does not explain the lack of a similar alignment effect in the second test.

As explored in Chapter 2, a second possible explanation is that the first-perspective alignment effect may share similarities to the 'primacy effect' found following serial list learning (e.g. Craik, 1970; Glanzer & Cunitz, 1966). The error and latency data from Experiments 7 and 8 provide some support for this possibility: in the first test of Experiment 7, errors were greater on A-B than B-A, with little differences in accuracy found on C-D and D-C judgements, which would be in the middle of the 'list;' a similar pattern was evident in the latency data from the single test in Experiment 8. However, three findings contrast with the predictions of this account. First, in the latency data from the first test in Experiment 7, the greater alignment effect on the first section of the route (8.2 and 11.0 s for aligned and contra-aligned respectively), by comparison to the last section (8.5 and 8.3 s for aligned and contra-aligned respectively), appears to result from higher errors on the last part of the route (B-A) rather than lower errors on the first part (A-B). Second, in the single test of Experiment 8 the alignment effect was of very similar magnitude on the first and last sections of the route; this outcome is more compatible with encoding the whole environment in the same orientation rather than serial list learning. Finally, there was no evidence of a first-perspective alignment effect in the second test of Experiment 7; if people learned the VE routes as a series of views, then this attenuation is difficult to explain. As concluded in Chapter 2, because the first-perspective alignment effect depends on the first experienced perspective defining the alignment of orientation judgements, a primacy effect may well contribute to the first-perspective alignment effect; however, the present results would not be predicted by a list-learning account.

A third possible account concerns the visual nature of VE exploration. For example, as one explanation of why they found an alignment effect following VE but not real-world learning, Richardson et al. (1999) speculated that the absence of vestibular feedback during VE learning might attenuate spatial updating, which could lead to first-perspective alignment effects as a consequence. Had Experiment 7 involved the learning of a single VE, this suggestion would remain plausible. However, participants in Experiments 7 learned two very similar VEs for which different patterns of orientation error data were found in the first and second tests; while evidence for first-perspective alignment encoding was observed in the first test, the second test data suggested orientation-free learning. As a lack of vestibular feedback would have affected encoding in both VEs equally, it seems unlikely that this is the crucial factor in producing this type of alignment effect.

A fourth explanation of the outcomes of Experiments 7 and 8 can be derived through consideration of the data alongside the results of the text-based experiments of Wilson et al. (1999), and those presented in Chapter 2. As one explanation of their finding of a difference in orientation errors between their text and VE conditions, Wilson et al. theorized that an important variable in defining the alignment of spatial memories might be whether information is learned directly through primary interaction with the physical world, or indirectly via secondary sources such as verbal descriptions, maps or pictures (Presson & Somerville, 1985). Wilson et al. suggested that because

VEs are primarily visual and interactive, the difference between primary and secondary learning may be more continuous than absolute (Wilson, 1997); as such, spatial learning from simulations might result in knowledge that is closer to that acquired from primary learning, than other secondary sources. However, the primary versus secondary media distinction cannot be a complete explanation of first-perspective alignment effects reported here because the same secondary VE medium was employed for learning in both the first and second VEs of Experiment 7, but the effect was absent in the second test. It appears that previous experience of the likely perspectives to be tested results in less cognitive effort to make a second set of orientation judgements. This outcome suggests that a further account of this change can be formulated in terms of cognitive load.

In the text-based experiments reported in Chapter 2, the mean difference between aligned and contra-aligned errors was approximately 32°; in Wilson et al.'s experiments, which used fewer participants, this difference was approximately 40°. In contrast, the two experiments reported in the present Chapter required large numbers of participants to demonstrate orientation-dependent learning from VEs, and where evident, the difference between aligned and contra-aligned errors averaged to approximately 13°. The difference in magnitude of the text and VE alignment effects reported in the present series, which reflects that found by Wilson et al., could have occurred because for spatial learning, intrinsic cognitive load is greater in the verbal than the visual case. Therefore, decreased cognitive load could be responsible for the less pronounced first-perspective alignment effect in the case of VEs compared to text, rather than the medium *per se*.

To extend this hypothesis to the outcomes of Experiments 7 and 8: In the first alignment test in Experiment 7, participants had not previously explored a similarly structured VE, nor had they any experience of making orientation judgements related to a similar VE. Therefore, maximum cognitive resources would be required to complete the first alignment tests, with orientation-dependent learning as a consequence. When exploring the second VE in Experiment 7, because participants had previously answered alignment test questions relating to the first VE, intrinsic cognitive load might be reduced because participants could anticipate the views necessary to make the spatial judgements in the second test. In the alignment test that followed the second route-VE in Experiment 8, participants had no previous experience at making alignment judgements after the first VE; therefore, cognitive load should have remained high, and an alignment effect was apparent. This account is comparable to the finding of Rossano and Moak (1998) that providing a still-picture of the test orientation attenuated the first-perspective alignment effect by comparison with when participants imagined that view, which these authors argue is a consequence of lowered cognitive load.

Although an explanation couched solely in terms of cognitive load preserves the graded distinction between primary and secondary learning suggested by Wilson et al. (1999), a problem with this account is that it does not specify the factors that might cause increases or decreases in cognitive load. However, one interpretation of the results of Experiment 7 is that 'active' spatial processing may engender more efficient encoding, possibly via a reduction in cognitive load. During their exploration of the second VE, with a memory of the first test available, participants may have actively rehearsed potential test judgements from each of the four locations on the route as these were encountered during exploration. Such rehearsal could have incurred equivalent processing at each of these locations, and therefore the cognitive demand incurred by test questions from these locations. An alternative speculation is that based on their experience of a first set of alignment test questions, and as a consequence of the similarities between route layouts, participants may simply have generalised their overall knowledge about four key locations from the first to the second VE. The difference between these possible accounts is subtle, and reflects the point at which cognitive load may be reduced in spatial memory under repeated-measures conditions. The first account suggests that it is active processing *during* exploration of the second VE that reduces the cognitive load incurred by a similar set of orientation judgements. The second account suggests that cognitive load is reduced for the second VE *prior* to their exploration of the second VE; that is, their pre-existing knowledge about the spatial arrangement of four building locations developed during the first test phase is then generalised directly from the first to the second VE test.

The way in which these accounts may be investigated is to eliminate the possibility of generalisation between VEs, by devising an experiment that uses a single phase of training and testing in one VE. The key manipulation is to ask participants to make spatial judgements from locations on the route during learning. If it is active spatial processing in this phase that reduces intrinsic cognitive load, this manipulation should engender a similar pattern of orientation-free performance to that found for the second tested VE in Experiment 7.

However, as noted above, Experiments 7 and 8 required large numbers of participants to demonstrate orientation-dependent learning from VEs, and where evident, the difference between aligned and contra-aligned errors was small (M = 13°). Given that this alignment effect appears to be a general phenomenon of spatial learning from secondary media, it should be possible to generalise between different types of secondary medium; therefore, Experiment 9 used a text-based procedure to investigate whether the attenuation of first-perspective encoding in the second tested condition of Experiment 7 was due to active processing of all of the key locations on the route during learning.

Experiment 9

The results of Experiment 7 suggest a possible role for 'active' spatial processing that leads to attenuation of the first-perspective alignment effect in VEs. With respect to text descriptions, this concept of active processing is particularly important, because simply increasing the amount of information at each of the key locations in a text-route description does not attenuate the first-perspective alignment effect. This hypothesis was explored by Wilson (2000, personal communication), who increased the number of occasions on which participants were required to read the text, and elaborated the amount of egocentric spatial information at each key building location on the described route. In this experiment, unlike Wilson et al.'s (1999) original text experiments, and those reported in Chapter 2, which recorded only judgements that were aligned or contra-aligned with the first part of the route, 90° misaligned judgements were also included in the alignment tests. Wilson hypothesized first, that increasing exposure to the text or the to-be-imagined viewpoints would lead to lower errors overall, or possibly lower errors under the misaligned and contra-aligned conditions, with a consequent attenuation of the first-perspective alignment effect. Second, that if memories constructed from text share properties with perceptually acquired spatial memories, then the overall pattern of results should parallel a previously documented perceptual effect (e.g. Rossano & Warren, 1989), in that error and time data from judgements made from a perspective 90° misaligned to the first part of the description should fall between those that were aligned and 180° contra-aligned with this perspective.

Wilson's (2000, personal communication) experiment comprised a within-participant comparison between four counterbalanced reading conditions using 'simple' and 'elaborated' (at key building locations) versions of routes used by Wilson et al., 1999 (Experiments 2-3B). These descriptions were read on either three or six occasions; each participant read one simple and one elaborated description on three occasions each, and one simple and one elaborated description on six occasions each. After reading each passage of text, one alignment test question was administered from each of four perspectives: aligned with the orientation of the first described pathway, 90° left-misaligned, 90° right-misaligned, and 180° with this perspective. As in Wilson et al.'s original experiments, all test locations were 'behind' participants' imagined facing orientation (i.e. the correct angle to the test location was greater than 90°).

The results of this experiment did not find any support for the hypothesis that either increasing the detail in the text descriptions, or increasing the number of readings of the text, should influence the overall pattern of orientation test data. However, in contrast to Experiments 7 and 8 (present Chapter), where 90° misaligned judgements were found to take longer to make, Wilson's (2000, personal communication) experiment did find a systematic increase in errors as the test viewpoint rotated from aligned with the first perspective described to 90° and 180°. Overall errors in the misaligned condition were greater in the aligned condition (*M*s = 53 and 32° respectively), but were significantly lower than in the contra-aligned condition (*M* = 65°). These differences between aligned, misaligned and contra-aligned errors supported the hypothesis of a parallel with the perceptual misalignment effect (e.g. Rossano & Warren, 1989); they also provide support for the suggestion that the greater errors and latencies for misaligned than aligned or contra-aligned found in Experiments 7 and 8 may have been an artefact of the 'misaligned' test questions used in those experiments.

While Wilson (2000, personal communication) found that simply increasing familiarity with each of the locations on the route failed to attenuate the text first-perspective alignment effect, other experiments have demonstrated superior recall when participants have physically enacted action phrases from verbal instructions than when they have passively learned the same phrases verbally (e.g. Cohen, 1985, 1989; Engelkamp & Zimmer, 1989). Therefore, Experiment 9 built on the finding of Wilson (2000) described above, and those of Experiment 7 (present Chapter). Participants were asked to make active spatial judgements at key building locations while reading a route description of similar dimensions to the VEs used in Experiments 7 and 8. They were asked to read a description of a route presented in sections (e.g. imagine that you walk from A to B, and then turn left to face C), then to make relative judgements about the direction of previous locations (e.g. 'from B, what is the relative direction to A?'), before proceeding to the next section of text. These judgements differed from those made in the final alignment test.

It was anticipated that this active spatial processing during reading would parallel that which may have been experienced by participants while exploring the second VE in Experiment 7. A pattern of orientation-free learning similar to that found for the second test in Experiment 7 would support the hypothesis that it was the active spatial processing at each of the key locations on the route during exploration of the second VE, rather than generalisation between the two VEs explored, that reduced the cognitive load incurred by the second set of orientation judgements in comparison to the first.

Method

Design

In a repeated-measures design, participants read two passages of text presented on a computer screen; these were based on Wilson et al.'s original descriptions and were similar to those used in Experiments 2-6 (Chapter 2). The independent variable was whether or not participants were asked to make relative direction estimates at key locations described in the text during reading. After each description had been read on three occasions, participants were asked to make direction estimates between imagined locations. The dependent variables were errors in orientation estimates between key locations that were aligned with the first part of the route, 90° left-misaligned, 90° right-misaligned, and 180° contra-aligned with the first part of the route, and the time taken to make these judgements. Given that the inclusion of distance judgements in Experiments 2-6 failed to reveal any interesting or consistent effects with respect to alignment, distance judgements were omitted from the current procedure. However, errors in orientation judgements that were made during the reading phase in the 'judgements' condition were additionally recorded.

Participants

The participants were 32 undergraduates from the University of Leicester, UK, of whom 25 were women. They had a mean age of 19 years (range: 18-21 years), and all participants received credit towards the fulfilment of a first year practical course requirement.

Apparatus and Procedure

Following verbally provided preliminary instructions that described the purpose and basic procedure, the experiment was entirely carried out using a purpose written computer program, run on a Pentium PC with a 17-inch monitor. The program initially presented a brief outline of the experiment which stated that participants would be asked to read written descriptions of a brief tour through city streets which all intersected at right angles, and that they were to try to visualise the routes as clearly as possible, as though actually walking along the streets.

In a pre-training phase, an illustration of a 360° protractor with an arrow at the top (i.e. at 0°) was presented in the top half of the screen; clockwise angles from 0° were marked in 10° intervals to 170°, with the anti-clockwise angles preceded by a minus sign. To ensure that participants were clear about the use of this protractor, they were asked to make judgements about the directional relationship between three letters drawn on the lower part of the screen by entering a numeric response. (e.g. Imagine that you are standing at X, and facing toward B. What number would you enter to indicate the direction of A?). If the absolute error for an initial judgement was less than 25°, a second judgement was presented; if the error for this second judgement was less than 25° the participant began the experiment. Where the errors in angle estimates were greater than 25° the task was repeated until the estimates were less than 25°. Following this training on the angle estimation procedure, the programme presented instructions for the main part of the procedure. Copies of the materials described above can be found in Appendix A.

The text descriptions of the routes were taken from those used by Wilson et al. (1999, Experiments 2, 3A and 3B), and were similar to those used in Chapter 2; these were counterbalanced according to the number of right and left turns; that is, Route A comprised left-hand turns on the outward journey and Route B comprised right-hand turns on the outward journey. For ease of reference, Route A is illustrated in Figure 3.9.1 below. Both route descriptions are included in Appendix B, with respect to the condition in which they were employed, and as they appeared on the computer screen.

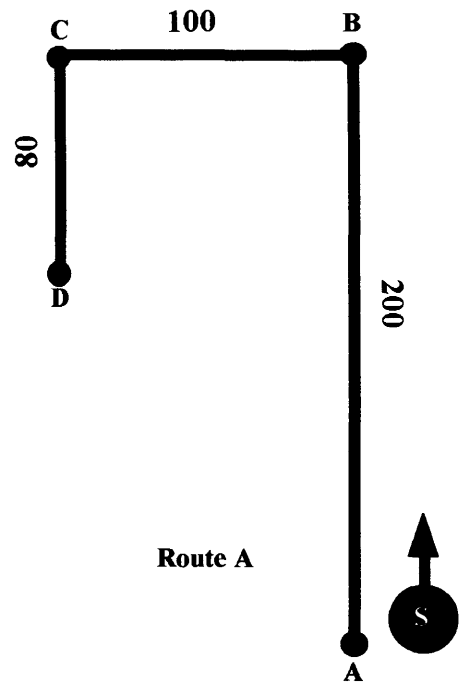


Figure 3.9.1. Experiment 9: Plan diagram (not to scale) of one of the routes used in Experiment 9. Illustrated are the positions of the target buildings (ABCD), the relative distances in metres between them, and the start position described in the text (large circle and arrow).

Each route description was presented in sections, such that the proportion of text on the screen at any one time described travelling along one segment of the route, and turning at the next junction to face a new direction. Different input to the computer was required, depending on the condition, before the next segment was presented. In the 'judgements' condition, participants read a section of the route, then were asked to make one or more judgements about the relative direction of locations already mentioned in the text. With respect to the facing direction that participants had read about, the angles to each imagined test location were 90° or less to avoid overlap with the test judgements made following learning which were all greater than 90°. With reference to Figure 3.9.1, an example of a judgement made during reading was: Imagine that you are at C, and D is in front of you. Enter the number that indicates the direction of A (= -25°); whereas an example of a judgement made during the final alignment test was: Imagine that you are at B, and A is behind you. Enter the number that indicates the direction of D (= -130°). In the 'no judgements' condition, following reading each section of the route, participants typed in "OK" before continuing to the next part of the description. Each description (and associated judgement tests during learning where appropriate) was repeated on three occasions.

Following the final reading of each passage of text, one alignment test question was presented on the computer screen from each of four perspectives: aligned with the orientation of the first described pathway, 90° left-misaligned, 90° right-misaligned, and 180° contra-aligned with this orientation. During the test, the 360° protractor illustration appeared in the top half of the screen while participants made their judgements. Response times were measured by the computer program.

The order of testing the two conditions (i.e. whether the direction estimates were required during the first, but not the second passage of text, and vice versa), and which description (Route A or Route B) served in each condition were counterbalanced. In the final alignment test, questions from the four imagined perspectives (aligned, 90° left-misaligned, 90° right-misaligned, and 180° contra-aligned with the first part of the route) were counterbalanced across the above factors. Because the questions used during learning in the 'judgements' condition would have otherwise eliminated some those questions available for use during the final alignment test, the counterbalancing factors of direction (whether the test location was in front of or behind participants imagined facing direction at test), and route section (whether the test judgement required a judgement made from an imagined location on the first or last segment of the route) used in Experiments 2-6 in Chapter 2 were not included in the present experiment. However, following the final alignment tests, the questionnaire used in those experiments and identical response-choice options were presented via the computer screen with respect to (a) participants' experiences while reading the text, and (b) while answering the location-to-location questions.

Results and Discussion

Angle of error scores were derived from the participants' estimated angles by subtracting the estimates from the true angles and taking the unsigned value. The mean error scores for the sets of orientation judgments during each of three consecutive readings of the text were 51, 39 and 33° respectively. A one-way repeated measures ANOVA found a statistically significant difference between these scores $F(1,45) = 12.52$, $MSE = 293.04$ [Greenhouse-Geisser adjustment], $p = .001$ (partial $\eta^2 = .29$). Paired samples analyses [Bonferroni correction applied] showed that the errors from the second and third readings did not differ significantly from each other ($p > .05$) but both differed significantly from the first set: Set 1 to Set 2, $t(31) = 4.66$, $SE = 2.67$, $p < .001$ ($\eta^2 = .41$) ; Set 1 to Set 3 $t(31) = 3.88$, $SE = 4.58$, $p = .001$ ($\eta^2 = .33$).

Angle of error scores for the 'no judgements' and 'judgements' conditions were derived in the same way as for the orientation judgements made during reading. Preliminary analyses of these data with 'left vs. right' misaligned judgements and conditions as factors found no statistically significant main effects and no interactions between these factors ($ps > .17$). A similar analysis of the response time data also failed to demonstrate either a significant left-right main effect, or a significant interaction between main effects ($ps > .09$); therefore, the left and right misaligned scores were averaged to provide a single 'misaligned' judgement score for each participant. Descriptive statistics of the overall aligned, misaligned and contra-aligned error data in the no judgements and judgements conditions are presented below in Table 3.9.1; the mean errors for these conditions are illustrated in Figure 3.9.2.

Table 3.9.1

Descriptive Statistics for Aligned, 90° Misaligned, and 180° Contra-aligned Absolute Error Scores in the No Judgements and Judgements Conditions.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
No Judgements							
Aligned	32	.00	80.00	23.91	21.88	16.02	31.79
Misaligned	32	2.50	120.00	39.61	33.49	27.53	51.69
Contraaligned	32	.00	170.00	49.06	54.93	29.26	68.87
Judgements							
Aligned	32	.00	170.00	38.59	43.76	22.82	54.37
Misaligned	32	2.50	132.50	38.36	35.44	25.58	51.14
Contraaligned	32	3.33	134.17	37.32	29.75	26.59	48.05

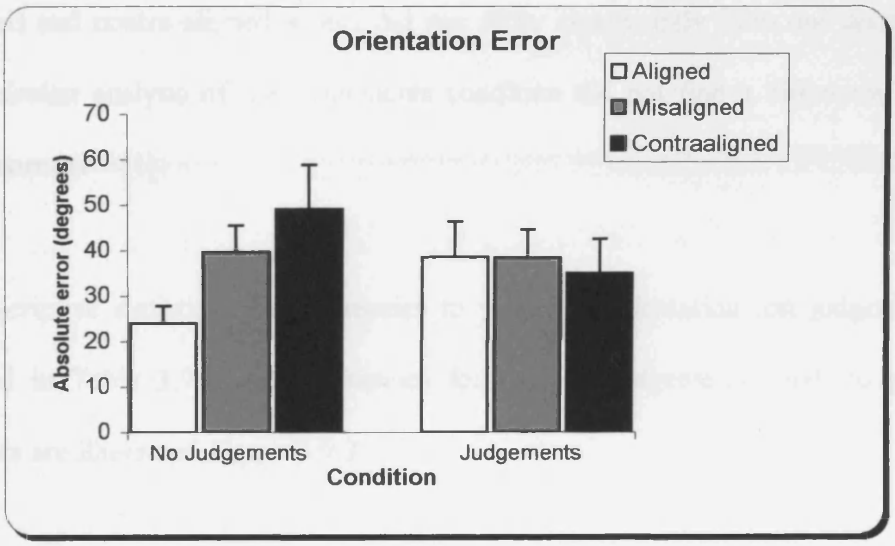


Figure 3.9.2. Experiment 9: Mean absolute error scores for aligned, 90° misaligned and 180° contra-aligned judgements in the 'no judgements' and 'judgements' conditions. Error bars represent one estimated standard error above the mean.

A 2 x 2 x 2 x 3 mixed ANOVA, with order of testing the two conditions (no judgements tested first or judgements tested first) and sex as between-participant factors, and conditions (no judgements or judgements) and alignment (aligned, 90° misaligned, and 180° contra-aligned with the first part of the route) as within-participant factors found a significant interaction between condition and alignment $F(2, 56) = 3.50$, $MSE = 1195.80$, $p = .04$ (partial $\eta^2 = .11$). No main effects and no other interactions between main effects were significant (*ps* > .1).

Separate 1-way analyses of the no judgements and judgements conditions with alignment as the repeated measures factor, found a statistically significant main effect of alignment in the no judgements condition, $F(1,45) = 4.97$, $MSE = 1143.73$ (Greenhouse-Geisser adjustment), $p = .02$ (partial $\eta^2 = .14$). Subsequent planned paired samples *t*-tests found a significant difference between aligned ($M = 24°$) and misaligned ($M= 40°$) test scores, $t(31) = 2.70$, $SE = 51.82$, $p = .01$ ($\eta^2 = .19$), and between aligned and contra-aligned ($M = 49°$) scores, $t(31) = 2.48$, $SE = 10.15$, $p = .02$ ($\eta^2 = .17$), but misaligned and contra-aligned scores did not differ significantly from one another ($p >$ .2). A similar analysis of the judgements condition did not find a difference between sets of scores ($F < 1$).

Descriptive statistics of the latencies to make the orientation test judgements are presented in Table 3.9.2; mean latencies for the 'no judgements' and 'judgements' conditions are illustrated Figure 3.9.3.

Table 3.9.2
Descriptive Statistics (tabled in seconds) for Aligned, Misaligned, and 180° Contra-aligned Latencies in the No Judgements and Judgements Conditions.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
No Judgements							
Aligned	32	6.90	114.00	24.95	19.38	17.97	31.94
Misaligned	32	3.70	56.25	23.34	10.22	19.65	27.02
Contraaligned	32	3.40	114.00	25.83	21.04	18.24	33.41
Judgements							
Aligned	32	5.20	38.70	19.45	8.16	16.51	22.39
Misaligned	32	7.40	41.20	19.98	7.53	17.26	22.69
Contraaligned	32	1.00	66.20	20.41	13.54	15.53	25.29

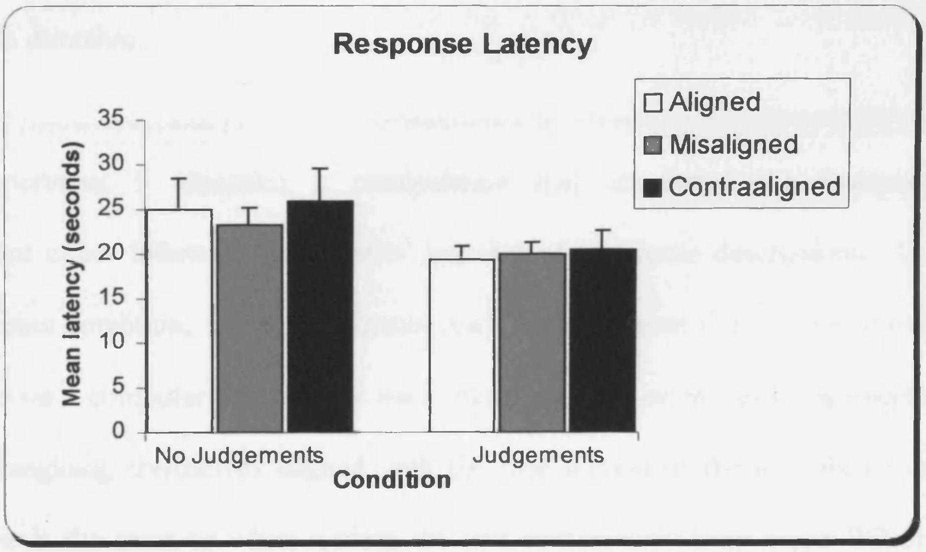


Figure 3.9.3. Experiment 9: Mean latencies to complete the orientation judgement task in the 'no judgements' and 'judgements' conditions. Error bars represent one estimated standard error above the mean

A similar 2 x 2 x 2 x 3 mixed ANOVA analysis to that carried out for the orientation error data revealed no main effects, but a statistically significant interaction between order of testing and condition, $F(1,28) = 5.59$, $MSE = 214.97$, $p = .03$ (partial $\eta^2 = .17$). The interaction effect reflects that when the no judgements condition was tested first, latencies were longer overall (M = 28s) for this condition than for the second tested (judgements) condition (M = 17s); when the judgements condition was tested first, a similar pattern of latencies was evident for both conditions (Ms = 20 and 22s for the no judgements and judgements conditions respectively).

For the post-test question, "Which of the following most closely describes your experience while reading the text?" the median response was 2. "I visualised myself walking from a ground level perspective, but imagined this from outside myself." The median response given for while making the location-to-location judgements was 3. "I visualised myself walking along the streets as though I was looking from above." This shift in perspective between reading and test was apparent for 9 of the 32 participants; for 21 participants there was no change; while for 2 participants, the shift was in the opposite direction.

Experiment 9 identified a manipulation that attenuated the first-perspective alignment effect following participants' learning of text-route descriptions. In the no judgements condition, when participants read the text route descriptions presented in sections on a computer screen, they made more accurate orientation judgements at test when imagining themselves aligned with the first section of the described route; this outcome is the same as when reading the text continuously from paper Wilson et al., 1999, Experiments 2-3B; Chapter 2, Experiments 3 & 6). However, when asked to make spatial judgements after reading each section of the route, encoding was from multiple perspectives. The data are supportive of the experimental hypothesis that, as appears to be the case for VEs, active spatial processing at key locations on the route appears to reduce the first-perspective alignment effect.

Chapter 3: Summary

In Experiment 7, participants explored two desktop VEs with similar dimensions to those employed by Wilson et al. (1999, Experiment 3C) and those in the text route descriptions used in Experiments 2-6 (Chapter 2); one VE was open and one was enclosed. The results provide evidence for first-perspective alignment encoding following VE learning. Judgements were orientation-dependent in that they were more accurate and took less time to make from imagined orientations that were aligned, rather than 90° misaligned or contra-aligned with the first section of the explored route. However, this outcome was confined to the first VE that was explored. Following exploration of a second VE, subsequent alignment tests showed a reduction in 90° misaligned and contra-aligned errors and latencies, and hence, attenuation of the first-perspective alignment effect, such that the pattern of errors conformed to that anticipated from an orientation-free memory.

In Experiment 8, when the alignment test following exploration of the first VE route was replaced with a spatial orientation test that was not related to that VE, a first-perspective alignment effect was evident following exploration of the second VE. This outcome suggests that it was prior experience of making orientation judgements about the first route, rather than experience of exploring the first VE, that brought about the attenuation of the first-perspective alignment effect in the second test of Experiment 7. In neither experiment did the factor of whether the explored VEs were enclosed or open exert a consistent influence on the overall patterns of error and latency data. At least with respect to the VEs used in Experiments 7 and 8, it appears that different experimental surroundings do not lead to encoding via different frames of reference.

Overall, the results of Experiments 7 and 8 extend those of Wilson et al. (1999), who, with fewer participants, did not find a statistically significant difference in accuracy between judgements that were aligned and contra-aligned with the first part of the route (see also Rossano & Moak, 1998; Tlauka & Wilson, 1996). The findings replicate and extend those of Richardson et al. (1999) and Rossano et al. (1999), and provide further evidence that the first-perspective alignment effect can occur as a result of perceptual spatial learning. Together with the text based first-perspective alignment effect found by Wilson et al. (1999) and in Experiments 2, 3 and 6 (Chapter, 2), the present results suggest: First, that as in the text case, even when allocentric information is provided in VEs, participants appear to preferentially encode the space using a primary forward-up-north equivalent frame of reference. Secondly, that the first-perspective alignment effect may be a general phenomenon of spatial learning from secondary learning sources; however, important to note is that the magnitude of the effect is much greater when learning is from text than when from VEs. Overall, the data are consistent with the hypothesis of similar forms of spatial encoding from language and perception (e.g. Bryant, 1992; Denis, 1996; Glenberg & McDaniel, 1992; Jackendoff & Landau, 1992).

Experiment 9 used a text-based procedure. In one condition, participants were asked to make active spatial judgements after reading each section of the route. Consistent with the hypothesis that active spatial processing may have attenuated the first-perspective alignment effect in the second test of Experiment 7, encoding was from multiple perspectives. In contrast, when participants read the route in sections, but were not asked to make spatial judgements after each section, they made more accurate orientation judgements at test when imagining themselves aligned, rather than 90° misaligned or contra-aligned with the first section of the described route.

With respect to secondary learning sources such as VEs and text descriptions, Experiments 7 and 9 suggest that active spatial processing from key perspectives on a route can attenuate the first-perspective alignment effect. However, while the current data identify active spatial processing as a factor that appears to reduce the first perspective alignment effect, it is important to consider a theoretical account of how this reduction might occur.

Given that the first-perspective alignment effect seems to be a general phenomenon of spatial learning, at least with respect to text descriptions and VEs, the present results provide further support for the anchor point hypothesis proposed in Chapter 2. It appears that, for route learning, and when allocentric information is absent or minimal, people preferentially encode space using an egocentric frame of reference based on alignment with the first perspective on a scene. Further, that this perspective may represent a default or primary anchor point for spatial recall (cf. Golledge (1978, 1984), and that the first direction of travel from this anchor point determines the alignment encoding of the entire route on the basis of a forward-up north equivalent principle. However, as noted in Chapter 2, an advantage to targets in front of rather than behind participants' imagined orientation at test that is predicted by the spatial framework model for egocentric retrieval (Franklin & Tversky, 1990), was not apparent in either the error or latency data of Experiments 7 and 8. One explanation for this outcome is that irrespective of whether a scene has been described in text, or explored in a VE, at retrieval, participants may imagine the whole scene from an external perspective, so that the scene is projected forward in their imagined field of view. Therefore, both front and behind (in terms of locations within the remembered scene) refer to locations that are in front of this external perspective. Because egocentric front-back asymmetry is not relevant to an external viewpoint, a front over back difference that favours target locations in front of this viewpoint should not be found (cf. Bryant et. al., 1992).

A problem with attributing the first-perspective alignment effect to reliance on a single egocentric anchor point is that a first-perspective alignment effect should be evident only, or primarily on the first section of the route. However, with respect to text descriptions, it was also suggested in Chapter 2 that the 180° turn at the end of the route might engender a second egocentric start point, such that both the first section of the route and the first return section are encoded as 'ahead' or 'north.'

To extend this account to Experiments 7 and 8, in Experiment 7, the analysis conducted to investigate aligned and contra-aligned errors on the first and last sections of the route for the first test found a strong alignment effect on the first (*M*s = 28 and 55° for aligned and contra-aligned judgements respectively) section of the route. These data are consistent with the idea that the first perspective may represent a primary, 'start' anchor point in spatial memory. Similarly, an alignment effect (although of smaller magnitude) was also found in the aligned and contra-aligned (*M*s = 45 and 50° respectively) error scores for the last section of the route. In contrast to this pattern of a stronger first-perspective alignment effect on the first than the last part of the route in Experiment 7, in Experiment 8, the pattern of judgement errors was of lower errors for aligned than contra-aligned errors on both sections of the route, and the latency data were in close agreement with this pattern. Overall, the error data from Experiment 7, and the error and latency data from Experiment 8 suggest that that anchor points may have been formed both at the start point of exploration, and the start point of the return journey. In other words, participants remembered two journeys, each with its own start point, rather than a single return journey. The 180° rotation at the end of the explored route appears to create a second egocentric anchor point that may be less cognitively salient than the start anchor point.

With respect to learning from secondary media, this outcome is consistent with the hypothesis that when allocentric information is absent or minimal, active processing of spatial information from key perspectives on the route may lead to the construction of multiple anchor points, and therefore, reduced reliance on the start anchor point from which to define orientation at test. In the case of primary learning, first-perspective alignment effects have been demonstrated, but only under conditions when participants have learned an environment under conditions where access to allocentric information has been prevented or limited. For example, Palij, Levine and Kahan (1984, Experiment 2) asked blindfolded participants to walk along five-point paths laid out on the floor of a large room. Each walk began at the first point of the path and ended at the fifth point (See Figure 2.1.1. p.14). These authors reported what they termed an "A-C effect" (p. 108), in that subsequent orientation test judgements were more accurate and made faster when participants imagined themselves in positions that were aligned rather than contra-aligned to the first direction of travel (i.e. point 1 - point 2 in Figure 2.1.1.). In one sense, this outcome is unsurprising, because when blindfolded, the only way in which orientation can be defined is with respect to the direction of travel. However, in the present experiments, participants also read about or explored a *return* journey (adding experience of the reverse direction of travel), but the first-perspective alignment effect was consistently found. It may be that real-world environments typically comprise salient landmarks or other environmental cues that can offer 'ready-made' anchor points thus rendering allocentric encoding more efficient; when an allocentric frame is a not available, participants encode space egocentrically, and in alignment with the first direction of travel.

In summary, the experiments reported in the present Chapter provide evidence that the first-perspective alignment effect is not an artefact of text presentation, but appears to be a more general feature of spatial encoding and retrieval when learning is from secondary sources. An account of the effect was developed in terms of spatial knowledge acquisition based on a primary anchor point, supplemented by further anchor points, which are influenced by aspects of the learning experience. However, these experiments do not address two potentially important aspects of the first-perspective alignment effect: First, whether the effect occurs following real world learning, and second, whether it is limited to the spatial arrangement and exploration parameters used in these experiments. Therefore, the experiments reported in Chapter 4 extend the current investigations of the anchor point hypothesis from route learning to learning about object arrays, and from text and VEs to learning from primary experience.

CHAPTER 4

Memories of Object Arrays: Investigating a Primary-Secondary Learning Distinction in Human Spatial Memory

During the course of the present research programme, investigations of the first-perspective alignment effect were being carried out independently at the University of Leicester, by Wilson (2001, personal communication). Wilson's research provided some preliminary evidence that secondary learning sources might lead to the first-perspective alignment effect, when a very different spatial arrangement was used. That is, when people viewed pictures, or read descriptions of arrays of objects depicted from more than one static viewpoint, recall was most efficient from the first depiction. This finding provides further evidence that the first-perspective alignment effect is a general feature of spatial learning from secondary sources, because the experimental procedure involves: a different spatial arrangement to the routes used in Experiments 2 - 9, external rather than internal views on a scene, and learning from static viewpoints rather than continuous exploration. These experiments also suggested that 'active' processing of a view other than the first might attenuate the first-perspective alignment effect; this finding is very similar to that in the current Experiment 9. However, Wilson did not provide evidence on whether the first-perspective alignment effect occurs in a real-world version of his experiments. Therefore, the experiments reported in the present chapter extend the current investigations of the anchor point hypothesis, using a real-world version of Wilson's paradigm. The experiments investigate whether the first-perspective alignment effect occurs following learning from a real-world array of objects, and whether procedures that would be expected to establish multiple anchor points systematically influence spatial learning.

Recent debate in the field of object recognition concerning whether both intra- and inter-object recognition are viewpoint-dependent or viewpoint-independent, provides a further theoretical rationale for extending the present investigations using object arrays. For single object recognition, proponents of viewpoint-independence argue that memories for objects are stored as structural descriptions of invariant parts of features of an object. Once a particular object has been stored in memory, recognition of that object from any view (including views that have not been seen) should not be affected by the viewpoint at test, as long as the necessary features can be recovered from that view (Burghund & Marsolek, 2000). In general, recognition performance supports structural description models when objects are composed of distinctive, identifiable parts (Biederman, 1987; Biederman & Gerhardstein, 1993; Cooper, Biederman & Hummel, 1992; Hummel & Biederman, 1992).

A second group of theorists have indicated that mental representations of a single object may consist of a collection of multiple, viewpoint-dependent representations, with each representation corresponding to a familiar view of that object. Recognition performance has been demonstrated as viewpoint-dependent for single objects that are not easily distinguishable by their component parts, such as wire frame objects (Tarr & Pinker, 1989), blob-like objects (Edelman & Bülthoff, 1992), and objects constructed from *LEGO* bricks in both the visual and haptic modalities (Newell, Ernst, Tjan & Bülthoff, 2001). In multiple viewpoint models, recognition judgements are accomplished by matching the visual stimulus with a stored representation in memory. If a viewpoint-dependent representation that corresponds to the orientation of the stimulus exists in memory, recognition will be accurate and fast. If no such representation exists, recognition is said to take place by a process of normalisation to the nearest familiar representation in memory. This normalisation procedure has been attributed to the mental rotation of an unfamiliar to a familiar view, and is thought to lead to longer recognition times and greater errors when learning has taken place from both single and multiple viewpoints (e.g. Tarr, 1995; Tarr & Pinker, 1989).

Clearly, this latter line of theorizing with respect to single object recognition from one or multiple viewpoints may correspond with investigations of the orientation dependence or independence of spatial memories of environments when multiple perspectives have been experienced. Multiple perspectives, as they are experienced and integrated would be anticipated to lead to orientation-free representations as has been reported for real-world learning (e.g. Evans & Pezek, 1980; Presson et al., 1989; Thorndyke & Hayes-Roth, 1982). In contrast, spatial information learned from a single viewpoint (e.g. a map), has been shown to define the orientation of the resultant mental representation with respect to the individual's view while learning (Levine, 1982; Presson & Hazelrigg, 1984). However, the number of views experienced is a factor that may have confounded the differences in performance between at least map and real-world navigational studies; specifically, whether multiple views of a test space are integrated to form an orientation-free representation of a scene, or whether memories of large-scale spaces comprise multiple, but orientation-dependent views.

A number of recent perceptual studies have addressed this issue using arrays of visually distinct objects that have been experienced from a small number of controlled perspectives. For example, Diwadkar and McNamara (1997) asked their participants to learn the arrangement of a collection of objects arranged on a circular desk top on the floor of a room, from a single view; then to learn to recognize the scene from this 'seen' view, and from three additional training views that were presented as digitised images. Recognition performance indicated that all four of the seen views were represented in memory, and that unseen views were recognised by normalisation to the nearest study or training view.

In a related experiment that was based on the alignment paradigm used in the present experiments, Shelton and McNamara (1997) similarly speculated that the recognition of spatial layouts of groups of objects experienced from a small number of clearly defined views might also be viewpoint dependent. Shelton and McNamara exposed their participants to two configurations of seven visually distinct objects. The objects were arranged on a 3 x 3m clear plastic sheet in one half of a large room, and each participant viewed one of the arrays from two viewing positions that differed by 90°. After studying the layout from both viewpoints, participants were asked to make orientation judgements from the two experienced viewpoints, and six non-experienced perspectives, based on their memories of the array. As in the present experiments, participants imagined themselves located at one of the objects in relation to a second object that established facing direction, and pointed out the direction of a third object. Shelton and McNamara hypothesised that if two views of a spatial layout produced two viewpoint-dependent representations in memory, orientation judgements made from imagined test locations that corresponded to the experienced views should show an advantage over imagined non-experienced views. Consistent with this hypothesis, their results revealed a seen-views alignment effect, in that mean errors were lower, and response latencies faster for the two experienced (aligned), than for non-experienced (misaligned or contra-aligned) views following equivalent training exposure. Shelton and McNamara concluded that participants had formed two egocentric representations of the layout.

The results of Diwadkar and McNamara (1997) and Shelton and McNamara (1997), in addition to a number of related experiments (e.g. Mou & McNamara, 2002; Nakatani, Pollatsek & Johnson, 2002; Roskos-Ewoldsen, McNamara, Shelton & Carr, 1998; Shelton & McNamara, 2001), indicate first, that there are important parallels between recognition performance of spatial layouts of objects and those recorded for single objects. Also, that in contrast to earlier studies of environmental spatial learning, which indicated that learning from multiple perspectives led to orientation-free representations (Evans & Pezdek, 1980; Thorndyke & Hayes-Roth, 1982), representations of space generated from multiple viewpoints may consist of multiple viewpoint-dependent representations based on each experienced viewpoint. Moreover, and of particular relevance to the current experiments, Shelton and McNamara's finding of a seen-views alignment effect from real world learning (in which experienced views of a test space were remembered more accurately and faster than non-experienced views), suggests that the tendency to encode space in a preferred egocentric orientation may be a dominant feature of human spatial learning.

However, although multiple views on a test space appear to be viewpoint-dependent, a seen-views account of real world spatial learning predicts that experienced perspectives on a scene will be remembered equally well. Shelton and McNamara (1997), for example reported equivalent performance with respect to both angular errors and response latencies for the two "familiar" views in their experiment (p. 104). This outcome for real world learning is not in agreement with the results of the experiments reported in Chapters 2 and 3 for learning from secondary sources, in which *all* perspectives were described or explored, but in which participants preferentially encoded and retrieved the space from the *first*-experienced perspective. Similarly, Wilson (2001, personal communication), found that following exposure to text and pictorial depictions of arrays of four objects from four perspectives, participants memorized the array under both the verbal and visual conditions preferentially, from the first depicted perspective. Although overall errors were slightly lower in the visual condition (*M*s 74 and 56° for text and pictures respectively), the combined data for the text and pictures conditions revealed evidence consistent with a first-perspective alignment effect; further that orientation judgement errors from imagined perspectives within the array increased linearly as the alignment changed from aligned with the first, second, third and fourth perspectives.

The consistent finding of first-perspective alignment encoding in Experiments 2 – 8 along with that of Wilson (2001, personal communication), with respect to secondary sources, stands in contrast to the equivalent performance for experienced perspectives found by Shelton and McNamara (1997) from primary learning, and therefore merits further investigation. In an initial extension of the present experiments to primary learning, participants in Experiment 10 were exposed to a real-world navigable array of four objects from four perspectives that were 0, 90, 180 and 270° misaligned from the centre of the array. Four objects only were used so that a direct comparison could be made to the results of Wilson's text- and picture-based experiments; in the former case, to describe more than four objects would have made the text much too complicated. Also, to facilitate comparisons between the route learning experiments reported in Chapters 2 and 3, the objects were arranged on a square table top, in a similar U-shape to that formed by the key locations in those experiments. Therefore, the primary difference between the two sets of experiments reported in Chapters 2 and 3 and those included in the present chapter, is that in the object array case, spatial information is presented from a static external, rather than the dynamic internal perspective used for text and VEs; in both cases, testing was from an internal perspective.

It was anticipated that if the first-perspective alignment effect found for secondary learning extends to primary learning, a similar pattern of errors and latencies to those found in Experiments 2-9, and by Wilson (2001) should be apparent in Experiment 10. Equivalent encoding from all four experienced perspectives would support a seen-views account of human spatial learning from primary sources, which is not usually evident when learning is from secondary sources, and would therefore suggest different forms of encoding following primary and secondary learning.

Experiment 10

Design

In a repeated-measures design, participants observed four everyday objects from four viewing perspectives that were 0, 90, 180 and 270° misaligned from the centre of the array. The dependent variables were measures of error in orientation and distance between imagined perspectives from each of the four experienced perspectives, and the times taken to make these judgements.

Participants

Participants were 40 undergraduates from the University of Leicester UK, of whom 35 were female, and who received credit toward the fulfilment of a first year practical course requirement. They had a mean age of 19.2 years (range: 18-42 years).

Apparatus

A configuration of four common, visually distinct objects was constructed. Objects were fixed on a 1m x 1m sheet of hardboard, which rested centrally on a table top (height = 75cm). The objects were arranged as the points of an invisible trapezium that corresponded to those of the major landmarks used in the route experiments reported in Chapters 2 and 3. The centres of three objects were placed at equal distance (10cm) from three corners of the hardboard, and the fourth object was fixed 20cm from one object, and 10cm from the edge of the hardboard, as indicated in the arrangement depicted in Figure 4.10.1.

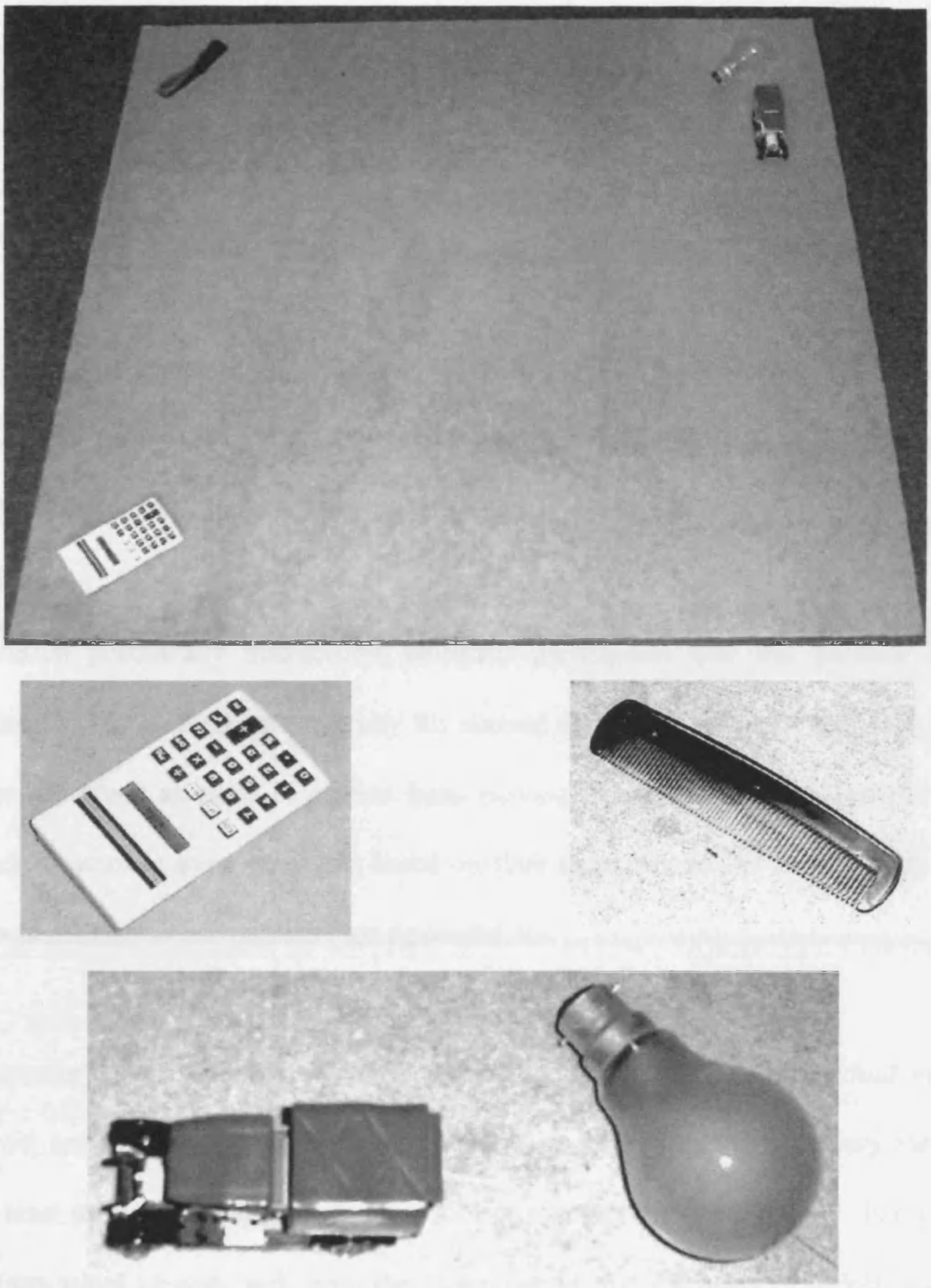


Figure 4.10.1. The spatial layout used in Experiment 10 (upper panel); individual illustrations of the four objects used (lower panels)

To view the array, standing participants looked through eye-level windows in hardboard screens (height = 185cm, width = 235cm), set at 90° angles from the centre of the display, and parallel with the four sides of the hardboard screen. One eye-level observation window (height = 15cm, width = 23cm) was cut centrally in each screen

(140cm from the bottom of the screen and 115cm from both sides); these are arbitrarily referred to here as Viewpoints 1, 2, 3 and 4. The apparatus stood at one end of a large room, with the table equally distanced from its centre to each side of the screen (120cm).

Angle estimates were made using the 360° protractor employed in the experiments reported in Chapters 2 and 3; reaction times were measured using a hand held stop watch.

Procedure

Written preliminary instructions informed participants that the purpose of the experiment was to investigate memory for scenes; they were informed that they would be asked to study an array of objects from viewing perspectives external to the array, and then to answer some questions based on their memories of the arrangement of the objects in relation to one another (see Appendix A).

Learning phase: Each participant was initially escorted to one of the four viewing windows, and verbally instructed to study the array in front of them "...very carefully, for at least thirty seconds, until you get a clear memory for the objects." Participants were then asked to step back from the viewpoint so that the array of objects was not visible; they then walked to the second, third and fourth viewing windows consecutively, where this sequence was repeated. Following viewing the array from each of the four perspectives, participants were escorted to another part of the room, asked to name the four objects aloud, and then asked eight orientation test questions, two aligned with each of the four experienced perspectives.

Counterbalancing included first, whether the initial perspective on the environments was from Viewpoint 1, 2, 3 or 4, and second, whether participants walked between the four viewpoints in a clockwise or anti-clockwise direction

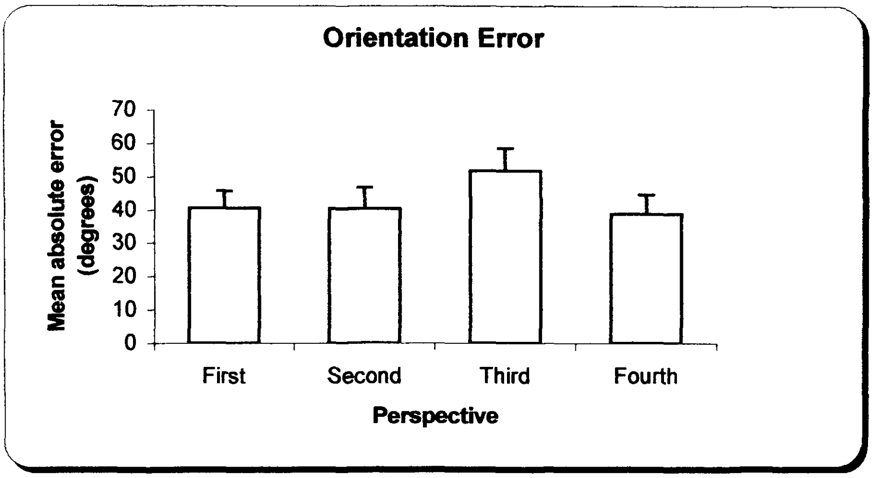
Testing phase: Eight alignment test questions were prepared, and these were constructed in the same way as for Experiments 2-9. For each directional pointing task, participants were asked to imagine that they were "...in the centre of the dial, as if you are actually on the table..." and facing zero degrees on the pointing device. With respect to the direction of the first viewing perspective, two questions were prepared that were aligned with each of the 0, 90, 180 and 270° views. The alignment test questions were counterbalanced according to the actual position of the target object with respect to the participant's imagined location within the array (i.e. front-left, back-right, back-left, front-right). The order of presentation of the alignment test questions (aligned with the first, second, third or fourth viewing perspective) was arranged according to a Latin Square, counterbalanced across the above factors. The mean absolute correct angle (rounded to the nearest 5°) for the test questions was 90°, with the means for front- and back-facing questions being 45 and 135° respectively. The alignment test questions used in Experiments 10 – 14 can be found in Appendix C. For all of the alignment tests, the sets of questions were read aloud by the experimenter; each judgements was timed from pronunciation of the last word of the test question, until the participant's verbal response indicated completion.

Results and Discussion

As for the experiments reported in Chapters 2 and 3, the distance error data for the experiments reported in the present Chapter were analysed both in raw form and following conversions to account for individual differences in distance estimates. Neither of these analyses, nor analysis of the respective time data proved to be sensitive to any of the variables under investigation, and are not reported. Angle of error scores were derived from the participants' estimated angles by subtracting the estimated angles from the true angles and taking the unsigned value. Sex was not included in the analyses below as the participants were predominantly women. Descriptive statistics of the error and latency data for each viewpoint are presented below in Table 4.10.1. The mean error and latency scores are illustrated in the upper and lower panels of Figure 4.10.2 respectively.

Table 4.10.1
Descriptive Statistics for Orientation Judgements (tabled in degrees) to Targets that were Aligned with the First, Second, Third and Fourth Perspectives on the Array, and the Times Taken to make these Judgements.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Orientation Error							
First	40	2.50	132.50	40.50	32.59	30.08	50.92
Second	40	5.00	165.00	40.38	40.21	27.51	53.24
Third	40	2.50	150.00	51.63	42.73	37.96	65.29
Fourth	40	0.00	122.50	38.75	36.67	27.02	50.48
Orientation Latency							
First	40	1.13	27.27	7.20	5.13	5.56	8.84
Second	40	2.37	21.58	8.31	4.76	6.79	9.83
Third	40	2.11	25.85	8.38	5.85	6.51	10.25
Fourth	40	1.83	31.76	7.99	5.58	6.20	9.77



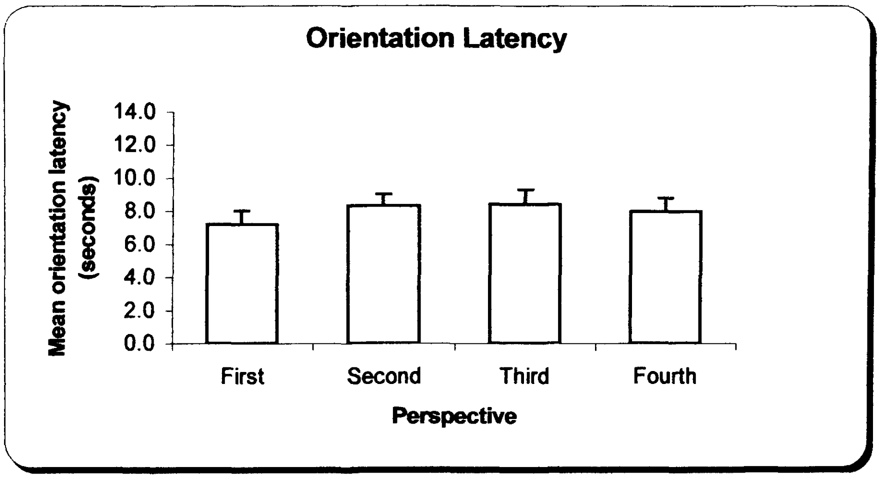


Figure 4.10.2. Experiment 10: Mean absolute error (upper panel) and latency (lower panel) scores for orientation judgements to target locations that were aligned with the first, second and fourth perspectives on the array. Error bars represent one estimated standard error above the mean.

The mean error and latency data were entered into separate 2 x 4 repeated-measures ANOVA with direction (whether the target object was in front of or behind participants' imagined facing direction within the array at test), and alignment (aligned with the first, second, third or final view) as factors. The analysis of the error data found no significant main effects or interactions (*p*s > .06). For the latency data, there was a significant main effect of direction, $F(1, 39) = 9.88$, $MSE = 40.49$, $p = .003$ (partial η^2

= .20), that reflects lower overall errors to target objects that were behind (*M* = 7s) than in front of (*M* = 9s) participants' imagined facing direction at test. No other main effects or interactions were significant (*p*s > .6).

In contrast to Experiments 2-9, and that of Wilson (2001, personal communication), all of which employed secondary learning media, Experiment 10 produced no evidence for first-perspective alignment encoding following primary learning. Orientation judgement errors were of a similar magnitude when the alignment changed from aligned with the first, second, third and fourth perspectives, and the pattern of latency data was supportive of this outcome. The finding in the latency data of faster judgements to targets that were behind rather than in front of participants' imagined facing direction at test is in contrast to a general lack of direction effects from secondary learning in Experiments 2 - 8, and although not significant, the mean error scores reflected a similar pattern (*M*s 48 and 37° for in front and behind targets respectively).

In Experiments 11 and 12, the focus of the present experiment was extended by looking, not only for first-perspective alignment effects, but also the seen-views alignment effects recorded by Shelton and McNamara (1997). In order to demonstrate seen-views alignment effects, it is necessary for participants to make judgements that are aligned with perspectives to which they have been exposed, as well as to perspectives that they have not. The experienced perspectives might comprise two that are 90° misaligned with each other from the centre of the array, or two that are opposite to each other; that is, 180° contra-aligned from the centre of the array. Seen-views alignment and first-perspective alignment accounts make quite different predictions about the patterns of data following these manipulations. When the experienced perspectives are 90° misaligned, a seen-views alignment account predicts equivalent performance for judgements aligned with the first and second experienced views (because both have been seen), and performance aligned with both of these views should be better than for non-seen views (i.e. opposite to the seen views). In contrast, a first-perspective alignment account predicts better performance for judgements that are aligned with the first than all other perspectives; critically, performance differences are predicted between the first and the second of the two experienced perspectives.

As described above for the 90° misaligned case, where the two experienced perspectives are 180° contra-aligned to each other, the seen-views alignment account predicts equivalent performance for judgements aligned with the first (0°) and second (180°) experienced perspectives, and that performance from these perspectives should be better than from the non-experienced (misaligned) perspectives. The first-perspective alignment effect predicts more efficient processing for the first (0°) experienced perspective than the second (180° opposite) experienced perspective, and better performance would be expected for both seen perspectives than the unseen perspectives.

Wilson (2001, personal communication) explored this hypothesis using text descriptions and still pictures of four objects arranged on a table top. When two perspectives on the array were depicted as 90° misaligned from each other with respect to the centre of the display, a seen-views alignment effect was found; however, a first-perspective alignment effect was also evident between the experienced views. Similar to the finding in Experiment 9, that asking participants to make spatial judgements while reading attenuated the first-perspective alignment effect, Wilson found that a similar manipulation (in which participants were asked to make spatial judgements immediately after reading a description of, or viewing each perspective) attenuated the first-perspective alignment effect for both text descriptions and picture presentations of arrays. However, in both cases, a general alignment effect was still found. When the experienced perspectives were described in text or presented as pictures that depicted 180° contra-aligned perspectives from the centre of the array, a first-perspective alignment effect was evident for both learning media. In the text case, making spatial judgements after reading a description from each of the two perspectives apparently reversed the first-perspective alignment effect, leading to lower errors from the last perspective than the first, with errors for the perspectives that had not been described in between. Wilson did not look experimentally at the effect of making judgements after seeing pictures in the contra-aligned case. Overall, however, Wilson's experiments provide clear evidence of the first-perspective alignment effect following learning from text and pictures, and the data patterns do not support the predictions from a seen-views alignment hypothesis.

To extend Wilson's experiments to a real-world arrangement, in Experiments 11 and 12 participants viewed a real array of four objects from two static perspectives, and then answered alignment test questions; the procedure was then repeated using a different array of objects. In Experiment 11, the two experienced perspectives were 90° misaligned from the centre of the array (see Figure 4.11.1), whereas in Experiment 12, the two experienced perspectives were 180° contra-aligned from the centre of the array, that is, from opposite sides. A repeated-measures design was employed in both experiments to explore whether, as in the text case, asking participants to make spatial judgements following their exposure to each perspective yielded any influence on subsequent patterns of data.

Experiment 11

Design

In a repeated-measures design, participants were exposed to two configurations of four everyday objects, each from two external viewpoints set at 90° from the centre of the display. In Condition 1, the dependent variables were angle and distance judgements made from four imagined locations within the array (two aligned with each experienced perspective, and two opposite to each experienced perspective), and the times taken to make these judgements. In Condition 2, the dependent variables were the same, but additional angle and distance judgements were made immediately following participants' exposure to each of the two experienced perspectives; these angle and distance estimates, together with the respective reaction times were also recorded.

Participants

Participants were 32 undergraduate students from the University of Leicester, UK, who received credit towards the fulfilment of a first or second year practical course requirement. They had a mean age of 19.8 years (range: 18-21), and two participants were male.

Apparatus

The apparatus was identical to that used in Experiment 10 with two exceptions: First, an additional array of objects to that employed in Experiment 10 was constructed, that comprised a blue candle, a white plug, a red note book and an orange ball; the two arrays are referred to below as 'Array A' and 'Array B.' The objects were arranged in an identical manner to the array used in Experiment 10. Second, to view the array, participants looked through eye-level windows cut in two of the four sides of the hardboard screen set at 90° angles from the centre of the display, and parallel with two sides of the table (see Figure 4.11.1). The viewing windows in the remaining two sides of the screen were occluded.

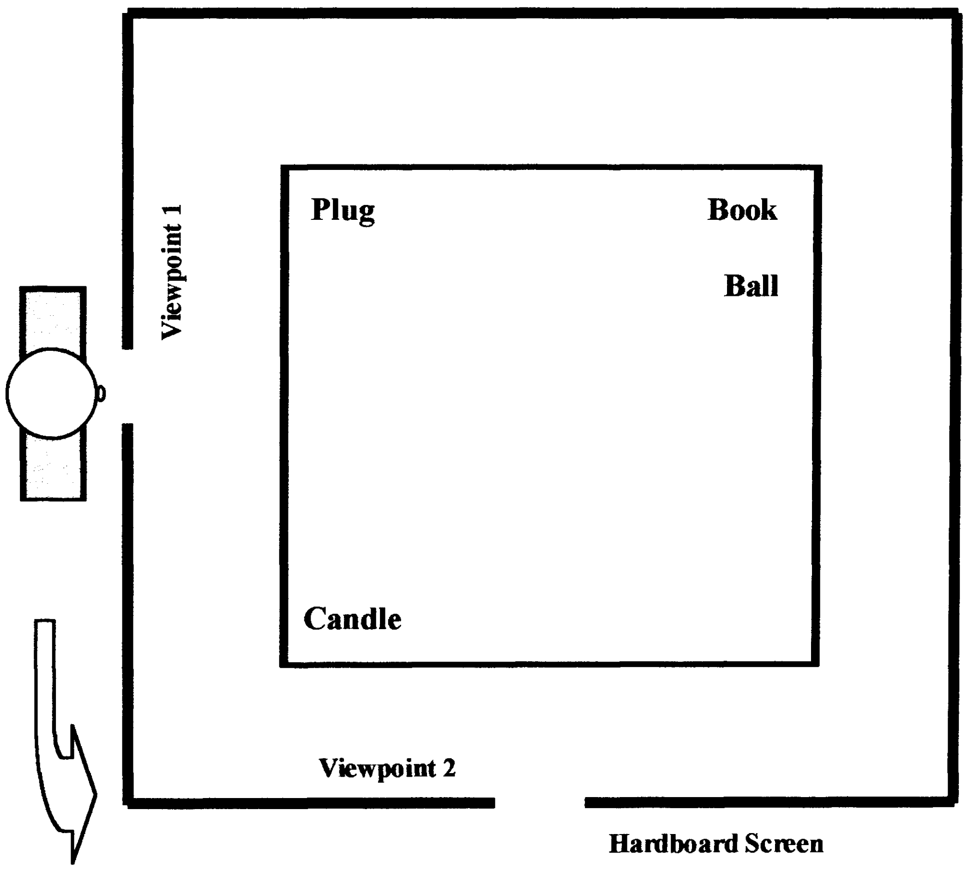


Figure 4.11.1. Diagram (not to scale) of the apparatus used in Experiment 11. Half the participants viewed the array from Viewpoint 1 first, and then walked in an anti-clockwise direction to Viewpoint 2 (as illustrated); the remaining half viewed the array from Viewpoint 2 first, and walked in a clock-wise direction to Viewpoint 1.

Procedure

Each participant carried out both Conditions of the experiment in a counterbalanced order. Preliminary instructions described the purpose of the experiment (see Appendix A), and asked participants to study each array of objects from both viewpoints "...very carefully, for at least thirty seconds, until you get a clear memory for the objects."

Learning phase: For Condition 1, participants were asked to study an array through one viewing window, then to stand away from the screen and to name each object aloud. Participants were then escorted to the second viewing window, where the study-name sequence was repeated. For Condition 2, the same study procedure was followed for each viewpoint, but immediately after each viewing, participants were asked to move to a position in the room where the screen was out of visual range, then to imagine that they were still in the viewing position facing the table, and to estimate their physical distance and angle from each object.

Testing phase: Participants answered eight alignment test questions following their exposure to both perspectives on the first array (A or B), and this testing procedure was repeated following their exposure to the second array. For each array, with respect to the direction of the first viewing experience, two questions were aligned with each of 0, 90, 180 and 270° (see Appendix C). Following each alignment test question, participants were asked to estimate the actual distance (cm) from their imagined station point within the array to the target object. An example of an aligned question for the array depicted in Figure 4.11.1 when the first perspective on this array was from 'Viewpoint 2' is: 'Imagine that you are at the candle and the plug is in front of you. Point out the direction of the note book. How far away from you is the note book?' From the same viewpoint, an example of a question opposite to this perspective is: 'Imagine that you are at the ball and the note book is behind you. Point out the direction of the plug. How far away from you is the plug?'

Counterbalancing comprised three training arrangements: First, whether participants initially undertook Condition 1 or Condition 2 (additional judgements). Second, whether Array A or Array B served as the initially presented configuration in

Conditions 1 or 2. Third, whether the initial observation was from Viewpoint 1 or Viewpoint 2, and whether this initial perspective on each environment was presented at 0, 90, 180 or 270 degrees rotation of the configuration from an arbitrary start position. In the test, the following were counterbalanced: First, the order of the orientation judgements according to the position of the target object (i.e. front-left, back-right, back-left, front-right), with respect to the participant's imagined location within the array. Second, the order of the alignment test questions (aligned with the first viewpoint, contra-aligned with the first viewpoint, aligned with the second viewpoint, and contra-aligned with the second viewpoint) was arranged according to a Latin Square, counterbalanced across the above factors. Any procedural details not specified above were identical to Experiment 10.

Results and Discussion

Angle of error scores for judgements made from the two experienced viewpoints during the learning phase of the experiment were derived for each object in the same way as for Experiment 10. These data, and their respective latencies were separately averaged for each participant to produce a single error and latency score for each experienced view. Paired samples analyses of the angle error scores and the respective latencies from the first and second views found no significant differences between the means in either analysis (ts < 2).

Angle of error scores for orientation judgements in the main experiment were also derived in the same way as for Experiment 10. Sex was not included as a factor in any of the analyses below, as only two men took part in the experiment. Descriptive statistics of the error and latency data for judgements aligned with the first and second experienced perspectives, and aligned with the opposite to first and opposite to second perspectives are presented in Tables 4.11.1 and 4.11.2 respectively.

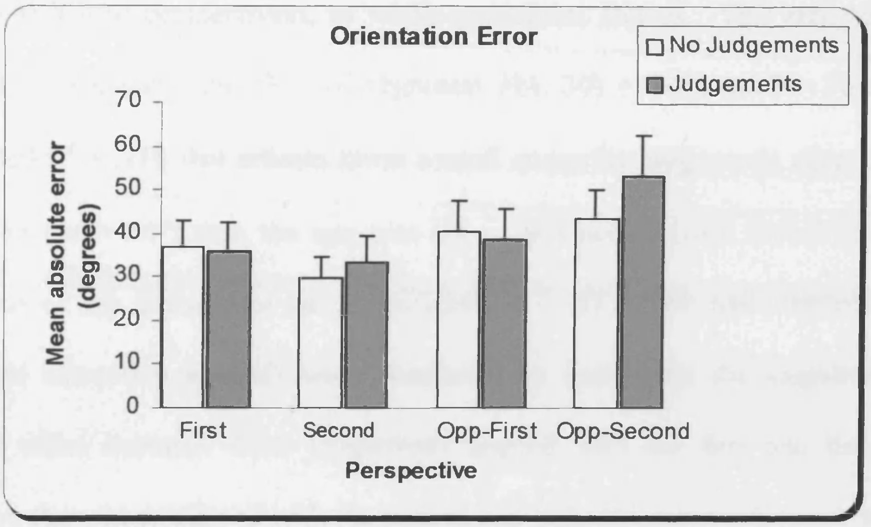
Table 4.11.1
Descriptive Statistics for Orientation Judgements (tabled in degrees) in the 'No Judgements' and 'Judgements' Conditions, to Targets that were Aligned with the First and Second Experienced Perspectives and Aligned with the Opposite to First and Opposite to Second Perspectives.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
No Judgements							
First	32	2.50	130.00	36.95	34.77	24.42	49.49
Second	32	2.50	92.50	29.61	28.70	19.26	39.96
Opposite-First	32	.00	140.00	40.23	41.36	25.32	55.15
Opposite-Second	32	5.00	177.50	43.20	39.51	28.96	57.45
Judgements							
First	32	2.50	140.00	35.70	38.35	21.87	49.53
Second	32	2.50	145.00	33.28	35.65	20.43	46.14
Opposite-First	32	.00	167.50	38.75	40.15	24.27	53.23
Opposite-Second	32	.00	170.00	53.05	52.89	33.98	72.11

Table 4.11.2
Descriptive Statistics for Orientation Latencies (tabled in seconds) in the 'No Judgements' and 'Judgements' Conditions, to Targets that were Aligned with the First and Second Experienced Perspectives and Aligned with the Opposite to First and Opposite to Second Perspectives.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
No Judgements							
First	32	1.50	27.00	7.43	5.27	5.53	9.33
Second	32	2.00	22.40	7.72	5.79	5.63	9.80
Opposite-First	32	2.50	35.00	9.45	6.37	7.15	11.74
Opposite-Second	32	2.50	22.50	9.27	5.75	7.19	11.34
Judgements							
First	32	2.00	29.50	8.23	6.03	6.06	10.41
Second	32	1.00	26.50	7.83	5.93	5.69	9.97
Opposite-First	32	1.50	33.00	8.11	6.66	5.70	10.51
Opposite-Second	32	1.00	27.00	8.54	6.12	6.34	10.75

The mean orientation error and latency scores are illustrated in the upper and lower panels respectively of Figure 4.11.2.



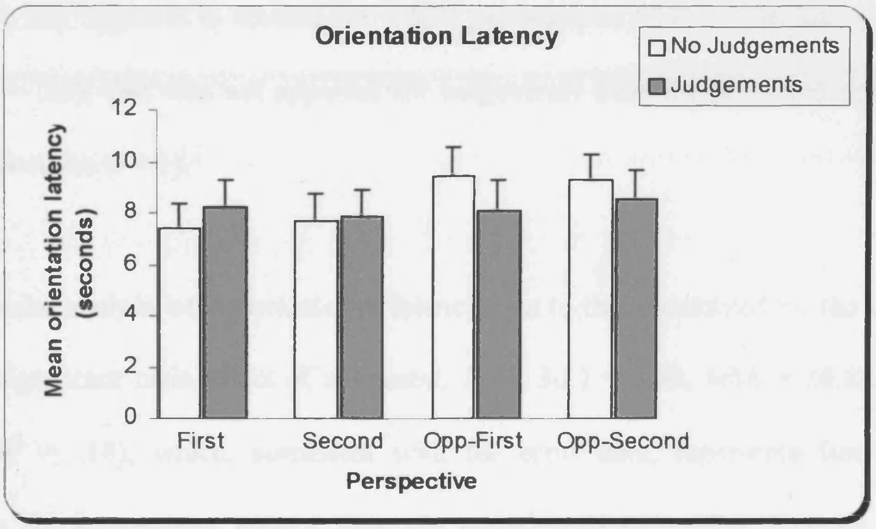


Figure 4.11.2. Experiment 11: Mean absolute error (upper panel) and latency (lower panel) scores for judgements that were aligned with the first, second, opposite to first, and opposite to second perspectives in the 'no questions' and 'questions' conditions. Error bars represent one estimated standard error above the mean.

The error data were entered into a 2 x 2 x 2 x 2 x 2 mixed ANOVA analysis, with order (no judgements or judgements tested first) as the between-participant factor, and condition (no judgements, judgements), direction (whether the target object was in front of or behind participants' imagined facing direction within the array), alignment (aligned with, or opposite to, the described perspective), and first-second (first and second experienced perspectives), as within-participant factors. This analysis found a statistically significant main effect of alignment $F(1, 30) = 7.73$, $MSE = 1629.86$, $p = .009$ (partial $\eta^2 = .21$), that reflects lower overall errors for judgements aligned with the experienced (M = 34°) than the opposite (M = 44°) perspectives; however, no other main effects or any interactions were significant ($ps > .1$). Two pair-wise comparisons (Bonferroni correction applied) were conducted to investigate the magnitude of the alignment effect between those judgements aligned with the first and the opposite perspective than those aligned with the second and opposite perspective. A significant difference was evident between the overall means for judgements made from the second (M = 31°) and opposite to second (M = 48°) perspectives $t(31) = 2.36$, $SE = 7.08$, $p = .025$ ($\eta^2 = .15$), that was not apparent for judgements from the first- and opposite-to-first perspectives ($t < 1$).

A similar analysis of the orientation latency data to that conducted for the error data found a significant main effect of alignment, $F(1, 30) = 6.59$, $MSE = 20.82$, $p = .02$ (partial $\eta^2 = .18$), which, consistent with the error data, represents faster overall responses for judgements aligned with the experienced (M = 8s) than the opposite perspectives (M = 9s). Also evident was a main effect of direction, $F(1, 30) = 5.08$, $MSE = 61.83$, $p = .03$ (partial $\eta^2 = .15$), and significant order x condition, $F(1, 30) = 47.14$, $MSE = 28.34$, $p = .00$ (partial $\eta^2 = .61$), condition x direction x first-second $F(1, 30) = 4.85$, $MSE = 30.00$, $p = .04$ (partial $\eta^2 = .14$), and condition x direction x alignment x first-second $F(1, 30) = 4.89$, $p = .04$ (partial $\eta^2 = .14$) interactions. As for the error data, post-hoc pair-wise comparisons were made between the means of judgements aligned with the first and the opposite perspective, and those aligned with the second and opposite perspective; significant differences were not apparent in either comparison (*t*s < 2).

The main effect of direction reflects faster overall responses to target objects that were in front of (M = 7.5s), rather than behind (M = 9s) participants' imagined facing direction within the array. The order of testing x condition interaction represents faster responses under the second tested condition (no judgements, M = 8s; judgements, M = 6s) than the first (no judgements, M = 9s; judgements = 11s), with the fastest response times recorded for the judgements condition, when tested second.

To further qualify the nature of the latency interactions involving condition, the data from the no judgements and judgements conditions were analysed separately, using 2 x 2 x 2 repeated-measures ANOVA analyses with direction, alignment and first-second as factors. Analysis of the 'no judgements' latency data found a significant main effect of alignment $F(1, 31) = 10.40$, $MSE = 19.70$, $p = .003$ (partial $\eta^2 = .25$), that reflects faster responses to test judgements that were aligned with the experienced (M = 7.5s) than the opposite (M = 9s) perspectives. Also significant was a direction x first-second interaction $F(1, 31) = 6.18$, $MSE = 21.63$, $p = .02$ (partial $\eta^2 = .17$), which for front-facing judgements, reflects faster responses to targets aligned with the first (M = 7s) than the second (M = 9s) experienced perspective, with the reverse pattern for back-facing judgements (*M*s = 10s and 8s for the first and second perspectives respectively). Analysis of the 'judgements' condition data found a main effect of direction, $F(1, 31)$ = 7.68, $MSE = 31.79$, $p = .009$ (partial $\eta^2 = .20$), which consistent with the 'no judgements' condition, reflects faster overall judgements to targets in front of, rather than behind, participants imagined position within the array (*M*s 7 and 9s for front- and back-facing respectively). No other main effects and no interactions were significant ($ps > .3$).

The overall error data in Experiment 11 are consistent with a seen-views alignment effect following spatial learning from a primary source; participants were more accurate and faster at making judgements from imagined orientations within the array that were aligned with the two perspectives to which they had been exposed, than from the two non-exposed perspectives. However, post-hoc analyses found the overall alignment effect results from greater errors for judgements made from the second- and opposite-to-second perspectives. While one can have little confidence in post-hoc analyses, this outcome implies that the second perspective was more strongly aligned than the first. The latency data complicate this picture slightly because the main effect of alignment was only apparent under the 'no judgements' condition; when participants were asked to make spatial judgements while after each viewing, their response times reflected an orientation-free memory. Evident in the latency, but not the error data was an advantage for judgements to targets that were in front of, rather than behind, participants imagined position within the array; this outcome offers some support for the suggestion, and consistent with Shelton and McNamara (1997), that participants appear to have formed two egocentric representations of the layout.

Experiment 12

The results of Experiment 11 did not provide evidence for first-perspective alignment encoding after participants had learned an object array from two perspectives that were 90° misaligned from the centre of the array. Overall, the error and latency data were consistent with a seen-views alignment account of spatial knowledge acquisition following primary learning, and therefore, the orientation-dependence of real-world spatial memories (cf. Shelton & McNamara, 1997). This outcome contrasts with the experiments reported in Chapters 2 and 3 using route learning, and that of Wilson (2001, personal communication), in which stimuli comprised text descriptions and pictures of similar arrays to those used in Experiment 11.

To extend the investigation of seen-views and first-perspective alignment accounts of spatial memory for object arrays in Experiment 11, participants in Experiment 12 also viewed two arrays of objects from two perspectives in a counterbalanced order. However, the experienced perspectives were 180° contra-aligned from the centre of the array. It was hypothesised that if general alignment effects are a feature of primary learning, orientation judgements and/or latencies should be equivalent for the first (0°) and second (180° contra-aligned) experienced perspectives (because both have been seen), with poorer performance from 90° misaligned, non-experienced perspectives. In contrast, evidence for a first-perspective alignment effect would reflect more efficient processing for the first experienced perspective than for the respective contra-aligned perspective, with errors and/or latencies misaligned from these perspectives being less accurate and/or slower than for the first perspective. A third possibility is that the pattern of error data might reflect that of Experiment 11, in which case, orientation judgements made from orientations aligned with the second experienced perspective would be least error prone.

Method

Design

In Condition 1, the dependent variables were angle and distance judgements made from four imagined locations within the array (two aligned with each experienced perspective, with two 90° left- and two 90° right-misaligned with respect to the first-experienced perspective). In Condition 2, additional angle and distance judgements were made immediately following participants' exposure to each of the two experienced perspectives, in the same way as for Experiment 11. The dependent variables were angle and distance estimates during learning and at test, and the times taken to make these judgements.

Participants

These were 32 first or second year undergraduate psychology students from the University of Leicester, with a mean age of 21.0 years (range: 18-39 years), of whom 7 were men. All took part in partial fulfilment of a practical course requirement.

Apparatus

The apparatus was identical to that used in Experiment 11, with the exception that to view the array, participants looked through two eye-level windows cut in two of the four sides of the hardboard screen set at opposite sides from the centre of the display. The viewing windows to the left and right of these perspectives were occluded.

Procedure

The experimental procedure, and all counterbalancing arrangements were identical to those followed for Experiment 11.

Results and Discussion

For the learning phase of the experiment, angle of error scores for judgements made from the two experienced viewpoints were derived and collated in the same way as for Experiment 11. Separate paired-samples analyses of the angle error scores for the first and second views found no significant differences between the means in either analysis (ts < 2). However, for the latency data, the mean latencies were 7 and 5s for the first and second views respectively, and this difference was found to be statistically significant $t(31) = 3.03$, $SE = .68$, $p = .005$ ($\eta^2 = .23$). That angle judgements were made faster from the second than the first experienced view, but with no advantage to accuracy in either case, appears to be an artefact of the repeated measures procedure.

For the final alignment tests, angle of error scores were derived in the same way as for Experiments 10 and 11. Judgements that were made from the left and right of the first experienced perspective were averaged for each participant to produce a single misaligned score. Descriptive statistics of the error and latency data for judgements that were aligned, misaligned and contra-aligned with the first experienced perspective are presented in Tables 4.12.1 and 4.12.2 respectively.

Table 4.12.1

Descriptive Statistics for Orientation Judgements (tabled in degrees), in the 'No Judgements' and 'Judgements' Conditions, to Targets that were Aligned, Misaligned and 180° Contra-aligned with the First-Experienced Perspective.

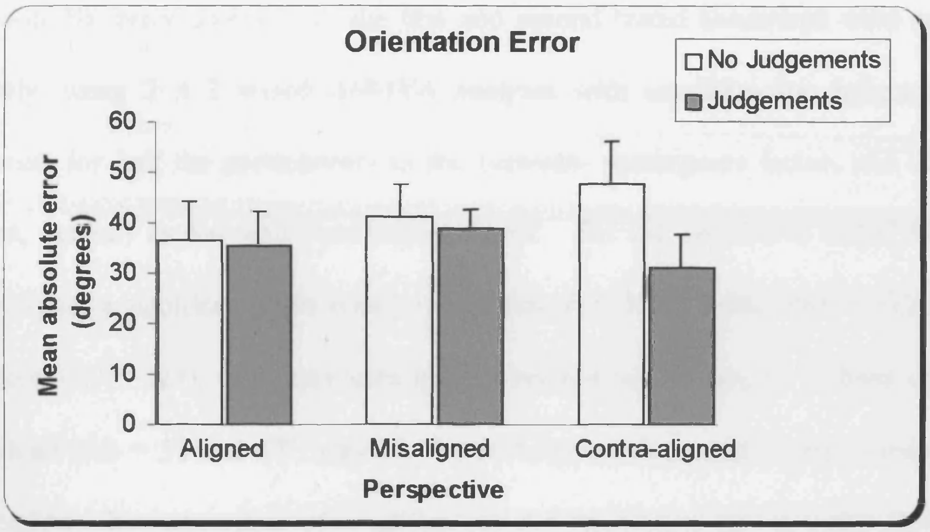
	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
No Judgements							
Aligned	32	.00	145.00	36.64	42.86	21.19	52.09
Misaligned	32	2.50	145.00	41.25	36.44	28.11	54.39
Contra-aligned	32	.00	175.00	47.81	48.16	30.45	65.18
Judgements							
Aligned	32	.00	147.50	35.39	39.79	21.04	49.74
Misaligned	32	6.25	88.75	39.98	20.51	31.59	46.38
Contra-aligned	32	2.50	137.50	31.09	37.21	17.68	44.51

Table 4.12.1

Descriptive Statistics for Orientation Latencies (tabled in seconds), in the 'No Judgments' and 'Judgements' Conditions, to Targets that were Aligned, Misaligned and 180° Contra-aligned with the First-Experienced Perspective.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
No Judgements							
Aligned	32	1.51	20.33	8.77	4.71	7.07	10.47
Misaligned	32	2.77	21.89	10.07	5.58	8.06	12.08
Contra-aligned	32	1.69	33.13	9.12	6.78	6.68	11.57
Judgements							
Aligned	32	2.15	41.13	8.99	8.57	5.90	12.08
Misaligned	32	2.86	23.84	10.93	5.59	8.92	12.94
Contra-aligned	32	2.79	55.42	12.30	12.01	7.97	16.63

The mean error and latency scores are presented in Figure 4.12.1. These data were entered into separate 2 x 2 x 2 x 3 mixed ANOVA analyses, with order (no judgements or judgements tested first) as the between-participants factor, and condition (no judgements, judgements), direction (whether the target was in front of or behind participants' imagined facing direction within the array), and perspective (judgements that were aligned, misaligned, or 180° contra-aligned, with respect to the first experienced perspective). Sex of participant was not included as a factor in either of these analyses as there were too few men to make meaningful comparisons.



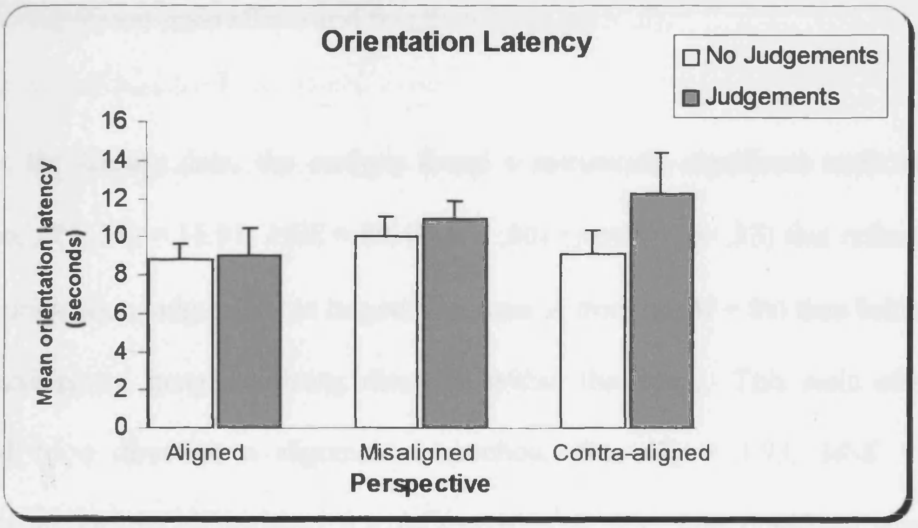


Figure 4.12.1. Experiment 12: Mean absolute error (upper panel) and latency (lower panel) scores for judgements that were aligned, misaligned and 180° contra-aligned to the first experienced perspective in the 'no judgements' and 'judgements' conditions. Error bars represent one estimated standard error above the mean.

Analysis of the error data found a significant main effect of direction, $F(1, 30)$ = 5.30, MSE = 1242.56, p = .03 (partial η^2 = .15), that reflects lower overall errors for judgements in front of (M = 34°), than behind (M = 43°) participants' imagined facing direction at test. Also significant was an order of testing x condition x direction interaction $F(1, 30) = 4.389$, $MSE = 1308.39$, $p = .05$ (partial $\eta^2 = .13$). No other main effects or interactions were significant ($ps > .1$). To investigate the three-way interaction, the error scores from the first and second tested conditions were analysed separately, using 2 x 2 mixed ANOVA analyses with condition (no judgements or judgements for half the participants) as the between- participants factor, and direction (in front, behind) as the within-participant factor. For the conditions tested first, the analysis found a significant main effect of direction $F(1, 30) = 9.88$, $MSE = 415.54$, $p = .004$ (partial $\eta^2 = .23$), that represents lower overall errors to targets in front of rather than behind (Ms = 31 and 47° respectively) participants' imagined facing orientation at test. Neither the main effect of condition nor the interaction between this factor and direction were significant ($ps >.4$). For the conditions tested second, the analysis found no significant main effects and no interactions ($ps > .5$).

For the latency data, the analysis found a statistically significant main effect of direction, $F(1, 30) = 15.01$, $MSE = 89.48$, $p = .001$ (partial $\eta^2 = .33$) that reflects faster overall orientation judgements to targets that were in front of (M = 8s) than behind (M = 12s) participants' imagined facing direction within the array. This main effect was qualified by a direction x alignment interaction, $F(1, 47) = 3.93$, $MSE = 76.02$ (Greenhouse-Geisser adjustment), $p = .04$ (partial $\eta^2 = .12$). Also significant were order x condition $F(1,30) = 5.81$, $MSE = 93.54$, $p = .02$ (partial $\eta^2 = .16$), and order x condition x direction $F(1, 30) = 5.64$, $MSE = 53.50$, $p = .02$ (partial $\eta^2 = .16$) interactions.

Simple main effects analyses of the direction x alignment interaction revealed a significant effect of alignment, $F(1, 50) = 3.50$, $MSE = 18.09$ (Greenhouse-Geisser adjustment), p = .05 (partial η^2 = .10) for judgements to targets that were in front of participants' imagined facing direction at test. Subsequent paired samples analyses (Bonferroni correction applied) revealed a significant difference between the means of front-facing misaligned (M = 10s) and contra-aligned (M = 7s) judgements $t(31)$ = 3.34, SE = .71, p = .002 (η^2 = .27); aligned means did not differ from either misaligned or contra-aligned means (ps < .08). For back-facing judgements, there was no significant effect of alignment (p = .08).

The interactions involving order of testing the two conditions and direction were further investigated by separately analysing the latency data from the conditions tested first and second. The collated data were entered into 2 x 2 mixed ANOVA analyses with condition (no judgements, judgements) as the between-participants factor and direction (in front, behind) as the within-participant factor. For the conditions tested first, the analysis revealed a significant main effect of direction $F(1, 30)$ = 13.24, MSE = 36.75, p = .001 (partial η^2 = .31), that reflects substantially faster overall judgements to targets in front of (M = 9s) rather than behind (M = 14s) participants' imagined facing direction at test. For the conditions tested second, the main effect of direction was also significant $F(1, 30)$ = 5.67, MSE = 10.92, p = .02 (partial η^2 = .16); however the difference between front- (M = 8s) and back-facing (M = 10s) orientation judgements was of smaller magnitude than when tested first. In neither analysis was the main effect of condition, nor the interaction between this factor and direction significant (ps > .2).

No evidence for a first-perspective alignment effect was apparent when participants were exposed to two perspectives that were 180° contra-aligned from the centre of the array; the lack of this effect is consistent with the results of Experiment 11. However, in contrast to Experiment 11, in which seen-views alignment effects were apparent in both the overall error and latency data, the error data for the present experiment reflected encoding from multiple perspectives (*M*s 36, 40 and 39° for aligned, misaligned and contra-aligned judgements respectively). This pattern is surprising to the extent that, according to a seen-views alignment prediction, orientation judgements should be equivalent for the first (0°) and second (180° contra-aligned) experienced perspectives, as both have been seen; but, poorer performance from 90° misaligned perspectives would be anticipated as these views have not been seen. The overall latency data also reflected encoding from multiple perspectives (*M*s 9, 11 and 11s for aligned, misaligned and contra-aligned judgements respectively); however, this outcome was restricted to when orientation judgements were behind, rather than in front of participants imagined facing direction within the array; for front-facing targets, misaligned judgements took longer to make than did contra-aligned judgements.

The results of Experiments 10 – 12 do not suggest the influence of first-perspective alignment encoding following participants' learning of real world arrays of static objects; nor do they suggest a consistent influence of making judgements at each seen view. However, the data are not fully supportive of a seen-views alignment account. Taken together with the procedurally related experiments of Wilson (2001, personal communication), the results of these experiments provide evidence consistent with a graded primary-secondary distinction with respect to spatial learning. First, when participants were exposed to four views on an array in Experiment 10, no preferred orientation was apparent. In contrast, when exposed to text and pictorial depictions of four views on an array, Wilson found a tendency for better recall of perspectives that were aligned with the first view. This latter outcome is consistent for both object arrays, and following route learning from text descriptions (Experiments 2 – 6), and VEs (Experiments 7 – 8).

Second, in Experiment 11, when participants were exposed to two perspectives, that were 90° misaligned from the centre of the array, the overall pattern of error data were of a seen-views alignment effect. The latency data were largely supportive of this outcome, and also provided weak evidence for the attenuation of alignment effects when participants were asked to make spatial judgements during learning; under this latter condition, response times reflected an orientation-free memory. In a similar procedure using text and pictures, Wilson (2001, personal communication) found a seen-views alignment effect, and also a first-perspective alignment effect with respect to the experienced views, following both text and picture presentation. In the case of text and pictures, making judgements following each viewing abolished the first-perspective alignment effect, but a general alignment effect was still evident.

Third, when the first-perspective alignment and general alignment effects were tested in the contra-aligned paradigm in Experiment 12, the error and latency data reflected encoding from multiple perspectives. In this experiment, making judgements from each experienced perspective did not have any consistent effect in comparison to a condition under which no judgements were made. However, the pattern of apparently orientation-free learning in Experiment 12 is at odds with a seen-views alignment account of spatial learning. In contrast, for the secondary case, Wilson found that with respect to both text and pictures, first-perspective alignment encoding was evident.

Finally, in contrast to the general lack of direction effects following secondary learning in Experiments 2-8, the latency data from Experiment 11 indicate faster response times for judgements to targets in front of, rather than behind, participants imagined orientation at test. A similar general pattern was evident in both the error and latency data in Experiment 12.

Why then, should these differences in spatial encoding and recall arise between secondary and primary learning? With respect to learning from secondary sources, the experiments reported in Chapters 2 and 3 suggested the hypothesis that when allocentric information is absent or minimal, people construct an egocentric frame of reference, in order to reduce cognitive load by providing a direction of alignment in space. The first-perspective therefore appears to represent a default primary reference frame, or psychological anchor point in spatial memory, and subsequent tests of orientation will be more accurate and/or faster when aligned rather than misaligned or contra-aligned with this perspective - the first perspective alignment effect. Active processing of perspectives other than the first appears to engender the construction of multiple anchor points from which position and orientation can be updated; reduced reliance on the first, single anchor point for this purpose serves to attenuate the first-perspective alignment effect.

By contrast, in the case of primary learning, it may be that salient cues in the surrounding environment similarly reduce cognitive load by providing an allocentric frame of reference. The finding in Experiment 10 of encoding from multiple perspectives following participants' exposure to four perspectives on the array, and that from Experiments 11 and 12, of the absence of clear differences in the error and latency data for orientation judgements made from the first and second experienced perspectives, provide some evidence that the first-perspective alignment effect may be reduced because the presence of environmental cues, such as the room in which the experiments were conducted, or the structure of the apparatus employed may make allocentric encoding more efficient by reducing cognitive load. In the secondary case, when environmental information is typically absent or limited, people encode and recall the space on the basis of an egocentric reference frame in preference; this reference frame is based on a primary anchor point that is defined by the first aligned perspective. Therefore, the first-perspective alignment effect represents the default or primary form of encoding in spatial memory, with allocentric encoding as secondary.

However, and prior to developing this theoretical account, one very important difference between learning from primary and secondary sources is that in the former, perspective changes usually occur when an observer moves. Therefore, in Experiments 10 – 12, participants may have accrued additional information such as visual, vestibular or proprioceptive during their movement around the array, which would not have been available following learning from text descriptions or pictures that were presented in relation to a static observer (Experiments 2 - 9; Wilson, 2001, personal communication). The availability of such information may have facilitated successful updating with respect to the experienced perspectives in the real array case. This possibility is explored in Experiments 13 and 14.

Experiment 13

There is some evidence that simulating viewpoint changes in front of a stationary observer, in comparison to when an observer moves around an array, may not lead to equivalent recognition performance. In change detection tasks, an updating advantage for observer movement over display rotation has been demonstrated for both object arrays (Simons & Wang, 1998; Wang & Simons, 1999; see also, Wraga, Creem & Proffitt, 2000), and single objects (Simons, Wang & Roddenberry, 2002), learned from a single viewpoint. For example, Simons and Wang (1998), asked their participants to study an array of five objects resting on a circular table. Following a brief delay during which a curtain occluded the table, one of the objects was moved to a different position within the array. Participants then viewed the collection of objects again, with the task of identifying which of the objects had moved. On some trials, participants in 'observer movement' and 'array rotation' groups viewed the array from the same perspective at the learning and test phases; on other trials, participants either moved to a different viewing position, or remained at the same viewpoint while the array was rotated. These authors found that when participants moved around the array, their ability to identify the re-positioned object was relatively unaffected in comparison to when they viewed the array from the same perspective. However, when the array was rotated, performance was significantly impaired in comparison to when participants viewed the array from the original perspective. Similar outcomes were recorded when the objects were painted with phosphorescent paint and the array presented in a darkened room (Simons & Wang, 1998, Experiment 2), thus reducing reliance on environmental information (but see Christou & Bülthoff, 1997); also when participants actively controlled the rotation of the array (Wang & Simons, 1999). In these experiments, display rotations produced viewpoint-dependent recognition, whereas observer movements did not.

Simons and Wang (1998) attributed the superior recognition performance of the latter group to the vestibular feedback available during observer movement, which appears to facilitate spatial updating. This finding is consistent with the outcomes of other studies of memories for spatial layouts that have compared imagined and real changes in orientation using blindfolded participants (e.g. Farrell & Robertson, 1998; Presson & Montello, 1994; Reiser, 1989). There is also evidence that when participants merely hear (Ashmead, DeFord & Northington, 1995; Loomis, Klatzky, Philbeck & Gollege, 1998), touch (Barber & Lederman, 1988; Hollins & Kelley, 1998), or are told about (Loomis, Lippa, Klatzky & Gollege, 2002) a stimulus in space, they are able to update a mental representation of that stimulus while moving.

With respect to the present experiments, the presence of vestibular feedback in the real-array case does not appear to be a sole determinant of alignment recall, because in Experiments 11 and 12, participants learned about similar arrays, but produced different overall patterns of alignment data, depending on the perspectives from which they had viewed the array. However, in contrast to when multiple perspectives are learned from text or pictures (Wilson, 2001, personal communication), the general lack of differences in accuracy or latency between judgements made from the experienced perspectives in Experiments 10 and 12 suggests that when vestibular feedback is present, it may provide an additional source of information that is not available when learning is from secondary sources.

To further investigate the role of observer movement in the real array case, participants in Experiment 13 either physically moved between two viewpoints set at 90° angles misaligned from the centre of the array, or the array was rotated between observations (cf. Simons & Wang, 1998; Wang & Simons, 1999). It was anticipated that participants might produce fewer errors and or faster response latencies for the experienced views under a condition where they physically move between two viewpoints, by comparison to one in which the array is rotated in relation to their static position at a single viewpoint. Equivalent encoding and recall from both seen perspectives would undermine the hypothesis of a crucial role for observer movement as the basis for a distinction between primary and secondary learning for object arrays in producing the first-perspective alignment effect.

Method

Participants

Participants were 24 undergraduates from the University of Leicester, UK, of whom 17 were female, and who received credit towards the fulfilment of a first year practical course requirement. They had a mean age of 20.4 years (range: 18-36 years).

Design

In a repeated measures design, participants served in two conditions in which they observed four everyday objects from viewing perspectives external to the array. In one condition participants moved between two viewpoint locations set at 90° from the centre of the display (observer movement). In a second condition, participants remained at the same viewpoint location, but the array was rotated by 90° between observations (array rotation). The dependent variables were angle and distance judgements from four imagined locations within the array (two aligned with each experienced view and two opposite to each experienced view), and the time taken to make these judgements.

Apparatus

This was identical to that used in Experiment 11.

Procedure

Learning phase: For both conditions, participants were initially escorted to one of the two viewing windows (counterbalanced) and verbally instructed to study the Array in front of them "very carefully, for at least thirty seconds, until you get a clear memory for the objects." Participants were then asked to step back from the viewpoint so that the array of objects was not visible, and asked to name each object aloud. For the observer movement condition, participants walked to the second viewing window where the sequence was repeated. For the array rotation condition, the experimenter rotated the array by 90°, and then asked the participant to step back to the original viewing window where the memorisation sequence as for the observer movement condition was repeated. Counterbalancing included the following arrangements: First, whether participants initially undertook the observer movement or the array rotation condition. Second, whether Array A or Array B served as the initially presented configuration in the observer movement and array rotation conditions. Third, whether the initial observation was from Viewpoint 1 or Viewpoint 2, and whether this observation was experienced 0, 90, 180 or 270 degrees rotation of the array from an arbitrary start position. Fourth, whether an array was rotated clock-wise or anti-clockwise in the between-views learning interval of the array rotation condition.

The test phase of the experimental procedure, and all counterbalancing arrangements were identical to those followed in Experiments 11 and 12.

Results and Discussion

Sex was not included as a factor in any of the analyses below due to the small number of men who took part in the experiment. A preliminary 2 x 2 repeated-measures ANOVA of the time spent viewing the array with condition (observer movement, array rotation) and first-second (first and second experienced perspectives) as factors revealed no main effects and no interactions ($ps > .1$).

Absolute orientation judgement error scores were derived in the same way as for Experiment 12. Descriptive statistics of the error and latency data for judgements aligned with the first and second experienced perspectives, and aligned with the opposite to first and opposite to second perspectives under the observer movement and array rotation conditions are presented in Tables 4.13.1 and 4.13.2 respectively.

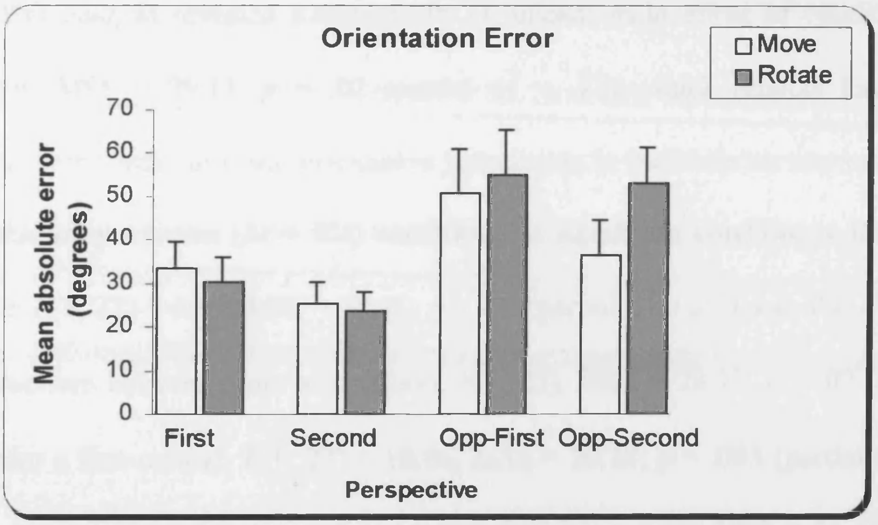
Table 4.13.1
Descriptive Statistics for Orientation Judgements (tabled in degrees) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were Aligned with the First and Second Experienced Perspectives and Aligned with the Opposite to First and Opposite to Second Perspectives.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Observer Movement							
First	24	.00	90.00	33.33	30.11	20.62	46.04
Second	24	.00	90.00	25.52	23.15	15.75	35.30
Opposite-First	24	2.50	175.00	50.83	51.03	29.29	72.38
Opposite-Second	24	.00	147.50	36.35	40.89	19.09	53.62
Array Rotation							
First	24	.00	102.50	30.42	28.47	18.39	42.44
Second	24	2.50	90.00	23.54	22.64	13.98	33.10
Opposite-First	24	2.50	162.50	54.90	51.70	33.07	76.73
Opposite-Second	24	2.50	170.00	53.13	41.96	35.41	70.84

Table 4.13.2
Descriptive Statistics for Orientation Latencies (tabled in seconds) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were Aligned with the First and Second Experienced Perspectives and Aligned with the Opposite to First and Opposite to Second Perspectives.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Observer Movement							
First	24	2.01	23.89	8.75	5.05	6.62	10.88
Second	24	1.93	15.42	7.13	3.62	5.60	8.66
Opposite-First	24	4.14	29.56	10.03	6.05	7.48	12.58
Opposite-Second	24	2.13	24.95	8.28	4.86	6.22	10.33
Array Rotation							
First	24	1.64	24.48	8.54	5.47	6.22	10.85
Second	24	1.77	30.15	9.88	6.82	7.00	12.76
Opposite-First	24	4.18	21.97	8.72	3.99	7.03	10.40
Opposite-Second	24	4.08	39.94	12.51	9.26	8.60	16.42

The error data were analysed using a 2 x 2 x 2 x 2 x 2 mixed ANOVA with order (observer movement or array rotation tested first) as the between-participants factor and condition (observer movement, array rotation), direction (whether the target object was in front of or behind participants' imagined facing direction within the array), alignment (aligned with, or opposite to the experienced perspectives), and first-second (first and second experienced perspectives), as within participant factors. As suggested in the upper panel of Figure 4.13.1, the analysis found a significant main effect of alignment $F(1, 22) = 13.84$, $MSE = 2943.82$, $p = .001$ (partial $\eta^2 = .39$), that reflects lower overall errors for judgements that were aligned with the experienced (M = 28°) than the opposite (M = 49°) perspectives. No other main effects or interactions were significant ($ps > .1$).



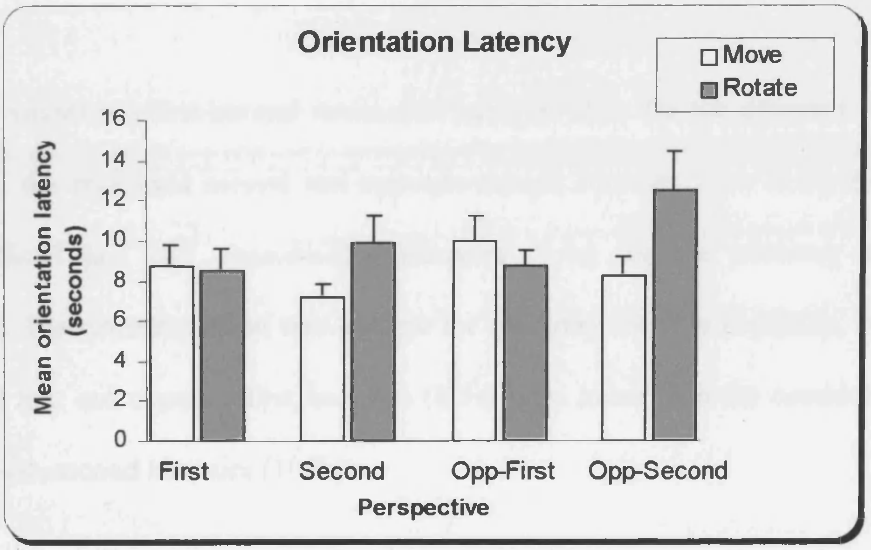


Figure 4.13.1. Experiment 13: Mean absolute error (upper panel) and latency (lower panel) scores for judgements that were aligned with the first, second, opposite to first, and opposite to second perspectives in the 'observer movement' and 'array rotation' conditions. Error bars represent one estimated standard error above the mean.

Analysis of the orientation latency data was carried out in the same way as for the orientation error data, and the mean latencies are illustrated in the lower panel of Figure 4.13.1. This analysis revealed a statistically significant main effect of condition, $F(1, 22) = 6.16$, $MSE = 29.13$, $p = .02$ (partial $\eta^2 = .22$), which reflects that overall, participants were faster to make orientation judgements in the observer movement (M = 9s) than the array rotation (M = 10s) condition. A significant condition x first-second interaction, $F(1, 22) = 6.13$, $MSE = 70.91$, $p = .02$ (partial $\eta^2 = .22$) was also evident, as were interactions between order x condition, $F(1, 22)$, $MSE = 29.13$, $p = .02$ (partial $\eta^2 = .22$), order x first-second, $F(1, 22) = 10.86$, $MSE = 26.28$, $p = .003$ (partial $\eta^2 = .33$), and order x condition x direction x first-second, $F(1, 22) = 6.50$, $MSE = 35.78$, $p = .02$ (partial $\eta^2 = .23$). No other main effects or interactions were significant ($ps > .06$).

The condition x first-second interaction indicates that, for the observer movement condition, the combined second and opposite-second latencies were lower (7.6s) than the combined first and opposite-first latencies (9.4s) for the observer movement condition. The reverse pattern was evident for the array rotation condition, in that the combined first and opposite-first latencies (8.5s) were lower than the combined second and opposite-second latencies (10.9s).

To further investigate the interactions involving order of testing the two conditions, the latency scores from the first and second tested conditions were analysed separately, using 2 x 2 x 2 x 2 mixed ANOVA analyses with condition (observer movement or display rotation for half the participants), as the between-participant factor, and direction, alignment and first-second as within-participant factors. For the conditions tested first, the analysis found a significant condition x first-second interaction, $F(1, 22) = 9.89$, $MSE = 72.02$, $p = .005$ (partial $\eta^2 = .31$), which reflects that reported above for the overall analysis. Also significant was a condition x direction, $F(1, 22) = 5.67$, $MSE = 45.86$, $p = .03$ (partial $\eta^2 = .21$) interaction, which represents faster overall responses to targets that were in front of ($M = 9$s) than behind ($M = 10$s) participants imagined facing direction within the array under the observer movement condition, with the reverse pattern in the array rotation condition (*M*s = 12 and 9s for in front and behind directions respectively). No other interactions, or main effects were significant (*p*s > .06). For the conditions tested second, the analysis found no main effects and no interactions (*p*s > .1).

The orientation error data for the present experiment are consistent with the outcomes of Experiments 10-12, in which no evidence for first-perspective alignment encoding was found following primary learning. As was the case in Experiment 11, in which the viewing perspectives were also 90° misaligned from the centre of the array, participants were most accurate when aligned in imagination with experienced views of the layout. In contrast to the results of previous studies on spatial updating that have used object arrays (Simons & Wang, 1998; Wang & Simons, 1999), no differences between overall orientation errors were apparent when participants either physically moved between the two viewpoints, or when the array was rotated between observations; however, differences in the current experimental procedures to those used by the above authors might account for dissimilar effects (see below).

Unlike the orientation error scores, the orientation latency data provide some support for the hypothesis that viewpoint changes caused by array rotation are not equivalent to those caused by observer movement (Simons & Wang, 1998; Wang & Simons, 1999). While the latency data reflected apparently orientation-free learning under both conditions, overall response times were faster in the observer movement than in the array rotation condition. The latency data also provide some, although limited evidence for different processing under the two conditions: First, the overall time scores were faster for judgements from the combined second and opposite-second perspectives (M = 7.6s) than the combined first and opposite-first perspectives (M = 9.4s) experienced perspective in the observer movement condition; for the array rotation condition, response times were faster for judgements from the combined first and opposite-first perspectives (M = 8.5s), than for the combined second and opposite-second (10.9s). However, this difference was limited to the first tested conditions; when tested second, the mean latencies for both conditions were 9 seconds. Second, for the observer movement condition and when tested first, judgements were made faster to targets in front of, rather than behind participants imagined facing direction within the array, with the reverse pattern in the array rotation condition. But, when tested second, the main effect of direction was not significant, and no significant interactions involving this factor were evident. As a lack of vestibular feedback will have influenced participants' learning of the array under the array rotation condition irrespective of whether this condition was tested first or second, these outcomes are difficult to reconcile with a crucial role for observer movement in spatial knowledge acquisition for this particular task. Nonetheless, the pattern of response times differed between the two conditions in a manner that suggests a trade-off between accuracy and decision time in the array rotation condition that was not apparent in the observer movement condition. In other words, while the error data indicate that participants encoded two views of the array equally well, and better than unseen views, the latency data suggest that the alignment task was more difficult under the array rotation condition, but with no cost to overall accuracy.

One explanation for the patterns of error and latency data observed in Experiment 13 is that while it is common for observers to move around in an environment, it is relatively unusual for an environment to rotate in front of a stationary observer. Therefore, it is not unreasonable to assume that an orientation task that mirrors real-world experience would be less cognitively demanding than one that does not. Increased task difficulty under the array rotation in comparison to the observer movement condition might have incurred greater cognitive resources at test, as reflected in the overall slower response times under the former condition.

In Experiment 11, in which the two experienced perspectives were also 90° misaligned from the centre of the array, response times for the two experienced perspectives did not differ when participants were encouraged to process both views equally by making relative spatial judgements following their exposure to each of the experienced views. Therefore, the aim of Experiment 14 was to investigate whether this manipulation would reduce the possibly increased cognitive demand incurred when the array was rotated in comparison to when observers moved around the array. The design was identical to that used in the present experiment, except that under conditions of observer movement and array rotation, after participants had viewed the array from the first viewing window, they were asked to make judgements about the angles and distances to each of the objects in the array while imagining themselves still positioned at this viewpoint; this procedure was then repeated for the second viewpoint.

Experiment 14

Method

Participants

These were 24 undergraduates from the University of Leicester, UK, of whom 21 were female. All participants received credit towards the fulfilment of a second year practical course requirement, and none had taken part in Experiment 13. Participants had a mean age of 20.4 years (range: 19- 27 years).

Design

As for Experiment 13, a repeated-measures design was employed, in which participants served under conditions of observer movement and array rotation in observing an array of four objects from two viewing perspectives set at 90° misaligned from the centre of the array. The dependent variables were angle and distance judgements made from four imagined locations within the array (two aligned with each experienced perspective, and two opposite to each experienced perspective), and the times taken to make these judgements. Angle and distance judgements made immediately following participants' exposure to each of the two experienced perspectives, together with the respective reaction times were also recorded.

Apparatus

This was the same as that used in Experiments 11-13.

Procedure

The procedure differed from Experiment 13 only with respect to the learning phase of the experiment as follows: For both the observer movement and the array rotation conditions, participants were initially escorted to one of the two external viewing windows and verbally instructed to study the array in front of them for at least 30 seconds. Participants were then asked to move to a position in the room where the screen was out of visual range, and asked to name each object aloud, then to imagine that they were still in the viewing position facing the table, and to estimate their physical distance and angle from each object. For the observer movement condition, participants were escorted to the second viewing window, where the above sequence was repeated. For the array rotation condition, the experimenter rotated the array either clockwise or anti-clockwise by 90°, then escorted the participant back to the original viewing window. The memorisation and testing sequence as for the observer movement condition was then repeated. All details not mentioned were the same as described for Experiment 13.

Results

Sex was not included in any of the analyses below due to the relatively small number of men who took part in the experiment. A preliminary 2 x 2 repeated-measures ANOVA was conducted for the time spent viewing the array with condition (observer movement, array rotation) and first-second (first and second experienced perspectives) as factors. This analysis revealed no main effects and no interactions (ps >.1).

Angle of error scores for judgements made from the two experienced perspectives during the learning phase of the experiment were derived and collated in the same way as for the 'judgements' conditions of Experiments 11 and 12. Analysis of the mean scores was conducted using a 2 x 2 repeated-measures ANOVA with condition (observer movement, array rotation), and first-second (after the first and second views) as factors. This analysis found no main effects and no interactions (ps > .07).

However, a similar analysis of the respective mean latency scores found a significant main effect of first-second, $F(1, 23) = 14.32$, $MSE = 2.77$, $p = 001$ (partial $\eta^2 = .38$), that reflects faster overall response times for judgements made from the second than the first experienced viewpoint (*M*s = 3 and 4s respectively). Neither the main effect of condition, nor the interaction between main effects was significant (*p*s > .09). The data from these preliminary judgements suggests that in the present experiment, angle estimates were easier when made from the second than the first of the experienced perspectives, irrespective of whether participants moved around the array, or whether the array was rotated with respect to their static position.

For the main analysis, absolute orientation judgements error scores were derived in the same way as for Experiment 13. Descriptive statistics of the error and latency data for judgements aligned with the first and second experienced perspectives, and aligned with the opposite to first and opposite to second perspectives under the observer movement and array rotation conditions are presented in Tables 4.14.1 and 4.14.2 respectively. The mean orientation and latency scores are illustrated in the upper and lower panels of Figure 4.14.1 respectively.

Table 4.14.1

Descriptive Statistics for Orientation Judgements (tabled in degrees) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were Aligned with the First and Second Experienced Perspectives and Aligned with the Opposite to First and Opposite to Second Perspectives.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Observer Movement							
First	24	.00	90.00	31.35	27.52	19.74	42.97
Second	24	.00	87.50	20.83	17.72	13.35	28.32
Opposite-First	24	2.50	140.00	44.90	37.41	29.10	60.69
Opposite-Second	24	.00	165.00	51.15	55.38	27.76	74.53
Array Rotation							
First	24	2.50	97.50	34.06	29.50	21.61	46.52
Second	24	2.50	105.00	28.23	26.71	16.95	39.51
Opposite-First	24	5.00	170.00	42.50	41.24	25.08	59.92
Opposite-Second	24	2.50	157.50	46.98	47.99	26.72	67.24

Table 4.14.2

Descriptive Statistics for Orientation Latencies (tabled in seconds) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were Aligned with the First and Second Experienced Perspectives and Aligned with the Opposite to First and Opposite to Second Perspectives.

	N	Minimum	Maximum	Mean	Standard Deviation	95% Confidence Interval	
						Lower	Upper
Observer Movement							
First	24	2.00	15.00	6.60	3.99	4.92	8.29
Second	24	1.00	34.50	7.60	6.64	4.80	10.41
Opposite-First	24	1.50	24.50	9.06	6.57	6.29	11.84
Opposite-Second	24	1.50	35.50	9.42	8.69	5.75	13.08
Array Rotation							
First	24	2.00	56.00	9.13	10.93	4.51	13.74
Second	24	1.50	15.00	5.69	3.64	4.19	7.23
Opposite-First	24	2.00	35.50	8.06	7.24	5.00	11.12
Opposite-Second	24	2.00	35.50	11.42	8.54	7.81	15.02

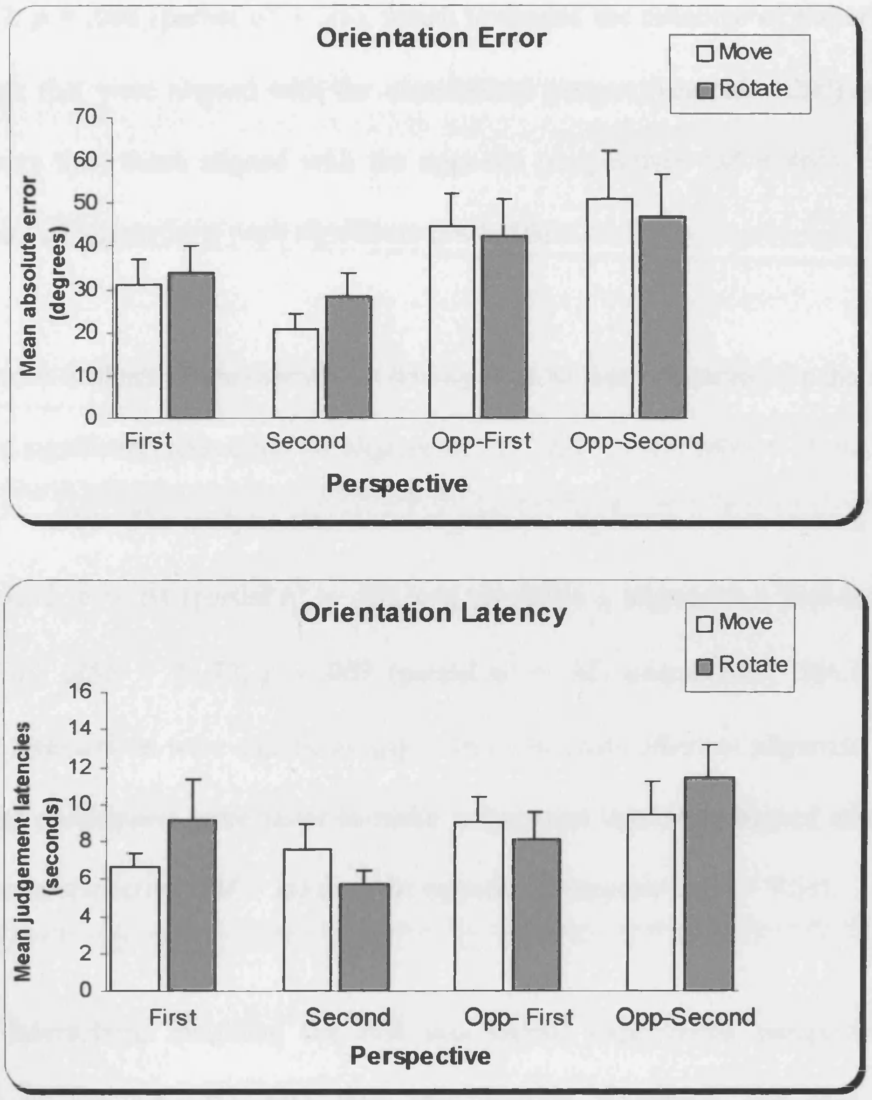


Figure 4.14.1. Experiment 14: Mean absolute error (upper panel) and latency (lower panel) scores for judgements that were aligned with the first, second, opposite to first, and opposite to second perspectives in the 'observer movement' and 'array rotation' conditions. Error bars represent one estimated standard error above the mean.

The mean error scores were entered into a 2 x 2 x 2 x 2 x 2 mixed ANOVA with order (observer movement or array rotation tested first) as the between-participants factor and condition (observer movement, array rotation), direction (whether the target object was in front of or behind participants' imagined facing direction within the array), alignment (aligned with, or opposite to the experienced perspectives), and first-second (first and second experienced perspectives), as within-participant factors. This analysis found a statistically significant main effect of alignment, $F(1, 22) = 8.51$, *MSE*

= 3516.47, p = .008 (partial η^2 = .28), which replicates the outcome of Experiment 13; judgements that were aligned with the experienced perspectives (M = 29°) resulted in lower errors than those aligned with the opposite perspectives (M = 46°). No other main effects or interactions were significant (ps > .16).

A similar analysis of the orientation latency data to that conducted for the error data revealed a significant main effect of alignment, $F(1, 22)$ = 9.41, MSE = 50.92, p = .006 (partial η^2 = .30). The analysis also found significant alignment x first-second, $F(1, 22)$, MSE = 47.52, p = .04 (partial η^2 = .18), and condition x alignment x first-second $F(1, 22)$ = 12.42, MSE = 26.72, p = .002 (partial η^2 = .36) interactions. No other main effects or interactions were significant (ps > .09). The main effect of alignment confirms that overall participants were faster to make judgements that were aligned with the two experienced perspectives (M = 7s) than the opposite perspectives (M = 9.5s).

The interactions involving the first and second experienced perspectives were examined by analysing the data from the observer movement and array rotation conditions separately, using 2 x 2 repeated-measures ANOVA analyses with alignment and first-second as factors. For the observer movement condition, neither of the main effects, nor the interaction between main effects was significant (ps >.06); worthy of note, however was that the main effect of alignment was of borderline significance, $F(1, 23)$ = 3.83, MSE = 28.59, p = .06 (partial η^2 = .14). For the array rotation condition, the analysis found a significant main effect of alignment, $F(1, 23)$ = 7.89, MSE = 16.65, p = .01 (partial η^2 = .25), which reflects that reported above for the main analysis, and an alignment x first-second interaction, $F(1, 23)$ = 12.12, MSE = 22.84, p = .002 (partial η^2 = .35). The latter interaction effect represents faster responses to judgements that were aligned with the second (M = 6s) than the first (M = 9s) experienced perspective, with the reverse pattern for the opposite perspectives (*M*s = 11 and 8s for the opposite to second and opposite to first perspectives respectively).

For the final alignment tests, and under conditions of both observer movement and array rotation, orientation error scores were more accurate when aligned in imagination with the experienced perspectives on the array, than when aligned with the opposite perspectives. These data are consistent with the error data from Experiment 13, and compatible with the outcomes of Experiments 11 and 12, in which no evidence for first-perspective alignment encoding or recall was found. The observed overall latency advantage observed in Experiment 13 for orientation judgements in the observer movement condition was not apparent in the present experiment. When the array rotated in Experiment 14, response times were faster from the second than the first experienced perspective (*M*s = 6 and 9s for second and first perspectives respectively).

Experiments 13 and 14 were specifically designed to assess the influence of additional vestibular information that participants might accrue while moving between two viewpoints, in comparison to when the array was rotated between observations. For this particular task and dependent variables, no differences in orientation errors were recorded between these conditions in either Experiment 13 or 14, implying that under both conditions, participants were equally able to update their representation of the array. These experiments do not provide support for previously reported experiments that have recorded differences between conditions of observer movement and array rotation (Simons & Wang, 1998; Wang & Simons, 1999). However, given that vestibular and proprioceptive information gained from self-motion has been shown to rapidly accumulate error (e.g. Etienne, Maurer & Séguinot, 1996), factors such as the longer, interrupted path between the two viewpoints and the multiple-questions format used in the present experiments which contrast to the short movement, short delay, single question format of Simons and Wang, may account for the difference experimental outcomes.

Nonetheless, the error data from both experiments suggest that the mental representations of small-scale object arrays are viewpoint-dependent, and as such, are encoded within preferred (in this case, experienced) orientations (cf. Shelton & McNamara, 1997). Further, the first-perspective alignment effect observed when learning is from secondary media (Experiments 2 - 9; Wilson, 2001, personal communication; Wilson et al., 1999) was not found when learning was from a primary source. Finally, with respect to the present experimental paradigm, the presence or absence of vestibular feedback does not appear to be the crucial factor in explaining this difference between primary and secondary sources, and the first-perspective alignment effect.

Chapter 4: Summary

In order to facilitate direct comparisons between spatial learning from primary and secondary sources, Experiments 10 - 14 comprised 'real-world' versions of experiments independently conducted by Wilson (2001, personal communication), in which participants read descriptions and/or viewed pictures of arrays of objects depicted from more than one static viewpoint. Although Wilson used a different spatial arrangement and experimental parameters to those employed in the route learning experiments reported in Chapters 2 and 3, his experiments also found consistent evidence for first-perspective alignment encoding and recall following secondary learning. Further, he found that asking participants to make relative spatial judgements from multiple perspectives during the learning phase reduced reliance on the first perspective at test. In contrast, recent experiments using real-world arrays and a similar paradigm to that of Wilson, have reported equivalent performance for (two) experienced views of the array (Shelton & McNamara, 1997; see also Diwadkar & McNamara, 1997) - a 'seen-views' alignment effect.

In an initial exploration of this difference in spatial encoding and recall following learning from secondary and primary sources, participants in Experiment 10 were exposed to a real-world navigable array of four objects from four perspectives that were 0, 90, 180 and 270° misaligned from the centre of the array. The results provide evidence for equivalent encoding from each of these perspectives, which was not observed by Wilson (2001, personal communication) in the secondary case. In Experiment 10, orientation judgement errors were of a similar magnitude when the alignment changed from aligned with the first, second, third and fourth perspectives, and the pattern of latency data was supportive of this outcome. In Wilson's experiment, following participants' exposure to text and pictorial depictions of object arrays from four perspectives, the error data were consistent with a first-perspective alignment effect.

Experiments 11 and 12 extended the focus of Experiment 10 by examining, not only first-perspective alignment effects, but also the 'seen-views' (or orientation anchor) alignment effects reported by Shelton & McNamara (1997). In Experiment 11, when participants viewed the array from two perspectives that were 90° misaligned from the centre of the array, and under conditions where they were either asked, or not asked to make relative spatial judgements following their exposure to each of these perspectives, the overall error and latency data were consistent with a seen-views alignment effect. Participants were faster and more accurate for judgements from imagined orientations within the array that were aligned with the two perspectives which they had experienced, than from the two opposite (non-experienced) perspectives; no differences in either errors or response times were evident between the experienced perspectives. Worthy of note is that for the latency data, the seen-views alignment effect was only evident under the 'no judgements' condition; when participants were asked to make active spatial judgements while learning, their response times reflected an orientation-free memory. Wilson (2001, personal communication), similarly found a seen-views alignment effect (error, but not latency data) using text descriptions and still pictures, but in contrast to Experiment 11, a first-perspective alignment effect was also evident between the experienced views in the case of both text and picture presentations; this effect was subsequently attenuated when participants were asked to make spatial judgements following their reading a description of, or viewing each perspective.

To extend the investigation of seen-views and first-perspective alignment accounts of spatial memory for object arrays, participants in Experiment 12 viewed the array from two perspectives that were 180° contra-aligned from the centre of the array under similar conditions ('judgements' and 'no judgements' during learning) to those used in Experiment 11. Using an identical manipulation for text and pictures, Wilson (2001, personal communication) found that first-perspective alignment encoding was dominant; also, that for text descriptions, making judgements following each described perspective led to a 'reversal' effect between the described perspectives, with lower errors for the second that the first perspective. In contrast to the findings of Wilson, but consistent with the outcome of Experiment 11, the overall error and latency data in Experiment 12 revealed no evidence for first-perspective alignment encoding or recall. Also in this experiment, making judgements from each experienced perspective during learning did not have any consistent effect in comparison to a condition under which no judgements were made. Surprisingly, both the error and latency data in Experiment 12 reflected an apparently orientation-free memory. This finding is also inconsistent with a seen-views account of spatial memory because this account predicts equivalent errors and/or latencies for the first (0°) and second (180°) experienced perspectives, with poorer performance from 90° misaligned perspectives as these were not seen.

In addition to the consistent finding of first-perspective alignment encoding and recall following spatial learning from secondary sources (Wilson, 2001, personal communication; Experiments 2 - 9) and the absence of this effect following primary learning (Experiments 10 - 12), another important difference between primary and secondary learning was also noted. That is, there was a general lack of direction effects following secondary learning in Experiments 2-8, but the latency data from Experiment 11 indicated faster responses to targets that were in front of, rather than behind, participants imagined orientation at test. A similar pattern was evident in both the error and latency data in Experiment 12.

Taken together, the findings of Wilson (2001, personal communication) and those of Experiments 10-12 suggested the hypothesis that, in the real world, salient cues in the surrounding environment offer a 'ready-made' allocentric frame of reference; therefore, the first-perspective alignment effect does not occur because such cues render allocentric encoding more efficient by reducing cognitive load. In contrast, for the secondary case, allocentric information may be absent or limited, therefore, people construct a frame of reference on the basis of the first perspective on a space, in order to reduce cognitive load. The first-perspective therefore appears to represent a default primary reference frame, based on a psychological anchor point in spatial memory, at the first location encountered. However, active spatial processing of perspectives other than the first appears to establish additional anchor points from which position and orientation can be updated. When reliance on the first, single anchor point is reduced in this way, the first-perspective alignment effect is attenuated, and encoding and recall is from multiple perspectives.

One possible explanation for the differences in encoding and recall of arrays between the results of Experiments 10 - 12 and those of Wilson (2001, personal communication), is that in the former case participants may have benefited from additional information (visual, vestibular or proprioceptive) during their movement around the array (Simons & Wang, 1998; Wang & Simons, 1999), which would not be available following learning from text descriptions or pictures. To investigate the role of observer movement with respect to the current paradigm, in Experiments 13 and 14, participants either physically walked between two viewpoints set at 90° misaligned to the centre of the array, or the array was rotated between observations. The error data for Experiment 13 reflected a seen-views alignment effect; under conditions of observer movement and array rotation, participants were more accurate when aligned in imagination with the experienced perspectives than when aligned with the opposite perspectives. However, overall response latencies were faster in the observer movement condition than when the array was rotated.

In a procedure that essentially replicated that of Experiment 13, participants in Experiment 14 were encouraged to process both views equally by making relative spatial judgements following their exposure to each of the experienced views. The resultant patterns of error and latency data that emerged following this manipulation were representative of the seen-views alignment effect found in Experiment 11, and are therefore compatible with the outcome of that experiment, in which no evidence for first-perspective alignment encoding and recall was found. Under conditions of both observer movement and array rotation, participants were faster and more accurate for orientation judgements that were aligned with the two experienced perspectives than when aligned with the opposite perspectives.

To summarise: In contrast to both the outcomes of Experiments 2-9, in which the first-perspective alignment effect represented the dominant form of encoding and recall, and the results of Wilson (2001, personal communication), who consistently found evidence for first-perspective alignment encoding for pictures and text descriptions of similar object arrays to those used in the present experiments, this alignment effect was consistently not found following participants exposure to real arrays. Further, the presence of vestibular feedback in the case of real-world learning, that would be unavailable when learning is from secondary sources, does not readily explain the differences in spatial encoding and retrieval when learning is from a secondary or primary source.

Since the outset of the present research programme, Shelton and McNamara (2001) have published further experiments using small-scale object arrays. These authors found that when a spatial reference frame was provided by the properties of the external environment (i.e. when the display was surrounded by symmetrical walls, or when the objects were placed on a mat), participants encoded multiple (although orientation-dependent) views of the array. In other words, and as had been previously found (Shelton & McNamara, 1997), participants were more accurate when making judgements that were aligned with experienced views than when aligned with non-experienced views. This suggested that they had formed two egocentric representations of the layout, one from each experienced view. However, when participants learned the array from three viewpoints (0, 90 and 225°), and no frame of reference was provided (the test area was encased by a multi-sided cardboard room surrounded by a circular curtain, and no mat was present), participants encoded the array on the basis of their first experienced view of the array, with greater errors for the remaining two experienced views. Clearly, this latter finding of first-perspective alignment and recall is at odds with Shelton and McNamara's (1997, 2001) 'seen-views' hypothesis, because subsequent orientation judgements should always be more accurate when they correspond to an experienced view of the layout. As all of the procedures involved primary learning, the difference in outcome must be due to the reference frame.

A similar line of reasoning can be applied to the differences in outcomes between the experiments of Wilson (2001, personal communication), and those reported in the present Chapter. For pictures and text descriptions of object arrays, cognitive load is high, and encoding and recall are similarly based on the first described or depicted perspective on the array. In contrast, when the object arrays are viewed in the larger context of an experimental room, the opportunity arises to reduce cognitive load by encoding and recalling the array in relation to salient features of this external environment. Therefore, experienced perspectives will be better remembered than non-experienced perspectives due to the availability of additional environmental information in the former, but not the latter case.

CHAPTER 5

First-Perspective Alignment Encoding and Recall: A Theoretical Interpretation

5.1. Summary of Aims and Hypotheses

The overall aim of the experiments included here was to investigate a novel form of alignment effect described by Wilson, Tlauka and Wildbur (1999). Wilson et al. found that after reading, or listening to a description of a three-path route, participants encoded the route in alignment with the first described pathway, the first-perspective alignment effect. Because this effect was not significantly replicated following real-time, visuo-perceptual exploration of three-dimensional computer-simulated environments (VEs), Wilson et al. interpreted their findings as inconsistent with a common form of encoding for text and perceptual representations of space (e.g. Mani & Johnson-Laird, 1982). In their experiments, learning from text led to an orientation-dependent representation, whereas perceptual learning led to apparently similar encoding and recall from multiple perspectives.

The experiments in Chapters 2 and 3 concurrently addressed four potential accounts of the apparent difference in spatial encoding from verbal and a perceptual source recorded by these authors: First, as suggested by Wilson et al. (1999) an important variable in determining the alignment of a spatial representation may be the type of secondary learning medium employed. The visual and self-guided nature of VE exploration, might render spatial learning from this medium closer to that acquired from primary learning, following which orientation-free representations had previously been reported (Evans & Pezdek, 1980; Thorndyke & Hayes-Roth, 1982). Second, whether encoding and recall within different spatial reference frames might be responsible for the contrasting results; the text-based experiments of Wilson et al. did not include allocentric information, whereas in their VE experiments, the environments were visually extended beyond the test area. Further, previously published experiments using text-route descriptions that had provided additional environmental cues had documented apparently orientation-free recall (Taylor & Tversky, 1992). The third account was whether the first-perspective alignment effect might share similarities to the 'primacy effect' found in free recall tasks (e.g. Glanzer & Cunitz, 1966). The final account considered the extent to which the cognitive demands of the alignment task might vary with respect to the type of learning medium employed (Sweller, 1988, 1994), and the influence of this factor on whether the mental representation is constructed from single or multiple perspectives.

The outcomes of the experiments reported in Chapters 2 and 3 are briefly summarised below in relation to these possible accounts; the findings are further explored with respect to their theoretical relevance in Section 5.4.

5.2. Text Descriptions, Virtual Environments and the First-Perspective Alignment Effect

The six experiments reported in Chapter 2 employed verbal descriptions of simple three-path routes that had similar dimensions to those used by Wilson et al. (1999), and examined the conditions under which the first-perspective alignment effect occurs, and the manipulations that might attenuate or eliminate this effect. The results of a map drawing task in Experiment 1 demonstrated preliminary evidence that, just as when learning is from maps (Levine, 1982), or from directly walking a path (Palij, Levine & Kahan, 1984), participants apply 'forward-up equivalence' (Levine, 1982) in the construction of memories of these routes.

Experiments 2 - 6 explored the 'reference frame' account of Wilson et al.'s (1999) experiments, and investigated the effect of including allocentric information in text descriptions. When a large salient landmark was described as either in front of or behind the start orientation of the routes, overall analyses of the error and latency data from two experiments revealed evidence for first-perspective alignment encoding of a similar magnitude to that found when no landmarks were present. However, in Experiments 5 and 6, the introduction of an allocentric frame of reference in the form of already familiar cardinal terms, systematically affected the text first-perspective alignment effect (see below).

In Experiments 7 and 8 of Chapter 3, participants explored two desktop VEs with similar dimensions to those employed by Wilson et al. (1999, Experiment 3C); one of the VEs provided additional environmental information to that under exploration, whereas the other did not. However, in neither experiment did the factor of whether the explored VEs included additional environmental information exert a consistent influence on the overall patterns of error and latency data. The results of Experiment 7 provided evidence for first-perspective alignment encoding following VE learning. This outcome is consistent with the results of other published experiments, which have also found statistically significant evidence of this alignment effect following learning from VEs (Rossano, West, Robertson, Wayne & Chase, 1999; Richardson, Montello & Hegarty, 1999). However, in Experiment 7, first-perspective alignment encoding and recall was confined to the first VE that was explored. Following exploration of the second VE, the patterns of error and latency data conformed to those anticipated from an orientation-free memory. In Experiment 8, when the alignment test following exploration of the first VE route was replaced with a different kind of spatial orientation test that was not related to that VE, a first-perspective alignment effect was evident following exploration of the second VE. This outcome suggested that it was prior experience of making orientation judgements in the first test, rather than experience of exploring the first VE that attenuated the first-perspective alignment effect in the second test of Experiment 7. Important to note here is that while the observed attenuation of the first-perspective alignment effect in the second test was interpreted as resulting from encoding from multiple perspectives, an alternative explanation is that reduced overall performance might have a similar effect. However, supportive evidence for the former explanation was evident from the lower misaligned and contra-aligned error scores in the second test of Experiment 7 in comparison those recorded in Experiment 8; similar patterns were also found in the latency data of these experiments.

To further investigate whether prior experience of making orientation judgements could attenuate the first-perspective alignment effect, Experiment 9 used a text-based procedure. In one condition, participants were asked to make active spatial judgements after reading each section of the route. Consistent with the experimental hypothesis that active spatial processing at key points may have attenuated the first-perspective alignment effect, in the second test of Experiment 7, the first-perspective alignment effect was not found. By contrast, when participants read the route in sections, but did not make spatial judgements after each section, the first-perspective alignment effect was evident.

Before relating these findings to the possible accounts of the first-perspective alignment effect proposed above, one explanation of their data considered by Wilson et al. (1999), which was also systematically assessed in Chapters 2 and 3 is worthy of consideration. This refers to whether participants were able to imagine the routes used in Experiments 2 - 9 from a ground-level perspective, or whether they encoded the entire representation from an overhead perspective as has been shown when learning is from maps (e.g. Levine, 1982). If the latter were the case, then the first-perspective alignment effect could be explained as a typical map-based alignment effect. For the text case, and as reported by Wilson et al., for some participants, this appears to be a possibility. However, also noted was that participants reported switching from a ground level to an overhead perspective between reading and recall in a manner that was inconsistent, both within and between experiments. With respect to VE-learning, less than 10% of participants reported adopting a map-like perspective at test in which they imagined looking down on the route 'from above,' and approximately three quarters of participants made comments consistent with their having adopted a ground-level perspective as they made their orientation judgements. Taken together, these subjective reports do not offer support for the idea that across these eight experiments, the majority of participants consistently resorted to a map view at test.

Similarly, neither the text-based experiments included in Chapter 2, nor the VE experiments in Chapter 3 provide support for an account of the first-perspective alignment effect in terms of similarities between this alignment effect and that found for serial list learning (e.g. Glanzer & Cunitz, 1966). Additional analyses of the error and latency data that included 'route section' as a factor were conducted for the VE experiments included in Chapter 3, and with one exception (Experiment 5), this factor was included in the main error and latency analyses of the text-based experiments in Chapter 2. In neither case did these analyses reveal consistent support for an account of first-perspective encoding and recall that shares properties with the 'primacy effect' found following serial list learning. It was noted, however, that because the first-perspective alignment effect depends, by definition, on the first-experienced perspective defining the alignment of orientation judgements, a primacy effect of some kind must play a role in producing the effect. Nonetheless, the results of the present text and VE experiments do not provide good evidence for their interpretation in the same way as for serial order free-recall tasks.

To turn to the account of the first-perspective alignment effect proposed by Wilson (1997; Wilson et al., 1999), that spatial learning from VEs may be more similar to real world learning than when learning is from text descriptions. The VE route-learning experiments provide good evidence that the first-perspective alignment effect is not an artefact of text presentation, but appears to be a more general feature of spatial encoding and recall that extends to perceptual learning, at least with respect to learning from secondary sources. Considered together, the overall data from the present text and VE experiments are more consistent with the theory of similar forms of spatial encoding from language and perception (e.g. Bryant, 1992; Denis, 1996; Glenberg & McDaniel, 1992; Jackendoff & Landau, 1992). As in the case of text, spatial memories from VEs appear to be preferentially aligned with the first perspective that is presented, even when multiple perspectives have been explored.

Important to note, however, is that in the text-based experiments reported in Chapter 2, the mean difference between aligned and contra-aligned errors was approximately 32°; in Wilson et al.'s experiments, which used fewer participants, this difference was approximately 40°. In contrast, the two VE experiments reported in Chapter 3 required large numbers of participants to demonstrate orientation-dependent learning from this medium, and where evident, the mean difference between aligned and contra-aligned errors approximated 13°. The difference in magnitude of the text and VE alignment effects reported in the present experiments, which is consistent with that found by Wilson et al., could have occurred because for spatial learning, cognitive load is greater for verbally than visually presented routes. Therefore, decreased cognitive load could have been responsible for the less pronounced first-perspective alignment effect in the case of VEs compared to text, rather than, as speculated by Wilson et al. (1999), the medium *per se*.

There is also evidence in favour of a cognitive load explanation of the results of the VE experiments included in Chapter 3. For example, the first-perspective alignment effect observed in the error and latency data of Experiment 7 was only apparent in the first tested VEs; for the VEs tested second, the data conformed to that anticipated for orientation-free learning. It appears that when exploring the second VE in that experiment, because participants had previously answered alignment test questions relating to the first VE, cognitive load was reduced because they could anticipate the views necessary to make the spatial judgements in the second test. By contrast, in the alignment test that followed exploration of the second route-VE in Experiment 8, participants had no previous experience of making judgements after the first VE; therefore, cognitive load remained high, and a first-perspective alignment effect was apparent. Experiment 9, which used a text-based procedure, provided a clear demonstration that it is active spatial processing at key locations on the route that appears to reduce the cognitive demand incurred in making later orientation judgements, and therefore subsequent reliance on the first part of the route.

The final account of the first-perspective alignment effect investigated in Chapters 2 and 3 was whether the respective presence or absence of allocentric information in the VE and text-based experiments of Wilson et al. (1999) might account for the differences in their results. In contrast to this speculation there was no effect of this factor in attenuating the first-perspective alignment effect when it was manipulated as a factor in

VEs. In the case of text, the data from Experiments 2 - 6 suggested that, when a specific allocentric frame of reference was not provided, participants encoded the space using an egocentric frame, within a preferred orientation defined by the first perspective described in the text (Experiments 3 & 6), in which the direction of the first path is automatically assigned as 'north bound' (Experiments 3, 5 & 6). Further, this egocentric structure was resistant to modification when an allocentric reference system that comprised salient environmental cues was provided in the text (Experiments 2 - 4). However, when a well learned allocentric frame was provided (in this case, one that used cardinal terms), if this reference frame was compatible with the egocentric frame (as appears to be the case in Experiments 5 and 6 when the first part of the route was described as heading 'north'), then the first perspective alignment effect remained evident. In contrast, when the allocentric frame was incompatible with the egocentric frame (when the first part of the route was described as heading 'south'), participants appeared to attempt to rotate the egocentric frame into alignment with the allocentric frame. The additional processing incurred by such rotation appeared to lead to more complete learning (although at a cost of increased reaction time), and attenuation of the first-perspective alignment effect in errors. The intermediate effects noted in Experiment 6, when initial orientation was described as east- or west-facing suggest that the extent of this attenuation may depend on the degree of misalignment between the egocentric and allocentric frames.

Taken together, the results of the experiments presented in Chapters 2 and 3 suggested the hypothesis that first-perspective alignment encoding appears to represent a default form of encoding when learning is from secondary sources, with allocentric encoding as secondary. An account of this effect was developed in terms of spatial knowledge acquisition based on a primary anchor point, supplemented by further anchor points which may develop at other landmarks or cues as part of the learning process; for example, at key localities where a change in direction is made, or at semantically important locations such as the start of the return journey.

5.3. Object Arrays and the First-Perspective Alignment Effect

The experiments included in Chapter 4 investigated the extent to which the above findings could be generalised to real world learning. Recent perceptual experiments using real arrays of static objects as stimuli had not reported evidence for first-perspective alignment encoding and recall (Diwadkar & McNamara, 1997; Shelton & McNamara, 1997), which stood in contrast to the present findings with respect to when learning was from secondary sources.

To facilitate direct comparisons between spatial learning from primary and secondary sources, Experiments 10 – 14 comprised 'real-world' experiments based on those independently conducted by Wilson (2001, personal communication), in which participants read descriptions and/or viewed pictures of arrays of common objects depicted from more than one static viewpoint. A number of differences emerged between the two sets of experiments that are consistent with a primary-secondary distinction with respect to spatial learning from object arrays.

In Experiment 10, when participants were exposed to an array of four objects from four perspectives that were 0, 90, 180 and 270° misaligned from the centre of the array, orientation judgement errors were of a similar magnitude when judgements were aligned with the first, second, third and fourth perspectives, and the latency data were consistent with this outcome. In Wilson's (2001, personal communication) related experiment, following participants' exposure to text and pictorial depictions of object arrays from four perspectives, the error data were consistent with a first-perspective alignment effect.

Experiments 11 and 12 extended the focus of Experiment 10 by looking not only for first-perspective alignment effects, but also the more general alignment effects reported by Shelton and McNamara (1997, 2001) for object arrays. These experiments also assessed the effect of asking participants to make relative spatial judgements following their exposure to each of two viewing perspectives. In Experiment 11, when participants viewed the array from two perspectives that were 90° misaligned from the centre of the array, they were faster and more accurate for judgements made from imagined orientations within the array that were aligned with the two perspectives which they had experienced. No differences between the experienced perspectives were evident either with respect to errors or response times, and asking participants to make spatial judgements prior to the final alignment tests did not exert any influence on this overall outcome. Similarly, Wilson (2001, personal communication) found a 'seen-views' alignment effect using text descriptions and still pictures of four objects arranged on a table top, when viewed from two misaligned perspectives. But, in contrast to Experiment 11, a first-perspective alignment effect between the experienced views was also evident in the case of both text and picture presentations; this effect was subsequently attenuated when participants were asked to make spatial judgements following their reading a description of, or viewing each perspective.

In Experiment 12, participants viewed the arrays from two perspectives that were 180° contra-aligned from the centre of the array, under similar conditions (i.e. 'judgements' and 'no judgements' during learning) to those used in Experiment 11. The error and latency data from this experiment reflected an apparently orientation-free memory. However, using an identical manipulation for text and pictures, Wilson (2001, personal communication) found that first-perspective alignment encoding was dominant.

An explanation for the differences in encoding and recall between the results of Experiments 10 - 12 and those of Wilson (2001, personal communication) was suggested in terms of the additional information (visual, vestibular or proprioceptive), that participants may have accrued during their movement around the array, which would not be available following learning from text descriptions or pictures. Therefore, to investigate the role of observer movement with respect to the current paradigm, participants in Experiments 13 and 14 either physically walked between two viewpoints set at 90° misaligned from the centre of the array, or the array was rotated between observations for a stationary observer. The error data for Experiment 13 reflected a seen-views alignment effect under both conditions; however, overall response latencies were faster in the observer movement condition than when the array was rotated.

In a procedure that replicated that of Experiment 13, participants in Experiment 14 were asked to make active spatial judgements following their exposure to each of the experienced views. The resultant patterns of error and latency data were representative of the seen-views alignment effect found in Experiment 11, in which the two viewpoints were also set at 90°. Under conditions of both observer movement and array rotation, participants were more accurate for orientation judgements that were aligned with the two experienced perspectives than when aligned with the opposite perspectives.

In summary, the outcomes of Experiments 10 - 14 demonstrated that the first-perspective alignment effect was not a general characteristic of real-world spatial learning from object arrays. This outcome contrasted to both the results of Experiments 2 - 8 for route learning, in which first-perspective alignment encoding and recall was dominant, and those of Wilson (2001, personal communication), who consistently found evidence for this alignment effect following learning from pictures and text descriptions of similar object arrays to those used in the present experiments. Finally, the presence or absence of vestibular feedback did not readily explain these differences in spatial encoding and recall when learning was from a primary or secondary source.

Overall, the experiments reported in Chapters 2, 3 and 4 suggest at least three theoretical accounts of why people sometimes recall an environment based on their first-experienced perspective. First, in terms of a graded secondary-primary distinction for spatial learning; second, the greater cognitive load that might be incurred for learning from secondary than primary sources; and third the absence of allocentric information in the secondary, but not the primary case.

A graded secondary-primary distinction rests on the consistent finding of first-perspective alignment encoding and recall for route-learning learning from text descriptions, and the presence of this effect (although of lesser magnitude) following VE learning. Further, that this effect was also found following participants exposure to verbal descriptions and still pictures of object arrays (Wilson, 2001, personal communication), but was not evident when participants in Experiments 10 - 14 explored a real-world equivalent array.

The present results also indicate that the lack of first-perspective alignment encoding in the case of real world object arrays, and the presence of this effect following learning from secondary media may be a consequence of lower cognitive load in the former than the latter case. For example, the four experienced views in Experiment 10 for the real array, had lower errors (*M*s = 41, 41, 52 and 39°) than those recorded by Wilson (2001, personal communication) for text descriptions and pictures of comparable arrays (combined means for both depictions = 49, 68, 70 and 75°).

Evidence is also provided for an explanation couched in terms of the spatial reference frames used by participants to encode the spaces that were read about, explored in VEs, or directly experienced. The experiments included in Chapters 2 and 3 systematically attempted to provide an allocentric frame of reference in the secondary case, but overall, egocentric encoding, based on the first-aligned perspective was preferred; it therefore appears that the first perspective alignment effect is an automatic primary spatial learning mechanism that can only be over-ridden when salient environmental cues make allocentric encoding more efficient. In contrast, when real arrays were viewed in the broader context of the experimental room, the first-perspective alignment effect was not found (cf. Shelton & McNamara, 1997). It may be that in the real world case, allocentric encoding is dominant, but if allocentric information is absent or limited, people will fall back on a more egocentric reference frame in which to encode space; hence the finding of first-perspective alignment and recall of Shelton and McNamara (2001) when allocentric information was not provided.

To explain the overall patterns of data in the present experiments on the basis of a secondary versus primary distinction would be descriptive rather than analytic. This account allows a graded distinction between different learning media as a possible predictor of when the first-perspective alignment effect may occur and when it may not, but does not explain the reason for the different experimental effects. A similar argument applies to an interpretation of the present data solely on the basis of increased or decreased cognitive load. First, the presence or absence of a reference frame may facilitate or retard encoding and recall due to decreased or increased cognitive load, but the question remains as to whether cognitive load is dependent on the medium used to present spatial information, or on the degree to which the environment provides a frame of reference. Second, the present experimental procedures do not facilitate a clear interpretation of whether cognitive load is increased or decreased during encoding or at retrieval. Future experiments might usefully explore the effect on the first-perspective alignment effect of systematically increasing the difficulty of the learning (encoding) or retrieval task, both within and between primary and secondary learning experiments. However, while the predictive power of a cognitive load hypothesis is limited, one prediction from this explanation is that when 'load' is high, and people encode on the basis of the first-aligned perspective, response times at test for both misaligned and contra-aligned judgements should be slower in comparison to when 'load' is low and the first-perspective alignment effect is absent. Consistent with this prediction, in Experiment 7 (second test), the mean latencies were 10.9 and 8.6s for misaligned and contra-aligned judgements respectively, whereas in Experiment 8, the mean latencies were 12 and 9.3s for misaligned and contra-aligned judgements respectively.

A theoretical interpretation of the first-perspective alignment effect is presented in Section 5.4 that includes elements from each of the above explanations, and which proposes this effect as the primary encoding mechanism that supports preferred orientations in spatial memory. The account is restricted to the new environment case, and rests on the data presented in Chapters 2, 3 and 4. These data are envisaged as a foundation for the more general theory of the organisation of spatial knowledge proposed in Section 5.5.

5.4. Toward an Anchor Point Theory of First-Perspective Alignment Encoding and Recall

There are two basic accounts of why people sometimes recall an environment based on their first-experienced perspective. First, it may be that allocentric encoding is dominant in human spatial learning, and when the environment or learning medium does not provide an allocentric frame, people need to construct their own reference frame as a substitute, probably to reduce cognitive load. The first-experienced perspective provides an egocentrically defined start point for 'replacement' allocentric encoding in a preferred orientation (Shelton & McNamara, 2001). According to this account, allocentric encoding represents the default form of encoding in spatial memory; however, if allocentric information is absent or limited, people will fall back on a more egocentric reference frame.

McNamara and his colleagues have produced evidence consistent with the above account. For example, in their experiments using object arrays, when allocentric information was not provided, people recalled the array from the first of three seen perspectives. However, when walls and a mat in their experimental room provided a reference frame; people encoded multiple seen perspectives of the array (Shelton & McNamara, 2001). More recently, and since the completion of the experimental work included here, McNamara, Rump and Werner (2003) have found a strong influence of environmental information on the organization of spatial memories following real world exploration. These authors asked participants to walk around one of two square pathways that surrounded a prominent rectangular building in a city park, and to learn the locations of eight objects. For half the participants the path ran parallel to the walls of the building, and for the remainder, the path was offset by 45° with respect to the building. In a subsequent test conducted in a remote location, participants were asked to imagine themselves at locations on one of the paths, facing a variety of orientations, and to make judgements of the relative directions to other nearby locations. In the aligned condition, pointing accuracy was high for judgements that required an imagined orientation parallel to the path and the walls of the building, and also when oriented towards a nearby lake (the most salient nearby landmark). In the misaligned condition, the highest pointing accuracy was found for imagined orientations in alignment with the lake.

Both of the above findings (Shelton & McNamara, 2001; McNamara et al., 2003) are compatible with the suggestion that, where an environment provides a ready-made allocentric reference frame, this frame will be adopted; and that where no allocentric frame is available, egocentric encoding will be adopted. However, because the data of McNamara et al. do not relate directly to the primary versus secondary learning distinction, this account cannot address the finding in the present experiments, that asking participants to make active spatial judgements prior to their final alignment tests may influence the presence or absence of orientation-dependent encoding and recall.

A second possible account of why people sometimes recall an environment based on their first-experienced perspective is suggested by the results of the experiments reported here, and those conducted by Wilson (2001, personal communication). This is, that the first-perspective alignment effect is an automatic primary spatial learning mechanism that is only over-ridden when salient environmental cues make allocentric encoding more efficient by reducing cognitive load (see below). The difference between this, and the account outlined above, is that in the latter, the first-perspective alignment effect is, at least under some circumstances, the default form of encoding in spatial memory.

Irrespective of the learning medium in which spatial information is presented, one spatial reference system is always available to people for encoding. This egocentric reference frame is that which is hierarchically organized by the three body-axes, head/feet, front/back, and left/right, due to gravity and forward dominance of the senses (Franklin & Tversky, 1990; Bryant, Tversky & Franklin, 1992). Therefore, when an explorer encounters a new environment, they must begin by encoding it from an egocentric perspective; effectively, scanning the environment at the start point. Leaving a railway station and walking through its exit into the centre of a previously unexplored city centre provides a useful example of such egocentric scanning. Before people begin to explore, they form an extended egocentric reference frame, based on the first perspective, in which the start location forms an anchor point for encoding (Clouclelis, Golledge, Gale & Tobler, 1987). Here, 'anchor point' refers to a spatial memory structure that defines a particularly important location and a preferred orientation. The first direction of travel from this anchor point represents the first-perspective alignment effect. If the environment is lacking in salient features, or lacks symmetry, first-perspective alignment encoding persists, and continued exploration results in a 'projected' egocentric frame that is tied to the initial anchor point (e.g. Rossano, West, Robertson, Wayne & Chase; Richardson, Montello & Hegarty, 1999). This part of the theory shares similarities with that developed by Bryant and his colleagues (Bryant & Tversky, 1999; Bryant, Tversky & Franklin, 1992). This theory proposes that people can imagine an environment from an external perspective, which affords them a view of the entire scene. Locations can be encoded using an external frame of reference, which comprises axes based on the body, but projected forward in the field of view. Alternatively, locations can be encoded, not on the basis of egocentric bodily axes, but within intrinsic reference frames relative to the top-bottom, front-back, or left-right of a specified location within an environment (Bryant & Tversky, 1999).

However, if salient features of, or symmetry within the environment provide a ready allocentric frame of reference, this frame will be adopted in preference to the process of developing a projected egocentric frame, because adopting a ready made frame engenders less cognitive load. Because the extended egocentric frame works on a 'forward-up-north equivalent' principle, an allocentric reference frame may also be adopted in preference to first-perspective alignment encoding under circumstances where there is no ready symmetry in the environment, but a salient feature can be used to define a 'north-up' alignment (e.g. McNamara, Rump & Werner, 2003).

Experiments 2 - 6 explored the effect on first-perspective alignment encoding and recall of including allocentric information in text descriptions. In effect, these manipulations placed the 'first-perspective alignment effect' and 'salient feature' reference frame hypotheses into opposition. In Experiments 3 and 4, the text-route description referred to a large external landmark positioned either in front of or behind the start orientation of the route. Whether the landmark was described as in front of, or behind "...the direction you plan to walk..." encoding was primarily based on the first-perspective alignment effect. In Experiment 6, the introduction of an allocentric frame of reference that conveyed already familiar cardinal terms (a 'ready made' allocentric frame), systematically affected the text first-perspective alignment effect. As was the case in Experiments 3 and 4, this manipulation placed the first-perspective alignment effect and reference frames hypotheses into opposition. The 'south' condition' provided evidence of an equal effect of the first-perspective alignment effect and cardinal terms, as indicated by the orientation errors; neither dominated because errors for aligned and contra-aligned judgements were equal. Most important here, is that participants *did not* adopt a preferred allocentric frame. Further, the first-perspective alignment effect was evident in the latency data, even though overall errors were lowest under this condition. This pattern of data is also consistent with the idea that encoding on the basis of an egocentrically defined first-perspective on a space is preferred to allocentric encoding.

Two potential problems arise at this point: First, as noted for both text descriptions and VEs, an advantage to targets in front of rather than behind participants' imagined orientation at test that is predicted for egocentric recall (Franklin & Tversky, 1990), was generally not found in either set of experiments, even though the alignment test questions encourage egocentric judgements. However, the first-perspective alignment 'dominance' theory, and the 'projected' frame theory of Bryant and his colleagues (Bryant & Tversky, 1999, Bryant, Tversky and Franklin, 1992), anticipate this outcome because participants are imagining the whole scene using a 'projected' frame, in which all of the key locations are in front of the egocentric anchor point. Egocentric asymmetries in the participant's imagined view are only directly relevant at the egocentric anchor point, not at locations in the forward frame. Interestingly, in the 'real-array' objects experiments reported in Chapter 3, in which no evidence for first-perspective alignment encoding was found, a forward superiority was noted.

A second problem in attributing the first-perspective alignment effect to reliance on a single egocentric anchor point, is that in the text-based experiments included in Chapter 2, and in Experiments 7 and 8 which used VEs, this alignment effect was found on the first and last parts of the route. A single anchor point hypothesis should lead to a first-perspective alignment effect only, or primarily, on the first section of the route, with all other locations being forward in the projected frame. However, the overall error data from these experiments, suggest that anchor points may have been formed both at the start point of exploration, and the start point of the return journey. In other words, participants remembered two journeys, each with its own start point, rather than a single return journey. The 180° rotation at the end of the described or explored route appears to create a second egocentric anchor point that may be less cognitively salient (Experiment 7), or of similar strength (Experiments 2-6 & 8), in comparison to the start anchor point.

If this account is accurate, there may be other ways in which more than one anchor point, or indeed 'anchor orientation' (that is, orientations from which information can be more easily retrieved), can be established. Experiments 7 and 8 suggest that following testing in (but not simply exploration of) one VE, some information is transferred to second exploration and test procedure that attenuates the first-perspective alignment effect. In Experiment 9, in which participants were asked to make active spatial judgements after reading each section of the route presented on a computer screen, a first-perspective alignment effect was not found. Therefore, it appears that active spatial processing may be another way in which multiple anchor points can be established.

The hypothesis of a start anchor point in spatial memory is strengthened by considering the results of the series of 'real array' objects experiments reported in Chapter 4, in comparison to those conducted independently by Wilson (2001, personal communication), who used secondary learning media to depict similar arrays. When real arrays are viewed in the larger context of an experimental room, the opportunity arises to reduce cognitive load by encoding and recalling the array in relation to features of the external environment. Experienced perspectives will therefore be equally and better remembered than non-experienced perspectives (Experiments 10 - 12), due to the availability of additional environmental information in the former, but not the latter case. Asking people to make active spatial judgements at each viewpoint prior to testing has little effect on this outcome. For pictures, and descriptions of object arrays, where the first-perspective alignment effect was consistently found, asking participants to make active spatial judgements at each viewpoint, prior to testing, abolished the effect. Making active judgements appears to establish an additional anchor points at the second view that reduces the influence of the start anchor point, possibly because the second view becomes as strong an anchor point as the first view. Therefore, as in the route learning experiments presented in Chapter 3, actively making judgements at locations other than the start appears to increase the number of anchor points.

5.5. The First-Perspective Alignment Effect: A General Theory

The theory presented below is based on two main premises. First, to the knowledge of this author, no published studies have reported evidence for first-perspective alignment effects following exploration of real world, large-scale environments. However, given that more general alignment effects are well documented from map learning (Levine, 1982; Levine, Jankovic & Palij, 1982; McDonald & Pellegrino, 1993; Presson & Hazelrigg, 1984; Sholl & Nolin, 1997), and from real world learning (Shelton & McNamara, 1997; 2001; see also, Werner & Schmidt, 1999), it seems that the tendency to encode space in a preferred orientation is a dominant feature of human spatial learning. Secondly, two suggestions are taken from Couclelis, Golledge, Gale and Tobler (1987): That anchor points perform "active cognitive functions such as organizing spatial knowledge, facilitating navigational tasks, and helping estimate distances and directions etc." (p. 102), and that there is a "hierarchy of cognitive salience" of anchor points (p. 103).

When people encounter a new environment, by default, they begin by encoding spatial information from an egocentric perspective based at the start point, which forms a psychological anchor point. As they explore, and increase the number of experienced perspectives, they form an extended egocentric reference frame, which remains tied to the first perspective because aligned encoding minimises cognitive load. If the environment lacks salient landmarks, or is asymmetrical, it will not offer a ready-made or allocentric frame that could reduce cognitive load. In this case, continued exploration results in a 'projected' frame that is tied to the egocentric anchor point. However, less significant anchor points may develop at other landmarks or cues. In the present experiments, significant cues that can have the potential to form additional anchor points are likely to be primarily those that are spatially salient. For example, in the route learning experiments, these are likely to be at key localities where a change in direction is made. However, they could equally be semantically important locations, such as the start of the return journey. In the objects experiments, the potential to form additional anchor points will occur at the second, and any subsequent views.

When given tests of their spatial knowledge, people will recall most readily from the start anchor point, and less so from other anchor points. For route learning, the most efficient recall will be from the imagined start anchor point, the next most efficient will be the start of the return journey. In the absence of directed active processing, other key locations do not appear to form strong anchor points, and when people are required to adopt a perspective from one of these localities, they do so using the forward projected frame, based on the start anchor point. To make judgements from these localities, participants must mentally rotate either their egocentric perspective into alignment with the projected forward frame, or bring the forward frame into alignment with their egocentric perspective. The first-perspective alignment effect is a consequence of easy processing when the two are in alignment, and more difficult processing when the perspectives must be rotated to bring them into alignment.

However, if symmetry in the structure of the environment, or salient environmental cues provide a ready allocentric frame of reference, this frame will be adopted in preference to developing a projected egocentric frame, because adopting a ready-made frame engenders less cognitive load. Such symmetry in structure is much more likely to occur in the real world than when learning is from secondary sources. Hence, in McNamara, Rump and Werner's (2003) experiment, the structure of the environment, and the presence of a highly salient nearby lake determined preferred orientations at recall following real-world learning.

5.5. Future Directions and Conclusions

The results of the present experiments suggest at least three potential avenues for their extension: First, with respect to the experiments presented in Chapters 2 and 3, and the outcomes of previously published studies (Richardson et al., 1999; Rossano et al., Wilson et al., 1999), there is evidence that sometimes people encode space in alignment with the first-experienced perspective. However, all of the demonstrations of this type of alignment effect have relied on secondary learning sources. While, as proposed above, the lack of this effect following learning about real arrays of objects may reflect a primary-secondary distinction, carefully designed experiments carried out in large-scale environments, using similar procedures and measures to those used here are necessary to develop the current account of human spatial learning.

Second, this theoretical account lends to its extension in terms of the ontogenesis of human spatial learning experience. For example, Siegel and White (1975) made the explicit claim that during childhood, people first learn about landmarks, then about routes connecting landmarks, and subsequently form integrated representations of Euclidean space. While some supportive findings have been reported (e.g. Cohen & Schuepfer, 1980; Cousins, Siegel & Maxwell, 1983), where methodologies have varied, other authors have reported contradictory findings (e.g. Conning & Byrne, 1984). However, there is a parallel between the account of Siegel and White and the theory proposed here, with respect to the idea that primary learning appears to be based on encoding within initially egocentric, then projected, then allocentric frames of reference. Therefore, the present experiments, which employ carefully designed and similar procedures across different learning media could be usefully replicated to investigate the spatial reference frames used by children.

Finally, the overall data presented here reflect decreased cognitive load as a consequence of learning from primary than secondary sources. However, cognitive load can be affected by a number of contributory factors; for example, individual characteristics of the participants (e.g. their cognitive abilities), the environment in which testing takes place (e.g. noise or other distracters), the complexity of the task, and the inter-relationships between these factors. Moreover, increases or decreases in cognitive load can be measured objectively across such dimensions as the degree of mental effort allocated to the task and the extent to which performance might be affected by the contributory factors noted above (Kirschner, 2002). Therefore, exactly which features of cognitive load are increased or decreased both within and between learning media merits further investigation, on a theoretical and educational basis.

In summary, the results of the 14 experiments included here strongly suggest a graded, secondary-primary distinction in human spatial learning; moreover, that the first-perspective alignment effect represents the primary encoding mechanism in spatial memory. As such, spatial memories are fundamentally egocentric, but can be influenced by environmental cues. An 'anchor point' account of the first-perspective alignment is proposed that, first, includes an explanation not only of why the first-perspective alignment effect occurs, but also when it should be found. Second, which suggests an account of the finding in the present experiments and those of Wilson (2001, personal communication), that making active spatial judgements can attenuate the first-perspective alignment effect. It appears that actively elaborating on a spatial layout from an egocentric perspective increases the egocentric salience of the location at which it occurs, producing another anchor point. Finally, this account offers an integrated account of both the first-perspective and seen views alignment effects. When allocentric information is absent, or weak, participants encode the space on the basis of the default first-aligned perspective because aligned encoding minimises cognitive load. In contrast, when a strong allocentric frame of reference is provided, participants rely heavily on this frame and egocentrically based alignment effects are attenuated.

APPENDICES

Spatial Memories

This experiment is designed to investigate the properties of spatial memory.

Printed below is a description of four points marked on the floor in a large open room. The description is of a walk between these points that involves 90 degree turns. Please read the description at least 3 times, and as you read, try to imagine that you are actually walking between the points, visualising the journey as clearly as possible from a ground level perspective.

When you have finished reading, and you are sure that you have a really clear memory of the route you have imagined, please turn this page over and follow the instructions provided. *Thank You.*

Description:

Imagine that you are stood in the room at Point 1. Twenty metres from where you are standing is Point 2. Imagine walking from Point 1 to Point 2. At Point 2 you turn to face 90 degrees to the left. Ten metres away is Point 3. You walk from Point 2 to Point 3, and at Point 3 you turn to face 90 degrees to the left. Eight metres away is Point 4. Imagine walking to Point 4.

Please indicate:

Your age [ ] Your sex (M/F) [ ]

Without referring back to the description, draw a line diagram of your remembered route in the space below. Please label the diagram clearly with the numbers of the Points, and the lines between them to show the route that your imagined walking

Thank you for taking part ☺

APPENDIX A

Experiment 1: Instructions to Participants, Group Points 4-3

Spatial Memories

This experiment is designed to investigate the properties of spatial memory.

Printed below is a description of four points marked on the floor in a large open room. The description is of a walk between these points that involves 90 degree turns. Please read the description at least 3 times, and as you read, try to imagine that you are actually walking between the points, visualising the journey as clearly as possible from a ground level perspective.

When you have finished reading, and you are sure that you have a really clear memory of the route you have imagined, please turn this page over and follow the instructions provided. *Thank You.*

Description:

Imagine that you are stood in the room at Point 1. Eight metres from where you are standing is Point 2. Imagine walking from Point 1 to Point 2. At Point 2 you turn to face 90 degrees to the right. Ten metres away is Point 3. You walk from Point 2 to Point 3, and at Point 3 you turn to face 90 degrees to the right. Twenty metres away is Point 4. Imagine walking to Point 4.

Please indicate:

Your age [ ] Your sex (M/F) [ ]

Without referring back to the description, draw a line diagram of your remembered route in the space below. Please label the diagram clearly with the numbers of the Points, and the lines between them to show the route that your imagined walking

Thank you for taking part ☺

APPENDIX A

Experiment 1: Instructions to Participants, Group Objects 1-2

Spatial Memories

This experiment is designed to investigate the properties of spatial memory.

Printed below is a description of four objects arranged on the floor of a large open room. The description is of a walk between these objects that involves 90 degree turns. Please read the description at least 3 times, and as you read, try to imagine that you are actually walking between the objects, visualising the journey as clearly as possible from a ground level perspective.

When you have finished reading, and you are sure that you have a really clear memory of the route you have imagined, please turn this page over and follow the instructions provided. *Thank You.*

Description:

Imagine that you are stood in the room next to a cooker. Twenty metres from where you are standing is a table. Imagine walking from the cooker to the table. At the table you turn to face 90 degrees to the left. Ten metres away is a chair. You walk from the table to the chair, and at the chair you turn to face 90 degrees to the left. Eight metres away is a filing cabinet. Imagine walking to the filing cabinet.

Please indicate:

Your age [ ] Your sex (M/F) [ ]

Without referring back to the description, draw a line diagram of your remembered route in the space below. Please label the diagram clearly with the numbers of the Points, and the lines between them to show the route that your imagined walking

Thank you for taking part ☺

APPENDIX A

Experiment 1: Instructions to Participants, Group Objects D-A

Spatial Memories

This experiment is designed to investigate the properties of spatial memory.

Printed below is a description of four objects arranged on the floor of a large open room. The description is of a walk between these objects that involves 90 degree turns. Please read the description at least 3 times, and as you read, try to imagine that you are actually walking between the objects, visualising the journey as clearly as possible from a ground level perspective.

When you have finished reading, and you are sure that you have a really clear memory of the route you have imagined, please turn this page over and follow the instructions provided. *Thank You.*

Description:

Imagine that you are stood in the room next to a filing cabinet. Eight metres from where you are standing is a table. Imagine walking from the filing cabinet to the table. At the table you turn to face 90 degrees to the right. Ten metres away is a chair. You walk from the table to the chair, and at the chair you turn to face 90 degrees to the right. Twenty metres away is a filing cabinet. Imagine walking to the filing cabinet.

Please indicate:

Your age [ ]   Your sex (M/F) [ ]

Without referring back to the description, draw a line diagram of your remembered route in the space below. Please label the diagram clearly with the numbers of the Points, and the lines between them to show the route that your imagined walking

Thank you for taking part ☺

APPENDIX A
Experiment 2: Instructions to Participants

Read by all participants prior to commencement of the experiment

The first part of this experiment investigates learning in a virtual or computer-generated environment (VE). Your position in the VE will be at the centre of an open area of countryside. A tree stump marks the centre of the area, and at equal 80 metre distances from where you are standing are four large landmarks.

Using the arrow keys to move, you will be asked to explore this environment; try to ensure that you travel to each of the landmarks in turn, and frequently rotate your view so that you are able to learn the relationships between the landmarks.

Following this exploration, you will be asked some questions about the positions of some of the landmarks in relation to the tree stump at the centre of the environment and in relation to one another. To help you make these judgements, you can use a simple pointing device that will be demonstrated before the start of the experiment

Thank you for taking part.

APPENDIX A
Experiment 2: Instructions to Participants

Read by all participants prior to the text phase of the experiment

In this part of the experiment, I would like you to imagine that you have travelled back to the same area that you have just explored on the computer, and that a shopping centre development has taken place. All of the landmarks are still present, but the tree stump has been removed and built over. I shall hand you a description of an imagined walk around the streets of the shopping centre. The streets are of varying length, and all intersect at right angles. At each intersection there is a building of the type usually found in a shopping centre.

Please read the description carefully, and imagine yourself walking along the streets as clearly as you can from a ground-level perspective. After you have read the description, I will ask you to answer some questions concerned with the location of each of the buildings from different imagined test locations.

APPENDIX A
Experiments 3 & 6: Instructions to Participants

Read by all participants prior to commencement of the experiment

This experiment is designed to investigate the properties of mental images and thank you for agreeing to take part. You will be asked to imagine yourself making two short journeys on foot, and it is important that you try to visualise the routes as clearly as possible from a ground level perspective. You may wish to close your eyes to aid concentration and avoid distractions during testing. Please read the following instructions carefully, and then I will answer any questions you may have.

I would like you to imagine that you have travelled to a large modern city. The streets, which are all of varying length, are arranged in a grid pattern, and all intersect at right angles. At each intersection there is a building of the type typically found in a modern city. For example, cinema, garage, bank and so on.

One at a time, I shall hand you two printed descriptions of simple imaginary routes through this city. Please read the description carefully, and imagine yourself walking along the pathways described at a ground level, and as clearly as you can.

After you have read each description, I will ask you to answer some questions concerned with the locations of some of the buildings from different imagined test locations. To help you answer the questions you can use a simple pointing device, which I will demonstrate before the experiment begins.

Do you have any questions?

APPENDIX A
Experiment 4: Instructions to Participants

Read by all participants prior to commencement of the experiment

This experiment is designed to investigate the properties of mental images and than you for agreeing to take part. You will be asked to imagine yourself making a short journey on foot, and it is important that you try to visualise the route as clearly as possible from a ground level perspective. You may wish to close your eyes to aid concentration and avoid distractions during testing. Please read the following instructions carefully, and then I will answer any questions you may have.

I would like you to imagine that you have travelled to a large modern city. The streets, which are all of varying length, are arranged in a grid pattern, and all intersect at right angles. At each intersection there is a building of the type typically found in a modern city. For example, cinema, garage, bank and so on.

I shall hand you a printed descriptions of a simple imaginary route through this city. Please read the description carefully, and imagine yourself walking along the pathways described at a ground level, and as clearly as you can.

After you have read the description, I will ask you to answer some questions concerned with the locations of some of the buildings from different imagined test locations. To help you answer the questions you can use a simple pointing device, which I will demonstrate before the experiment begins.

Do you have any questions?

APPENDIX A
Experiment 5: Instructions to Participants

Read by all participants prior to commencement of the experiment

This experiment is designed to investigate the properties of mental images, and thank you for agreeing to take part. You will be asked to imagine yourself making a short journey on foot. It is important that you try to visualise the route as clearly as possible from a ground level perspective. Please read the following instructions carefully, and then I will answer any questions you may have.

I would like you to imagine that you have travelled to a large modern city. The streets, which are all of varying length, are arranged in a grid pattern, and all intersect at right angles. At each intersection there is a building of the type typically found in a modern city. For example, cinema, garage, bank and so on. I shall hand you a printed description of a simple imaginary route through this city. Please read the description carefully, and imagine yourself walking along the pathways described as clearly as you can.

After you have read the description, I will ask you to read and answer two questions concerned with the location of two different buildings, each from a different imagined test location. The questions are written on a separate sheet, and underneath each one is a picture of a dial, which is calibrated in degrees. Please answer each question by clearly marking a line on the outer edge of the dial as in the example on the next page.

Do you have any questions?

APPENDIX A
Experiments 7 & 8: Instructions to Participants

Read to all participants by the experimenter, prior to the commencement of the training phase of the experiment

Before the actual experiment stars, I would like you to explore a simple virtual environment. You can do this by pressing the arrow keys on the keyboard – these move you forward and back, and you can rotate to the left and right. Please do not press any other keys.

The aim is for you to get used to the controls while you find four coloured cubes, which are located behind different walls. Try not to run into any walls, but if you do run into a wall, I will press a key to re-start the experiment.

I would like to keep exploring for five minutes, even if you are sure about the positions of all of the cubes. At the end of this time, I will move you to a location where none of the cubes can be seen directly, and ask you to point to each wall that has a coloured cube behind it, using crosshairs in the centre of the screen.

APPENDIX A
Experiments 7 & 8: Instructions to Participants

Read by all participants prior to commencement of the learning phase of the experiment.

The purpose of this experiment is to investigate how people remember scenes. You will be asked to explore two computer-simulated environments one at a time. Each environment comprises a small part of a city in which the streets all intersect at right angles. It is important that you try to explore the environments as carefully as you can; you can do this by pressing the arrow keys on the keyboard to move you forward and back, and to rotate to the left and right.

Each environment contains a number of distinctive buildings or objects, and these are marked by large blue dots on the ground adjacent to each building or object. After you have explored each environment three times, you will be asked to make some judgements about the direction of one building or object from the position of another building or object. You should use the blue dots as reference points as you make these judgements.

Thank you for taking part

APPENDIX A
Experiment 9: Instructions to Participants

Read to all participants by the experimenter at the start of the experimental session

The purpose of this experiment is to learn about how people remember scenes described only in text. You will read a passage of text describing a street scene three times. When you have a clear mental picture, you will be asked to make some judgements about the direction of some localities from the position of other localities. To do this, imagine that you rotate an arm on the dial that will be displayed, and type in the number that corresponds to the appropriate direction. Remember to enter the " – " sign when making estimates to the left of the direction that you imagine you are facing. The same procedure will then be repeated for a second street scene. It is very important that you reply on your memory and do not use any artificial aids such as drawing the scene.

'On-screen' instructions read by participants

Screen 1:

The concern of this experiment is with people's imagination for objects and events presented in text descriptions.

For two separate described scenes you will be asked to imagine yourself making a short journey through the streets of a modern city on foot. It is important that as you read through the text, you try to visualise yourself walking along the routes as clearly as you can.

The streets vary in length, and all intersect at right angles. At each intersection there is a building of the sort that you might expect in a modern city (e.g. 'McDonald's,' Newsagents and so on).

APPENDIX A
Experiment 9: Instructions to Participants

You will read descriptions of simple imaginary routes through this city, and occasionally, you will be asked to judge where a building is in relation to where you imagine your current location to be.

Type 'ok' to continue.

Screen 2

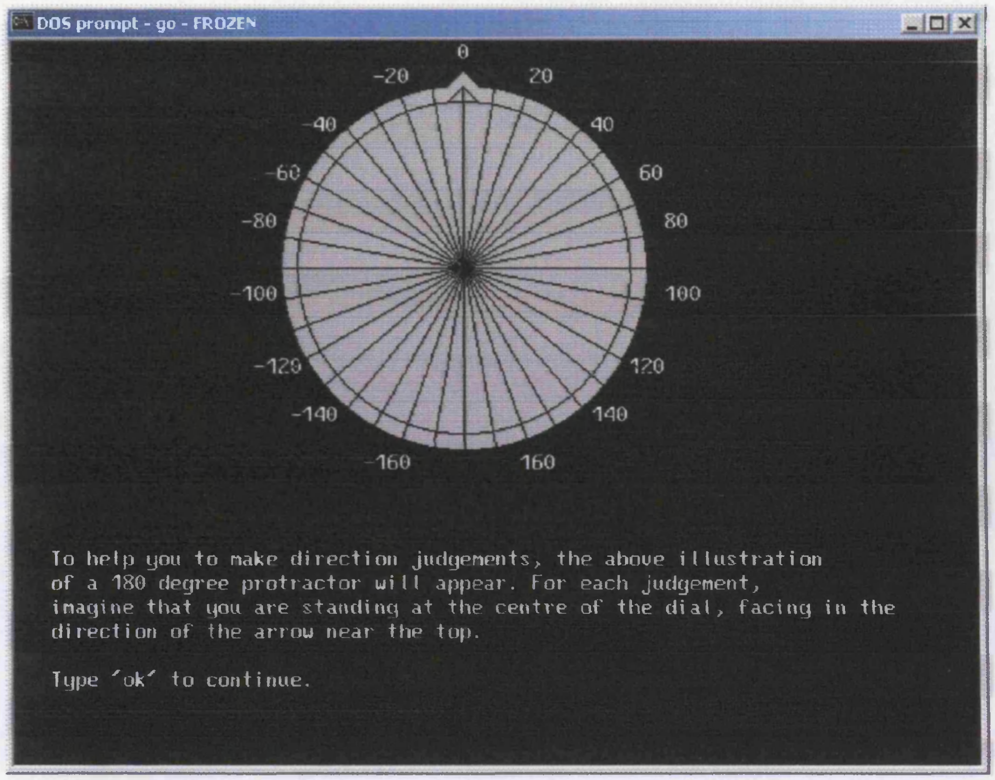
Please read each description carefully, and try to imagine yourself walking along the streets as clearly as you can.

After reading each short passage three times, you will be asked to judge the direction of several different test locations, each from a different imagined place.

Because the experiment is designed to investigate mental images, it is important that you do not draw any diagrams or make any notes.

Type 'ok' to continue.

Screen 3



Screen 4

This screen presented three locations (A B and X) that were printed on the screen, and participants were asked to make two judgements from memory involving these locations, while the 360 degree protractor was presented in the top half of the screen. An example judgement was:

Imagine you are standing at X, and facing towards B.

What number would you enter to indicate the direction of A?

INPUT: please type in a number between –180 and 180.

Type 'ok' to continue.

APPENDIX A
Experiment 9: Instructions to Participants

Screen 5

The first description will appear next.

Just follow the instructions on the screen.

Each passage of text will be repeated on three occasions, and sometimes you will be asked to make direction judgements on route.

Try to visualise the scene clearly as though you are standing or walking along the street.

Type 'ok' to continue.

APPENDIX A
Experiment 10: Instructions to Participants

Read by all participants prior to the commencement of the experiment

In this experiment, I am investigating how people remember scenes, which they have learned from different perspectives. You will be asked to look through eye-level windows in a screen, and to learn the arrangement of a group of objects, which are arranged on a table top. You will see each group of objects from four different perspectives.

When you have studied the array from all four perspectives, I shall ask you a set of questions based on your memory of the array. For each question, you will be asked to imagine yourself standing at the position of one object within the array, as if you were actually on the table, then to make some judgements concerning the direction and distance of a second object in relation to where you imagine yourself standing.

To help you answer the questions, you can use a simple pointing device, which I will demonstrate before the experiment begins.

Thank you very much for taking part…☺

APPENDIX A
Experiments 11 and 12: Instructions to Participants

Read by all participants prior to the commencement of the experiments.

In this experiment, I am investigating how people remember scenes, which they have learned from different perspectives. You will be asked to look through eye-level windows in a screen, and to learn the arrangements of two groups of objects, one at a time, which are arranged on a table top. You will see each group of objects from two different perspectives.

For one group of objects, after you have studied the array from the first perspective, I shall ask you a number of questions about how you remember the arrangement of the objects in relation to where you were actually standing. You will then see the same array from the second perspective and these questions will be repeated. For the other group of objects, you will be asked to view the array from the two viewing windows consecutively.

For each group of objects, I shall ask you a set of questions based on your memory of the array. For each question, you will be asked to imagine yourself standing at the position of one object within the array, as if you were actually on the table, then to make some judgements concerning the direction and distance of a second object in relation to where you imagine yourself standing.

To help you answer the questions, you can use a simple pointing device, which I will demonstrate before the experiment begins.

Thank you very much for taking part… ☺

APPENDIX A
Experiment 13: Instructions to Participants

Read by all participants prior to the commencement of the experiments.

In this experiment, I am investigating how people remember scenes, which they have learned from different perspectives. You will be asked to look through either one or two eye-level windows in a screen, and to learn the arrangements of two groups of objects, one at a time, which are arranged on a table top. You will see each group of objects from two different perspectives.

For each group of objects, I shall ask you a set of questions based on your memory of the array. For each question, you will be asked to imagine yourself standing at the position of one object within the array, as if you were actually on the table, then to make some judgements concerning the direction and distance of a second object in relation to where you imagine yourself standing.

To help you answer the questions, you can use a simple pointing device, which I will demonstrate before the experiment begins.

Thank you very much for taking part… ☺

APPENDIX A
Experiment 14: Instructions to Participants

Read by all participants prior to the commencement of the experiments.

In this experiment, I am investigating how people remember scenes, which they have learned from different perspectives. You will be asked to look through either one or two eye-level windows in a screen, and to learn the arrangements of two groups of objects, one at a time, which are arranged on a table top. You will see each group of objects from two different perspectives.

For each group of objects, after you have studied the array from the first perspective, I shall ask you a number of questions about how you remember the arrangement of the objects in relation to where you were actually standing. You will then see the same array from the second perspective and these questions will be repeated.

For each group of objects, I shall ask you a set of questions based on your memory of the array. For each question, you will be asked to imagine yourself standing at the position of one object within the array, as if you were actually on the table, then to make some judgements concerning the direction and distance of a second object in relation to where you imagine yourself standing.

To help you answer the questions, you can use a simple pointing device, which I will demonstrate before the experiment begins.

Thank you very much for taking part... ☺

APPENDIX B
Experiment 2: Text-Route Descriptions

Left-hand turns on the outward journey

First perspective, aligned with rock

Imagine that you have travelled to the same area now that the shopping centre has been built. You re standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking along the path from the Bus Terminus, you can see the large rock in the distance ahead. The tall fir tree is on your right-hand side and when you turn, you see that the pylon is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends fifty metres in the direction of the large rock. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' The large rock is now on your right-hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second hand Book Shop. You turn left at the Book Shop and walk another twenty metres until you come to a Health Food Store. As you walk towards the Health Food Store you can see the castle tower in the distance ahead and to your right.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back towards the Book Shop. The castle tower is now on your left and slightly behind you. Imagine that you walk the twenty metres back to the Book Shop and turn right. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's and turn right so that you are now facing towards the Bus Terminus and the large rock is behind you.

Imagine that you walk the fifty metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the tall fir tree to your left and the pylon in the distance in front of you.

First perspective, aligned with tower

Imagine that you have travelled to the same area now that the shopping centre now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking along the path from the Bus Terminus, you can see the castle tower in the distance ahead. The large rock is on your right-hand side and when you turn, you see that the tall fir tree is in the distance behind you.

Imagine that on leaving the Bus Terminus, you walk along the path that extends fifty metres in the direction of the castle tower. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' The castle tower is now on your right-hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop and walk another twenty metres until you come to a Health Food Store. As you walk towards the Health Food Store you can see the pylon in the distance ahead and to your right.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back toward the Book Shop. The pylon is now on your left and slightly behind you. Imagine that you walk the twenty metres back to the Book Shop and turn right. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus and the castle tower is behind you. Imagine that you walk the fifty metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the large rock to your left and the tall fir tree in the distance in front of you.

First perspective, aligned with tree

Imagine that you have travelled to the same area now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking long the path from the Bus Terminus, you can see the tall fir tree in the distance ahead. The pylon is on your right-hand side and when you turn, you see that the castle tower is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends fifty metres in the direction of the tall fir tree. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' The tall fir tree is now on your right-hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop and walk another twenty metres until you come to a Health Food Store. As you walk towards the Health Food Store you can see the large rock in the distance ahead and to your right.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back toward the Book Shop. The large rock is now on your left and slightly behind you. Imagine that you walk the twenty metres back to the Book Shop and turn right. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus and the tall fir tree is behind you.

First perspective, aligned with pylon

Imagine that you have travelled to the same area now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking along the path from the Bus Terminus, you can see the pylon in the distance ahead. The castle tower is on your right-hand side and when you turn, you see that the large rock is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends fifty metres in the direction of the pylon. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' The pylon is now on your right hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop and walk another twenty metres until you come to a Health Food Store. As you walk towards the Health Food Store you can see the tall fir tree in the distance ahead and to your right.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back toward the Book Shop. The tall fir tree is now on your left and slightly behind you. Imagine that you walk the twenty metres back to the Book Shop and turn right. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus and the pylon is behind you. Imagine that you walk the fifty metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the castle tower to your left and the large rock in the distance in front of you.

Right-hand turns on the outward journey

First perspective, aligned with rock

Imagine that you have travelled to the same area now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking along the path from the Bus Terminus, you can see the large rock in the distance ahead. The castle tower is on your left-hand side and when you turn, you see that the pylon is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends thirty-five metres in the direction of the large rock. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a right-hand turn at 'McDonald's.' The large rock is now on your left-hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second-hand Book Shop. You turn right at the Book Shop and walk another fifty metres until you come to a Health Food Store. As you walk towards the Health Food Store you pass the tall fir tree in the distance on your left.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back toward the Book Shop. The tall fir tree is now on your right and slightly in front of you. Imagine that you walk the fifty metres back to the Book Shop and turn left. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's' and turn left so that you are now facing towards the Bus Terminus and the large rock is behind you. Imagine that you walk the thirty-five metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the castle tower to your right and the pylon in the distance in front of you.

First perspective, aligned with tower

Imagine that you have travelled to the same area now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking along the path from the Bus Terminus, you can see the castle tower in the distance ahead. The pylon is on your left-hand side and when you turn, you see that the tall fir tree is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends thirty-five metres in the direction of the castle tower. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a right-hand turn at 'McDonald's.' The castle tower is now on your left-hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second-hand Book Shop. You turn right at the Book Shop and walk another fifty metres until you come to a Health Food Store. As you walk towards the Health Food Store you pass the large rock in the distance on your left.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back toward the Book Shop. The large rock is now on your right and slightly in front of you. Imagine that you walk the fifty metres back to the Book Shop and turn left. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's' and turn left so that you are now facing towards the Bus Terminus and the castle tower is behind you. Imagine that you walk the thirty-five metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the pylon to your right and the tall fir tree in the distance in front of you.

First perspective, aligned with tree

Imagine that you have travelled to the same area now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking along the path from the Bus Terminus, you can see the tall fir tree in the distance ahead. The pylon is on your right-hand side and when you turn, you see that the castle tower is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends thirty-five metres in the direction of the tall fir tree. As you start walking along this path, you see a sign for 'McDonald's,' which is situated at the first junction. You wlk to the junction and make a right-hand turn at 'McDonald's.' The tall fir tree is now on your left-hand side.

Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second-hand Book Shop. You turn right at the Book Shop and walk another fifty metres until you come to a Health Food Store. As you walk towards the Health Food Store you pass the pylon in the distance on your left.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back towards the Book Shop. The pylon is now on your right and slightly in front of you. Imagine that you walk the fifty metres back to the Book Shop and turn left. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's' and turn left so that you are now facing towards the Bus Terminus and the tall fir tree is behind you. Imagine that you walk the thirty-five metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the large rock to your right and the castle tower in the distance in front of you.

First perspective, aligned with pylon

Imagine that you have travelled to the same area now that the shopping centre has been built. You are standing at a Bus Terminus directly over the spot where the tree stump once stood. Looking along the path from the Bus Terminus, you can see the pylon in the distance ahead. The tall fir tree is on your left-hand side and when you turn, you see that the large rock is in the distance behind you.

Imagine that on leaving the Bus Terminus you walk along the path that extends thirty-five metres in the direction of the pylon. As you start walking along this oath, you see a sign for 'McDonald's,' which is situated at the first junction. You walk to the junction and make a right-hand turn at 'McDonald's.' The pylon is now on your left-hand side. Imagine that you walk a further twenty-five metres to the next junction at which you see a very large second-hand Book Shop. You turn right at the Book Shop and walk another fifty metres until you come to a Health Food Store. As you walk towards the Health Food Store you pass the castle tower in the distance on your left.

Imagine that you are at the Health Food Store, and that you turn 180 degrees to face back toward the Book Shop. The castle tower is now on your right and slightly in front of you. Imagine that you walk the fifty metres back to the Book Shop and turn left. As you round the corner you can see 'McDonald's' twenty-five metres away. Imagine that you walk back along the path to 'McDonald's' and turn left so that you are now facing towards the Bus Terminus and the pylon is behind you. Imagine that you walk the thirty-five metres back to the Bus Terminus. When you reach the Bus Terminus, you can see the tall fir tree to your right and the large rock is in the distance in front of you.

APPENDIX B
Experiment 3: Text-Route Descriptions

Route A

No Landmark

Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. As you start walking along this path you see a sign for 'McDonald's' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's.' Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that you turn 180 degrees to face back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

Landmark "In front"

Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. In the distance, in the same direction is a cathedral spire that towers over the city. As you start walking along your planned path you see a sign for 'McDonald's' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. While you are walking to the Book Shop, the cathedral spire is in the distance to your right. You turn left at the Book Shop so that the cathedral spire is behind you, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food store, and that you turn 180 degrees to face back toward the Book Shop. When you have turned, the cathedral spire is in front of you in the distance. Imagine that you walk the eighty metres back to the Book Shop and turn right. As you round the corner, you can see 'McDonald's' one hundred metres away. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus and the cathedral spire is in the distance behind you. Imagine that you walk the two hundred metres back to the Bus Terminus.

Landmark "Behind"

Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. In the distance, in the opposite direction is a cathedral spire that towers over the city. As you start walking along your planned path you see a sign for 'McDonald's' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. While you are walking to the Book Shop, the cathedral spire is in the distance to your left. You turn left at the Book Shop so that the cathedral spire is in front of you, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food store, and that you turn 180 degrees to face back toward the Book Shop. When you have turned, the cathedral spire is behind you in the distance.

Imagine that you walk the eighty metres back to the Book Shop and turn right. As you round the corner, you can see 'McDonald's' one hundred metres away. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus and the cathedral spire is in the distance in front of you. Imagine that you walk the two hundred metres back to the Bus Terminus.

Route B

No Landmark

Imagine that on leaving the Tube Station you see a path extending one hundred and ten metres in the direction that you plan to walk. As you start walking along this path you see a sign for the Job Centre which is situated at the junction ahead. You walk to the junction and make a right-hand turn at the Job Centre. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. You turn right at the Concert Hall and walk for another two hundred metres to the 'Penny-a-Pint' Pub. Imagine that you are at the Pub and that you turn 180 degrees to face back toward the Concert Hall. Imagine that you walk the two hundred metres back to the Concert Hall and turn left. As you round the corner, you can see the Job Centre one hundred metres ahead. Imagine that you walk back along the path to the Job Centre and turn left so that you re now facing towards the Tube Station. Imagine that you walk the one hundred and ten metres back to the Tube Station.

Landmark "In front"

Imagine that on leaving the Tube Station you see a path extending one hundred and ten metres in the direction that you plan to walk. In the distance, in the same direction is a block of flats that towers over the city. As you start walking along your planned path you see a sign for the Job Centre which is situated at the first junction. You walk to the junction and make a right-hand turn at the Job Centre. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. While you are walking to the Concert Hall, the block of flats is in the distance to your left. You turn right at the Concert Hall so that the block of flats is behind you and walk for another two hundred metres to the 'Penny-a-Pint' Pub. Imagine that you are at the Pub and that you turn 180 degrees to face back towards the Concert Hall. When you have turned, the block of flats is in front of you in the distance. Imagine that you walk the two hundred metres back to the concert Hall and turn left. As you round the corner, you can see the Job Centre one hundred metres away. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing back towards the Tube Station and the block of flats is in the distance behind you. Imagine that you walk the one hundred and ten metres back to the Tube Station.

Landmark "Behind"

Imagine that on leaving the Tube Station you see a path extending one hundred and ten metres in the direction that you plan to walk. In the distance, in the opposite direction is a block of flats that towers over the city. As you start walking along your planned path you see a sign for the Job Centre which is situated at the first junction. You walk to the junction and make a right-hand turn at the Job Centre. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. While you are walking to the Concert hall, the block of flats is in the distance to your right. You turn right at the Concert Hall so that the block of flats is in front of you and walk another two hundred metres to the 'Penny-a-Pint' Pub. Imagine that you are at the Pub and that you turn 180 degrees to face back towards the Concert Hall. When you have turned, the block of flats is behind you in the distance. Imagine that you walk the two hundred metres back to the Concert Hall and turn left. As you round the corner, you can see the Job Centre one hundred metres away. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing back towards the Tube Station and the block of flats is in the distance in front of you. Imagine that you walk the one hundred and ten metres back to the Tube Station.

APPENDIX B
Experiment 4: Text-Route Descriptions

Route A

Landmark "In front"
Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. In the distance, in the same direction is a cathedral spire that towers over the city. As you start walking along your planned path you see a sign for 'McDonald's' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. While you are walking to the Book Shop, the cathedral spire is in the distance to your right. You turn left at the Book Shop so that the cathedral spire is behind you, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food store, and that you turn 180 degrees to face back toward the Book Shop. When you have turned, the cathedral spire is in front of you in the distance. Imagine that you walk the eighty metres back to the Book Shop and turn right. As you round the corner, you can see 'McDonald's' one hundred metres away. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus and the cathedral spire is in the distance behind you. Imagine that you walk the two hundred metres back to the Bus Terminus.

Landmark "Behind"
Imagine that on leaving the Bus Terminus you see a path extending two hundred metres in the direction that you plan to walk. In the distance, in the opposite direction is a cathedral spire that towers over the city. As you start walking along your planned path you see a sign for 'McDonald's' which is situated at the first junction. You walk to the junction and make a left-hand turn at 'McDonald's.' Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. While you are walking to the Book Shop, the cathedral spire is in the distance to your left. You turn left at the Book Shop so that the cathedral spire is in front of you, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food store, and that you turn 180 degrees to face back toward the Book Shop. When you have turned, the cathedral spire is behind

you in the distance. Imagine that you walk the eighty metres back to the Book Shop and turn right. As you round the corner, you can see 'McDonald's' one hundred metres away. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus and the cathedral spire is in the distance in front of you. Imagine that you walk the two hundred metres back to the Bus Terminus.

Route B

Landmark "In front"

Imagine that on leaving the Tube Station you see a path extending one hundred and ten metres in the direction that you plan to walk. In the distance, in the same direction is a block of flats that towers over the city. As you start walking along your planned path you see a sign for the Job Centre which is situated at the first junction. You walk to the junction and make a right-hand turn at the Job Centre. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. While you are walking to the Concert Hall, the block of flats is in the distance to your left. You turn right at the Concert Hall so that the block of flats is behind you and walk for another two hundred metres to the 'Penny-a-Pint' Pub. Imagine that you are at the Pub and that you turn 180 degrees to face back towards the Concert Hall. When you have turned, the block of flats is in front of you in the distance. Imagine that you walk the two hundred metres back to the concert Hall and turn left. As you round the corner, you can see the Job Centre one hundred metres away. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing back towards the Tube Station and the block of flats is in the distance behind you. Imagine that you walk the one hundred and ten metres back to the Tube Station.

Landmark "Behind"

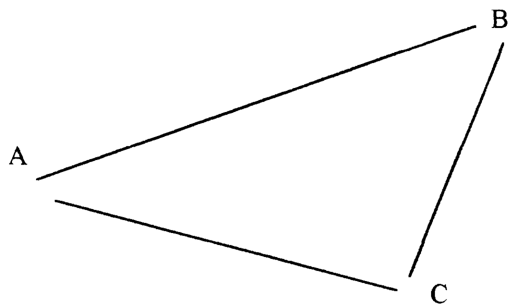
Imagine that on leaving the Tube Station you see a path extending one hundred and ten metres in the direction that you plan to walk. In the distance, in the opposite direction is a block of flats that towers over the city. As you start walking along your planned path you see a sign for the Job Centre which is situated at the first junction. You walk to the junction and make a right-hand turn at the Job Centre. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. While you are walking to the Concert hall, the block of flats is in the distance to your right. You turn right at the Concert Hall so that the block of flats is in front of you and walk another two hundred metres to the 'Penny-a-Pint' Pub. Imagine that you are at the

Pub and that you turn 180 degrees to face back towards the Concert Hall. When you have turned, the block of flats is behind you in the distance. Imagine that you walk the two hundred metres back to the Concert Hall and turn left. As you round the corner, you can see the Job Centre one hundred metres away. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing back towards the Tube Station and the block of flats is in the distance in front of you. Imagine that you walk the one hundred and ten metres back to the Tube Station.

APPENDIX B

Experiment 5: Example route & sample questions

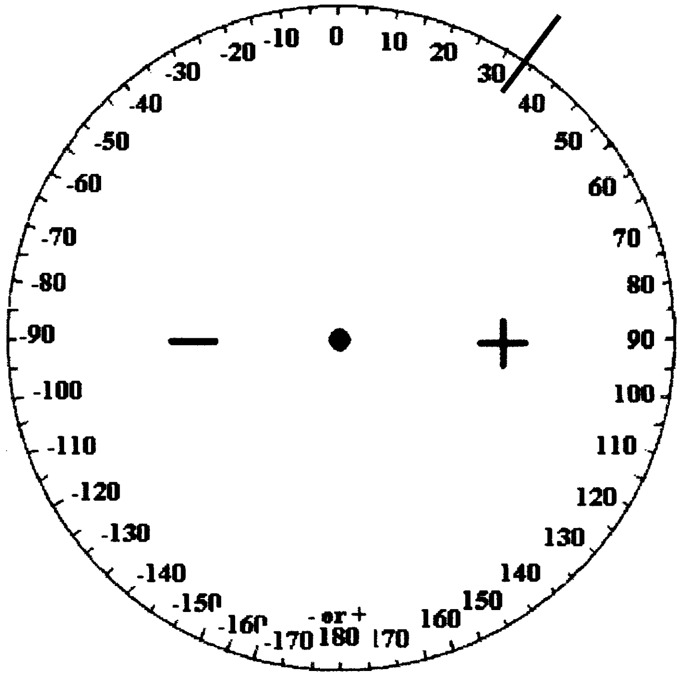
Imaginary Route



You walk this route starting from A. You then walk to B, turn and walk to C, turn and walk back to A. You are asked the following question:

"Imagine that you are at A, and B is in front of you. Use the diagram to indicate the direction of C."

To make the judgement, imagine that A is the centre 'dot' on the dial with 0° pointing the way you are facing. If you are in this position, point C would be at approximately 35° and you would score it on the diagram as in the illustration below.



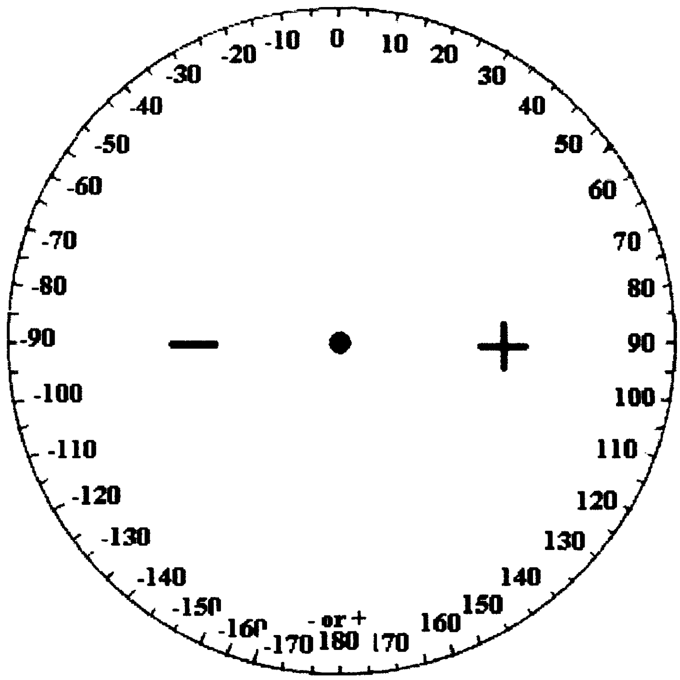
Using the same principle as above, now imagine that you are at B and C is behind you, what would be the direction of A?

Experiment 5: Example alignment test question sheet

P1Gr1N **AGE:** **SEX**

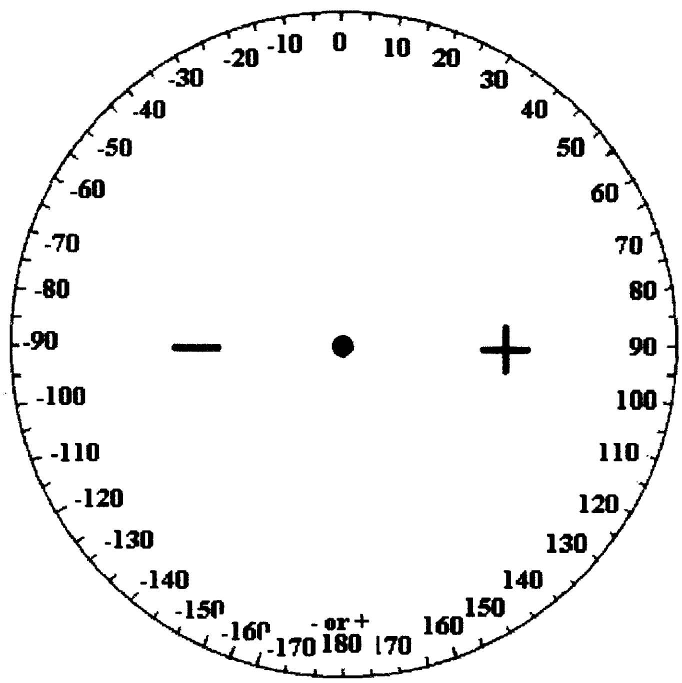
FFA1

Imagine that you are at the Bus Terminus and 'McDonald's' is in front of you; use the diagram to illustrate the direction of the Book Shop.



BFC2

Imagine that you are at the Health Food store and the Book Shop is behind you; use the diagram to illustrate the direction of 'McDonald's.'



Please draw a diagram of your imagined route on the reverse of this sheet *Thank you.*

APPENDIX B
Experiment 5: Text-Route Descriptions

North-facing
Imagine that on leaving the Bus Terminus you see a path extending two hundred metres northwards. As you start walking along this path you see a sign for 'McDonald's,' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face west. Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face south, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that you turn 180 degrees to face north, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right, to face east. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing south towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

South-facing
Imagine that on leaving the Bus Terminus you see a path extending to hundred metres southwards. As you start walking along this path you see a sign for 'McDonald's,' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face east. Image that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face north and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that you turn 180 degrees to face south, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book shop and turn right to face west. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing north towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

East-facing
Imagine that on leaving the Bus Terminus you see a path extending two hundred metres eastwards. As you start walking along this path you see a sign for 'McDonald's which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face north. Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at

the Book Shop to face west, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that you turn 180 degrees to face east, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right, to face south. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing west towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

West-facing

Imagine that on leaving the Bus Terminus you see a path extending two hundred metres westwards. As you start walking along this path you see a sign for 'McDonald's' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face south. Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face east, and walk another eight metres until you come to a Health Food Store. Imagine that you re at the Health Food Store and that you turn 180 degrees to face west, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right, to face north. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing east towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

APPENDIX B
Experiment 6: Text-Route Descriptions

Route A
"Ahead"

Imagine that on leaving the Bus Terminus you see a path extending two hundred metres straight ahead of you. As you start walking along this path you see a sign for 'McDonald's,' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's.' Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that you turn 180 degrees to face back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

North-facing
Imagine that on leaving the Bus Terminus you see a path extending two hundred metres northwards. As you start walking along this path you see a sign for 'McDonald's' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face west. Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face south, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that you turn 180 degrees to face north, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right, to face east. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing south towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

South-facing
Imagine that on leaving the Bus Terminus you see a path extending to hundred metres southwards. As you start walking along this path you see a sign for 'McDonald's' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face east. Image that you walk a further one hundred metres to

the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face north and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that yIou turn 180 degrees to face south, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book shop and turn right to face west. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing north towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

East-facing
Imagine that on leaving the Bus Terminus you see a path extending two hundred metres eastwards. As you start walking along this path you see a sign for 'McDonald's which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face north. Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face west, and walk another eighty metres until you come to a Health Food Store. Imagine that you are at the Health Food Store and that you turn 180 degrees to face east, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right, to face south. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back along the path to 'McDonald's' and turn right so that you are now facing west towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

West-facing
Imagine that on leaving the Bus Terminus you see a path extending two hundred metres westwards. As you start walking along this path you see a sign for 'McDonald's,' which is situated at the junction ahead. You walk to the junction and make a left-hand turn at 'McDonald's' to face south. Imagine that you walk a further one hundred metres to the next junction at which you see a very large second-hand Book Shop. You turn left at the Book Shop to face east, and walk another eight metres until you come to a Health Food Store. Imagine that you re at the Health Food Store and that you turn 180 degrees to face west, back towards the Book Shop. Imagine that you walk the eighty metres back to the Book Shop and turn right, to face north. As you round the corner, you can see 'McDonald's' one hundred metres ahead. Imagine that you walk back

along the path to 'McDonald's' and turn right so that you are now facing east towards the Bus Terminus. Imagine that you walk the two hundred metres back to the Bus Terminus.

Route B

"Ahead"

Imagine that on leaving the Tube Station, you see a path extending one hundred and ten metres straight ahead of you. As you start walking along this path you see a sign for the Job Centre, which is situated at the junction ahead. You walk to the junction and make a right hand turn at the Job Centre. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. You turn right at the Concert Hall and walk for another two hundred metres to the 'Penny-a-Pint Pub. Imagine that you are at the Pub and that you turn 180 degrees to face back towards the Concert Hall. Imagine that you walk the two hundred metres back to the Concert Hall and turn left. As you round the corner, you can see the Job Centre one hundred metres ahead. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing towards the Tube Station. Imagine that you walk the one hundred and ten metres back to the Tube Station.

North-facing

Imagine that on leaving the Tube Station, you see a path extending one hundred and ten metres northwards. As you start walking along this path you see a sign for the Job Centre which is situated at the junction ahead. You walk to the junction and make a right hand turn at the Job Centre to face east. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. You turn right at the Concert Hall to face south and walk for another two hundred metres to the 'Penny-a-Pint Pub. Imagine that you are at the Pub and that you turn 180 degrees to face north, back towards the Concert Hall. Imagine that you walk the two hundred metres back to the Concert Hall and turn left to face west. As you round the corner, you can see the Job Centre one hundred metres ahead. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing south towards the Tube Station. Imagine that you walk the one hundred and ten metres back to the Tube Station.

South-facing
Imagine that on leaving the Tube Station, you see a path extending one hundred and ten metres southwards. As you start walking along this path you see a sign for the Job Centre which is situated at the junction ahead. You walk to the junction and make a right hand turn at the Job Centre to face west. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. You turn right at the Concert Hall to face north and walk for another two hundred metres to the 'Penny-a-Pint Pub. Imagine that you are at the Pub and that you turn 180 degrees to face south, back towards the Concert Hall. Imagine that you walk the two hundred metres back to the Concert Hall and turn left to face east. As you round the corner, you can see the Job Centre one hundred metres ahead. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing north towards the Tube Station. Imagine that you walk the one hundred and ten metres back to the Tube Station.

East-facing
Imagine that on leaving the Tube Station, you see a path extending one hundred and ten metres eastwards. As you start walking along this path you see a sign for the Job Centre which is situated at the junction ahead. You walk to the junction and make a right hand turn at the Job Centre to face south. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. You turn right at the Concert Hall to face west and walk for another two hundred metres to the 'Penny-a-Pint Pub. Imagine that you are at the Pub and that you turn 180 degrees to face east, back towards the Concert Hall. Imagine that you walk the two hundred metres back to the Concert Hall and turn left to face north. As you round the corner, you can see the Job Centre one hundred metres ahead. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing west towards the Tube Station. Imagine that you walk the one hundred and ten metres back to the Tube Station.

West-facing
Imagine that on leaving the Tube Station, you see a path extending one hundred and ten metres westwards. As you start walking along this path you see a sign for the Job Centre which is situated at the junction ahead. You walk to the junction and make a right hand turn at the Job Centre to face north. Imagine that you walk a further one hundred metres to the next junction at which you see a very large Concert Hall. You turn right at the Concert Hall to face east and walk for another two hundred metres to

the ‘Penny-a-Pint Pub. Imagine that you are at the Pub and that you turn 180 degrees to face west, back towards the Concert Hall. Imagine that you walk the two hundred metres back to the Concert Hall and turn left to face south. As you round the corner, you can see the Job Centre one hundred metres ahead. Imagine that you walk back along the path to the Job Centre and turn left so that you are now facing east towards the Tube Station. Imagine that you walk the one hundred and ten metres back to the Tube Station.

APPENDIX B
Experiment 9: Text Route Descriptions

Note: The angles to each target location indicated below (e.g. 90°) did **not** appear on the screen.

Route A

Imagine that on leaving the Bus Terminus you see that the road extends 200 metres straight ahead of you. As you start walking along this path you see a sign for 'McDonald's,' which is situated at the junction ahead. You walk to the junction and turn to your left at 'McDonald's' and see a large second-hand Book Shop at the junction ahead.

No questions condition:

Type 'ok' to continue.

Questions condition:

Standing outside 'McDonald's' you are now looking down the road towards the Book Shop. What direction is the Bus Terminus? (-90°)

Imagine that you walk a further 100 metres to the next junction to the Book Shop. You turn left at the Book Shop and see a Health Food Store further down the road.

No questions condition:

Type 'ok' to continue.

Questions condition:

Standing at the Book Shop, you look down the road towards the Health Food Store. What direction is 'McDonald's?' (-90°)

Standing at the Book Shop, you look down the road towards the Health Food Store. What direction is the Bus Terminus? (-25°)

You walk on another 80 metres to the Health Food Store. Imagine you stop at the Health Food Store, and that you turn 180 degrees to face back towards the Book Shop.

No questions condition:

Type 'ok' to continue.

Questions condition

Standing at the Health Food Store, you are facing the Book Shop. What direction is 'McDonald's?' (50°)

Imagine that you walk the 80 metres back to the Book Shop and turn right. As you round the corner, you can see 'McDonald's' 100 metres ahead.

No questions condition:

Type 'ok' to continue

Questions condition:

Standing at the Book Shop, you look down the road towards 'McDonald's.' What direction is the Bus Terminus? (65°)

Imagine that you walk back along the 100 metre path to 'McDonald's' and turn right so that you are standing at 'McDonald's facing towards the Bus Terminus.

No questions condition:

Type 'ok' to continue

Questions condition:

As you look down the road towards the Bus terminus, what direction is the Book Shop? (90°)

As you look down the road towards the Bus Terminus, what direction is the Health Food Store? (50°)

Imagine that you walk the 200 metres back to the Bus Terminus.

Route B

Imagine that on leaving the Car Park, you see that the road extends 200 metres straight ahead of you. As you start walking along this path you see a sign for the 'Jungle Rap' Night Club, which is situated at the junction ahead. You walk to the junction and turn to your right at the Night Club, and see a Newsagent at the junction ahead.

No questions condition:

Type 'ok' to continue.

Questions condition

Standing outside the Night Club, you are now looking down the road towards the Newsagent. What direction is the Car Park? (90°)

Imagine that you walk a further 100 metres to the next junction to the Newsagent. You turn right at the Newsagent and see a Scrap Yard further down the road.

No questions condition:

Type 'ok' to continue

Questions condition:

Standing at the Newsagent, you look down the road towards the Scrap Yard. What direction is the Night Club? (90°)

Standing at the Newsagent, you look down the road towards the Scrap Yard. What direction is the Car Park? (25°)

You walk on another 140 metres to the Scrap Yard. Imagine that you stop at the Scrap Yard and turn 180 degrees to face back towards the Newsagent.

No questions condition:

Type 'ok' to continue.

Questions condition:

Standing at the Scrap Yard, you are facing the Newsagent. What direction is the Night Club? (-35)

Imagine that you walk the 140 metres back to the Newsagent and turn left. As you round the corner, you can see the Night Club 100 metres ahead.

No questions condition:

Type 'ok' to continue.

Questions condition:

Standing at the Newsagent, you look down the road towards the Night Club. What direction is the Car Park? (-25)

Imagine that you walk back along the 100 metre path to the Night Club and turn left so that you are standing at the Night Club facing towards the Car Park.

No questions condition:

Type 'ok' to continue.

Questions condition:

As you look down the road towards the Car Park, what direction is the Scrap Yard? (-35)

Imagine that you walk the 200 metres back to the Car Park.

APPENDIX B
Experiment 2: Post-Test Questionnaire

1. Which of the following most closely describes your experience while **reading the text?**

Please tick one box

a) Visualised everything through my own eyes from a ground level, as though I was actually walking. ❑

b) Visualised myself walking from a ground level perspective, but imagined this from outside myself ❑

c) Visualised myself walking along the streets as though I was looking from above ❑

d) Visualised just the streets and locations, not myself ❑

e) I was not aware of any internal visual images ❑

2. Which of the following most closely describes your experience while **answering the location to location** questions?

Please tick one box

a) Visualised everything through my own eyes from a ground level, as though I was actually walking. ❑

b) Visualised myself walking from a ground level perspective, but imagined this from outside myself ❑

c) Visualised myself walking along the streets as though I was looking from above ❑

d) Visualised just the streets and locations, not myself ❑

e) I was not aware of any internal visual images ❑

3. Did you find that the external landmarks helped you to make the orientation judgements?

Comments:

APPENDIX B
Experiments 3 & 4: Post-Test Questionnaire

1. Which of the following most closely describes your experience while **reading** the text?

Please tick one box

a) Visualised everything through my own eyes from ground level, as though I was actually walking ❑

b) Visualised myself walking from a ground level perspective, but imagined this from outside myself ❑

c) Visualised myself walking along the streets as though I was looking from above. ❑

d) Visualised just the streets and locations from above, not myself ❑

e) I was not aware of any internal visual images ❑

2. Which of the following most closely describes your experience while **answering the location to location** questions?

a) Visualised everything through my own eyes from ground level, as though I was actually walking ❑

b) Visualised myself walking from a ground level perspective, but imagined this from outside myself ❑

c) Visualised myself walking along the streets as though I was looking from above. ❑

d) Visualised just the streets and locations from above, not myself ❑

e) I was not aware of any internal visual images ❑

Please turn over

3. In the space below, the 'X' represents where you were standing at the start point of the **first/second** *(adjusted according to counterbalanced presentation of routes)* text description that you read.

   (a) Please draw an arrow outwards from the centre of the cross to indicate the direction that you imagined yourself facing as you started your journey.

   (b) Please write the letter 'L' in relation to the cross and the arrow that you have drawn, to indicate where you imagined the landmark that 'towers above the city' to be

X

4. We are interested in the memory processes that people use to carry out this type of task. Please use the space below to note any comments you wish to make about how you carried out the orientation judgements.

Thank you

APPENDIX B
Experiment 6: Post-Test Questionnaire

1. Which of the following most closely describes your experience while **reading the text?**

Please tick one box

a. Visualised everything through my own eyes from a ground level, as though I was actually walking. ❑

b. Visualised myself walking from a ground level perspective, but imagined this from outside myself ❑

c. Visualised myself walking along the streets as though I was looking from above ❑

d. Visualised just the streets and locations, not myself ❑

e. I was not aware of any internal visual images ❑

2. Which of the following most closely describes your experience while **answering the location to location** questions?

Please tick one box

a. Visualised everything through my own eyes from a ground level, as though I was actually walking. ❑

b. Visualised myself walking from a ground level perspective, but imagined this from outside myself ❑

c. Visualised myself walking along the streets as though I was looking from above ❑

d. Visualised just the streets and locations, not myself ❑

e. I was not aware of any internal visual images ❑

APPENDIX C
Experiment 2: Alignment Test Questions

VE:

1. Imagine that you are at the tree stump and that the large rock is in front of you. Point out the direction of the pylon. (180°)
   How far away from you is the pylon? (80m)

2. Imagine that you are at the tree stump and that the large rock is in front of you. Point out the direction of the tall fir tree. (90°)
   How far away from you is the tall fir tree? (80m)

3. Imagine that you are at the castle tower and that the tree stump is in front of you. Point out the direction of the pylon. (45°)
   How far away from you is the pylon? (115m)

4. Imagine that you are at the mid-point between the castle tower and the pylon. You then turn so that the tree stump is in front of you. Point out the direction of the large rock. (-25°)
   How far away from you is the large rock? (140m)

5. Imagine that you are at the tall fir tree and that the pylon is behind you. Point out the direction of the tree stump. (-135°)
   How far away from you is the tree stump? (80m)

TEXT:
Route 1 (Left-hand turns)

Front/Aligned/First
Imagine that you are at the Bus Terminus and that 'McDonald's' is in front of you; point out he direction of the Book Shop. (-25°)
How far away from you is the Book Shop? (55m)

Back/Contra-aligned/Second
Imagine that you are at the Health Food Store and the Book Shop is in front of you; point out the direction of 'McDonald's.' (-130°)
How far away from you is 'McDonald's?' (30m)

Back/Aligned/Second
Imagine that you are at the Book Shop and the Health Food store is behind you; point out the direction of the Bus Terminus. (155°)
How far away from you is the Bus Terminus? (55m)

Front/Contra-aligned/First
Imagine that you are at 'McDonald's' and that the Bus Terminus is in front of you; point out the direction of the Health Food Store. (50°)
How far away from you is the Health Food Store? (30m)

Front/Aligned/Second
Imagine that you are at the Health Food Store and that the Book Shop is in front of you; point out the direction of 'McDonald's.' (50°)
How far away from you is 'McDonald's?' (30m)

Back/Contra-aligned/First
Imagine that you are at the Bus Terminus and that 'McDonald's' is behind you; point out the direction of the Book Shop. (155°)
How far away from you is the Book Shop? (55m)

Back/Aligned/First
Imagine that you are at 'McDonald's' and that the Bus Terminus is behind you; point out the direction of the Health Food Store. (-130°)
How far away from you is the Health Food Store? (30m)

Front/Contra-aligned/Second
Imagine that you are at the Book Shop and that the Health Food Store is in front of you; point out the direction of the Bus Terminus. (-25°)
How far away from you is the Bus Terminus? (55m)

Route 2

Front/Aligned/First
Imagine that you are at the Bus Terminus and that McDonald's is in front of you; point out the direction of the Book Shop. (40°)
How far away from you is the Book Shop? (45m)

Back/Contra-aligned/Second
Imagine that you are at the Health Food Store and that the Book Shop is behind you; point out the direction of McDonald's. (150°)
How far away from you is McDonald's? (55m)

Back/Aligned/Second
Imagine that you are at the Book Shop and that the Health Food Store is behind you; point out the direction of the Bus Terminus. (-135°)
How far away from you is the Bus Terminus? (45m)

Front/Contra-aligned/First
Imagine that you are at McDonald's and that the Bus Terminus is in front of you; point out the direction of the Health Food Store. (-25°)
How far away from you is the Health Food Store? (55m)

Front/Aligned/Second
Imagine that you are at the Health Food Store and that the Book Shop is in front of you; point out the direction of McDonald's. (-25°)
How far away from you is McDonald's? (55m)

Back/Contra-aligned/First
Imagine that you are at the Bus Terminus and that McDonald's is behind you; point out the direction of the Book Shop. (-135°)
How far away from you is the Book Shop? (45m)

Back/Aligned/First
Imagine that you are at McDonald's and that the Bus Terminus is behind you; point out the direction of the Health Food Store. (150°)

How far away from you is the Health Food Store? (55m)

Front/Contra-aligned/Second
Imagine that you are at the Book Shop and that the Health Food Store is in front of you; point out the direction of the Bus Terminus. (40°)
How far away from you is the Bus Terminus? (45m)

APPENDIX C

Experiments 3, 4 & 6: Alignment Test Questions

Route A

Front/Aligned/First
Imagine that you are at the Bus Terminus and that 'McDonald's' is in front of you; point out he direction of the Book Shop. (-25°)
How far away from you is the Book Shop? (225m)

Back/Contra-aligned/Second
Imagine that you are at the Health Food Store and the Book Shop is in front of you; point out the direction of 'McDonald's.' (-130°)
How far away from you is 'McDonald's?' (125m)

Back/Aligned/Second
Imagine that you are at the Book Shop and the Health Food store is behind you; point out the direction of the Bus Terminus. (155°)
How far away from you is the Bus Terminus? (225m)

Front/Contra-aligned/First
Imagine that you are at 'McDonald's' and that the Bus Terminus is in front of you; point out the direction of the Health Food Store. (50°)
How far away from you is the Health Food Store? (125m)

Front/Aligned/Second
Imagine that you are at the Health Food Store and that the Book Shop is in front of you; point out the direction of 'McDonald's.' (50°)
How far away from you is 'McDonald's?' (125m)

Back/Contra-aligned/First
Imagine that you are at the Bus Terminus and that 'McDonald's' is behind you; point out the direction of the Book Shop. (155°)
How far away from you is the Book Shop? (225m)

Back/Aligned/First
Imagine that you are at 'McDonald's' and that the Bus Terminus is behind you; point out the direction of the Health Food Store. (-130°)
How far away from you is the Health Food Store? (125m)

Front/Contra-aligned/Second
Imagine that you are at the Book Shop and that the Health Food Store is in front of you; point out the direction of the Bus Terminus. (-25°)
How far away from you is the Bus Terminus? (225m)

Route B

Front/Aligned/First
Imagine that you are at the Tube Station and that the Job Centre is in front of you; point out the direction of the Concert Hall. (40°)
How far away from you is the Concert Hall? (150m)

Back/Contra-aligned/Second
Imagine that you are at the Pub and that the Concert Hall is behind you; point out the direction of the Job Centre. (150°)
How far away from you is the Job Centre? (225m)

Back/Aligned/Second
Imagine that you are at the Concert Hall and that the Pub is behind you; point out the direction of the Tube Station. (-135°)
How far away from you is the Tube Station? (150m)

Front/Contra-aligned/First
Imagine that you are at the Job Centre and that the Tube Station is in front of you; point out the direction of the Pub. (-25°)
How far away from you is the Pub? (225m)

Front/Aligned/Second
Imagine that you are at the Pub and that the Concert Hall is in front of you; point out the direction of the Job Centre. (-25°)
How far away from you is the Job Centre? (225m)

Back/Contra-aligned/First
Imagine that you are at the Tube Station and that the Job Centre is behind you; point out the direction of the Concert Hall. (-135°)
How far away from you is the Concert Hall? (150m)

Back/Aligned/First
Imagine that you are at the Job Centre and that the Tube Station is behind you; point out the direction of the Pub. (150°)
How far away from you is the Pub? (225m)

Front/Contra-aligned/Second
Imagine that you are at the Concert Hall and that the Pub is in front of you; point out the direction of the Tube Station. (40°)
How far away from you is the Tube Station? (150m)

APPENDIX C

Experiment 5: Alignment Test Questions

Front/Aligned/First
Imagine that you are at the Bus Terminus and that 'McDonald's' is in front of you; move the pointer of the Book Shop. (-25°)

Back/Contra-aligned/Second
Imagine that you are at the Health Food Store and the Book Shop is in front of you; score a line through the outer edge of the dial diagram to illustrate the direction of 'McDonald's.' (-130°)

Back/Aligned/Second
Imagine that you are at the Book Shop and the Health Food store is behind you; score a line through the outer edge of the dial diagram to illustrate the direction of the Bus Terminus. (155°)

Front/Contra-aligned/First
Imagine that you are at 'McDonald's' and that the Bus Terminus is in front of you; score a line through the outer edge of the dial diagram to illustrate the direction of the Health Food Store. (50°)

Front/Aligned/Second
Imagine that you are at the Health Food Store and that the Book Shop is in front of you; score a line through the outer edge of the dial diagram to illustrate the direction of 'McDonald's.' (50°)

Back/Contra-aligned/First
Imagine that you are at the Bus Terminus and that 'McDonald's' is behind you; score a line through the outer edge of the dial diagram to illustrate the direction of the Book Shop. (155°)

Back/Aligned/First
Imagine that you are at 'McDonald's' and that the Bus Terminus is behind you; score a line through the outer edge of the dial diagram to illustrate the direction of the Health Food Store. (-130°)

Front/Contra-aligned/Second
Imagine that you are at the Book Shop and that the Health Food Store is in front of you; score a line through the outer edge of the dial diagram to illustrate the direction of the Bus Terminus. (-25°)

APPENDIX C

Experiments 7 & 8: Alignment Text Questions

Environment 1

Front/Left/Aligned
Imagine that you are at the red car and the bank is in front of you. Point out the direction of the post box. (-40°)
How far away from you is the post box? (155m)

Front/Right/Aligned
Imagine that you are at the post box and the bar is in front of you. Point out the direction of the bank. (50°)
How far away from you is the bank? (130m)

Front/Left/Right-Misaligned
Imagine that you are at the post box and the bar is 90° to your left. Point out the direction of the bank. (-40°)
How far away from you is the bank? (130m)

Front/Right/Right-Misaligned
Imagine that you are at the post box and the bar is 90° to your left. Point out the direction of the red car. (50°)
How far away from you is the red car? (155m)

Front/Left/Left-Misaligned
Imagine that you are at the bank and the bar is in front of you. Point out the direction of the post box. (-40°)
How far away from you is the post box? (130m)

Front/Right/Left-Misaligned
Imagine that you are at the red car and the bank is 90° to your right. Point out the direction of the bar. (65°)
How far away from you is the bar? (225m)

Front/Left/Contra-aligned
Imagine that you are at the bar and the post box is in front of you. Point out the direction of the red car. (-25°)
How far away from you is the red car? (225m)

Front/Right/Contra-aligned
Imagine that you are at the bank and the red car is in front of you. Point out the direction of the post box. (50°)
How far away from you is the post box? (130m)

Back/Left/Aligned
Imagine that you are at the bank and the bar is 90° to your left. Point out the direction of the post box. (-130°)

How far away from you is the post box? (130m)

Back/Right/Aligned
Imagine that you are at the bar and the post box is behind you. Point out the direction of the red car. (155°)
How far away from you is the red car? (225m)

Back/Left/Right-Misaligned
Imagine that you are at the red car and the bank is 90° to your left. Point out the direction of the bar. (-115).
How far away from you is the bar? (225m)

Back/Right/Right-Misaligned
Imagine that you are at the bank and the bar is behind you. Point out the direction of the post box. (140°)
How far away from you is the post box? (130m)

Back/Left/Left-Misaligned
Imagine that you are at the post box and the bar is 90° to your right. Point out thd direction of the red car. (-130°)
How far away from you is the red car? (155m)

Back/Right/Left-Misaligned
Imagine that you are at the post box and the bar is 90° to your right. Point out the direction of the bank. (140°)
How far away from you is the bank? (130m)

Back/Left/Contra-aligned
Imagine that you are at the post box and the bar is behind you. Point out the direction of the bank. (-130°)
How far away from you is the bank? (130m)

Back/Right/Contra-aligned
Imagine that you are at the red car and the bank is behind you. Point out the direction of the post box. (140°)
How far away from you is the post box? (155m)

Environment 2
Front/Left/Aligned
Imagine that you are at the land rover and the van is in front of you. Point out the direction of the tank. (-25°)
How far away from you is the tank? (225m)

Front/Right/Aligned
Imagine that you are at the telephone box and the tank is in front of you. Point out the direction of the van. (35°)
How far away from you is the van? (170m)

Front/Left/Right-Misaligned
Imagine that you are at the telephone box and the tank is 90° to your left. Point out the direction of the van. (-55°)
How far away from you is the van? (170m)

Front/Right/Right-Misaligned
Imagine that you are at the tank and the van is in front of you. Point out the direction of the land rover. (65°)
How far away from you is the land rover? (225m)

Front/Left/Left-Misaligned
Imagine that you are at the van and the tank is in front of you. Point out the direction of the telephone box. (-55°)
How far away from you is the telephone box? (170m)

Front/Right/Left-Misaligned
Imagine that you are at the land rover and the van is 90° to your right. Point out the direction of the tank. (65°)
How far away from you is the tank? (115m)

Front/Left/Contra-aligned
Imagine that you are at the tank and the telephone box is in front of you. Point out the direction of the land rover. (-25°)
How far away from you is the land rover? (225m)

Front/Right/Contra-aligned
Imagine that you are at the van and the land rover is in front of you. Point out the direction of the telephone box. (35°)
How far away from you is the telephone box? (170m)

Back/Left/Aligned
Imagine that you are at the van and the land rover is behind you. Point out the direction of the telephone box. (-145°)
How far away from you is the telephone box? (170m)

Back/Right/Aligned
Imagine that you are at the tank and the telephone box is behind you. Point out the direction of the land rover. (155°)
How far away from you is the land rover? (225m)

Back/Left/Right-Misaligned
Imagine that you are at the land rover and the van is 90° to your left. Point out the direction of the telephone box. (-150°)
How far away from you is the telephone box? (170m)

Back/Right/Right-Misaligned
Imagine that you are at the van and the tank is behind you. Point out the direction of the telephone box. (125°)
How far away from you is the telephone box? (170m)

Back/Left/Left-Misaligned
Imagine that you are at the telephone box and the tank is 90° to your right. Point out the direction of the land rover. (-150°)
How far away from you is the land rover? (115m)

Back/Right/Left-Misaligned
Imagine that you are at the telephone box and the tank is 90° to your right. Point out the direction of the van. (125°)
How far away from you is the van? (170m)

Back/Left/Contra-aligned
Imagine that you are at the telephone box and the tank is behind you. Point out the direction of the van. (-145°)
How far away from you is the van? (170m)

Back/Right/Contra-aligned
Imagine that you are at the land rover and the van is behind you. Point out the direction of the telephone box. (120°)
How far away from you is the telephone box? (115m)

APPENDIX C
Experiment 9: Alignment Test Questions

Route A
First aligned: Imagine that you are standing at 'McDonald's' and the Bus Terminus is behind you. Enter the number that indicates the direction of the Health Food Store (-130°).

Contra-aligned: Imagine that you are standing at the Health Food Store and the Book Shop is behind you. Enter the number that indicates the direction of 'McDonald's.' (-130°)

Left-misaligned: Imagine that you are standing at the Book Shop and 'McDonald's' is behind you. Enter the number that indicates the direction of the Bus Terminus. (-115°)

Right-misaligned: Imagine that you are standing at 'McDonald's' and the Book Shop is behind you. Enter the number that indicates the direction of the Health Food Store. (140°)

Route B
First aligned: Imagine that you are standing at the Scrap Yard and facing you is the Newsagent. Enter the number that indicates the direction of the Car Park. (-120°)

Contra-aligned: Imagine that you are standing at the Car Park and the Night Club is behind you. Enter the number that indicates the direction of the Newsagent. (-155°)

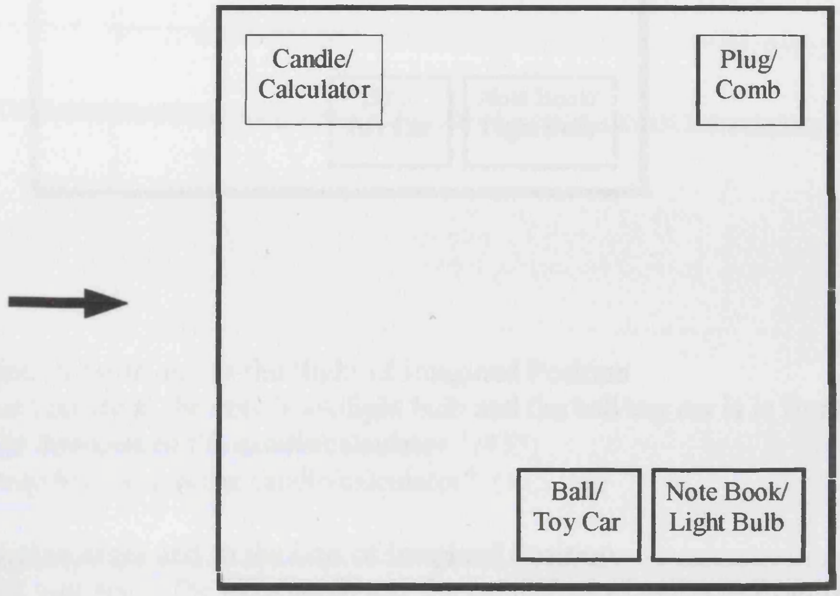
Left-misaligned
Imagine that you are standing at the Night Club and the Newsagent is behind you. Enter the number that indicates the direction of the Scrap Yard. (-125°)

Right-misaligned
Imagine that you are standing at the Newsagent and the Night Club is behind you. Enter the number that indicates the direction of the Car Park. (115°)

APPENDIX C

Experiments 10 – 14: Alignment Test Questions

Note: The alignment test questions used in Experiments 10 - 14 were dependent on the viewing perspectives from which participants experienced the array, and the counterbalancing requirements of each experiment. Questions were selected from the lists on the following pages. In each case, the black arrow in the diagrams represents the perspective on the arrays from which the questions were derived, and does not reflect the positions of the viewing windows in the apparatus.

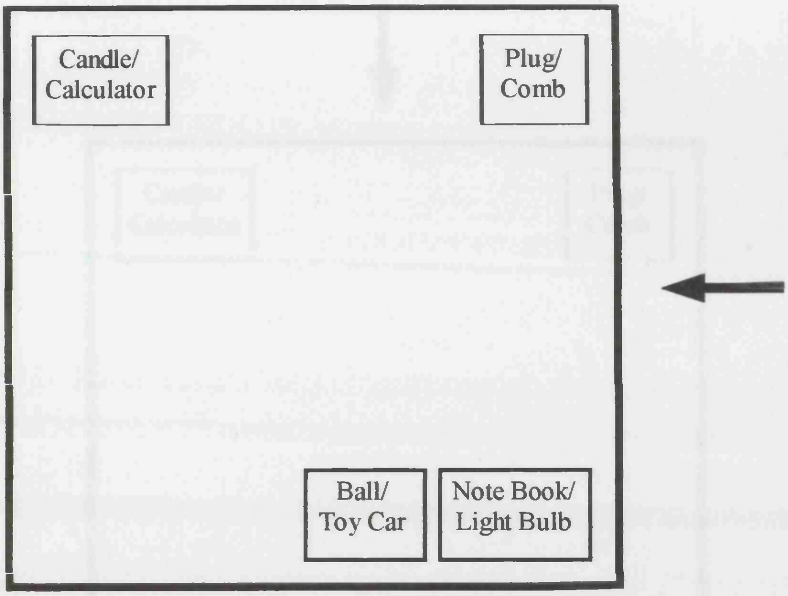


Target Object in Front and to the Right of Imagined Position
Imagine that you are at the candle/calculator and the plug/comb is in front of you; point out the direction of the note book/light bulb (45°)
How far away from you is the note book/light bulb? (115 cm)

Target Object in Front and to the Left of Imagined Position
Imagine that you are at the ball/toy car and the note book/light bulb is in front of you; point out the direction of the plug/comb. (-80°)
How far away from you is the comb/plug? (80 cm)

Target Object Behind and to the Right of Imagined Position
Imagine that you are at the plug/comb and the candle/calculator is behind you; point out the direction of the ball/toy car. (100°)
How far away from you is the ball/toy car? (80 cm)

Target Object Behind and to the Left of Imagined Position
Imagine that you are at the note book/light bulb and the ball/toy car is behind you; point out the direction of the candle/calculator. (-135)
How far away from you is the candle/calculator? (115 cm)

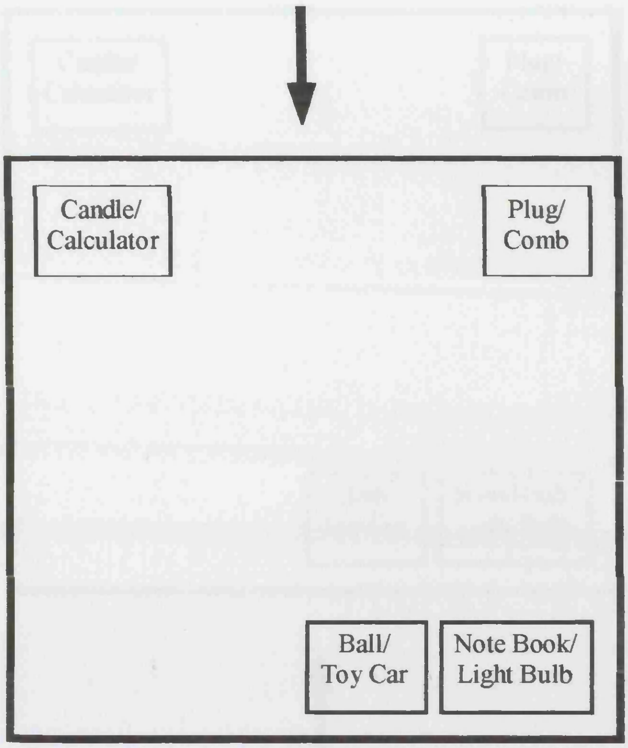


Target Object in Front and to the Right of Imagined Position
Imagine that you are at the note book/light bulb and the ball/toy car is in front of you; point out the direction of the candle/calculator. (45°)
How far away from you is the candle/calculator? (115 cm)

Target Object in Front and to the Left of Imagined Position
Imagine that you are at the plug/comb and the candle/calculator is in front of you; point out the direction of the ball/toy car. (-80°)
How far away from you is the ball/toy car? (80 cm)

Target Object Behind and to the Right of Imagined Position
Imagine that you are at the ball/toy car and the note book/light bulb is behind you; point out the direction of the plug/comb. (100°)
How far away from you is the plug/comb? (80 cm)

Target Object Behind and to the Left of Imagined Position
Imagine that you are at the candle/calculator and the plug/comb is behind you; point out the direction of the note book/light bulb. (-135°)
How far away from you is the note book/light bulb? (115 cm)

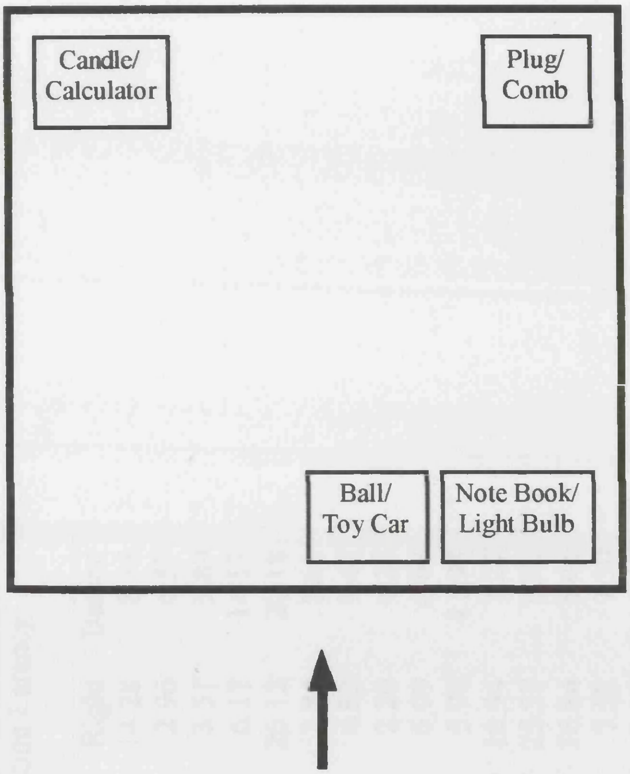


Target Object in Front and to the Right of Imagined Position
Imagine that you are at the plug/comb and the note book/light bulb is in front of you; point out the direction of the ball/toy car. (10°)
How far away from you is the ball/toy car? (80 cm)

Target Object in Front and to the Left of Imagined Position
Imagine that you are at the candle/calculator and the plug/comb is 90° to your left; point out the direction of the note book/light bulb. (-45°)
How far away from you is the note book/light bulb? (115 cm)

Target Object Behind and to the Right of Imagined Position
Imagine that you are at the note book/light bulb, and the plug/comb is behind you; point out the direction of the candle/calculator. (135°)
How far away from you is the candle/calculator? (115 cm)

Target Object Behind and to the Left of Imagined Position
Imagine that you are at the ball/toy car and the note book/light bulb is 90° to your left; point out the direction of the plug/comb. (-170°)
How far away from you is the comb/plug? (80 cm)



Target Object in Front and to the Right of Imagined Position
Imagine that you are at the ball/toy car and the note book/light bulb is 90° to your right; point out the direction of the plug/comb. (10°)
How far away from you is the comb/plug? (80 cm)

Target Object in Front and to the Left of Imagined Position
Imagine that you are at the note book/light bulb and the plug/comb is in front of you; point out the direction of the candle/calculator. (-45°)
How far away from you is the candle/calculator? (115 cm)

Target Object Behind and to the Right of Imagined Position
Imagine that you are at the candle/calculator and the plug/comb is 90° to your right; point out the direction of the note book/light bulb. (135°)
How far away from you is the note book/light bulb? (115 cm)

Target Object Behind and to the Left of Imagined Position
Imagine that you are at the plug/comb and the note book/light bulb is behind you; point out the direction of the ball/toy car. (-170°)
How far away from you is the ball/toy car? (80 cm)

Experiment 2: Table 1: Raw Absolute Orientation Error & Latency Scores (VE)

Absolute Error Scores for Orientation Judgements (tabled in degrees) to Targets that were to the Left, Right and Behind Participants' Imagined Facing Direction within the VE at Test. and the Times (tabled in seconds) taken to make these Judgements.

Orientation Error			Orientation Latency		
Left	Right	Behind	Left	Right	Behind
100	67.5	0	6.80	14.28	8.74
52.5	112.5	0	10.85	2.96	6.57
100	67.5	0	8.28	3.51	5.89
32.5	67.5	90	19.02	6.17	14.13
30	67.5	90	12.89	26.12	20.18
80	22.5	0	9.20	3.84	5.68
100	112.5	90	17.22	4.83	9.49
45	92.5	0	7.12	2.20	4.25
37.5	112.5	90	7.39	6.09	6.08
70	22.5	0	16.50	5.94	11.93
80	67.5	0	9.10	10.94	1.27
80	7.5	0	21.57	25.37	8.95
80	157.5	0	8.01	16.84	5.45
80	67.5	0	19.44	7.57	7.30
27.5	2.5	0	3.39	2.85	1.67
30	22.5	0	7.27	12.80	3.37
25	67.5	0	14.46	13.11	2.16
100	67.5	0	12.40	5.91	2.60
20	112.5	0	14.22	4.31	9.14
30	22.5	0	2.24	1.71	2.33

Experiment 2: Table 2: Raw Absolute Orientation Error & Latency Scores Text

Absolute Error Scores for Orientation Judgements (tabled in degrees) to Targets that were Aligned and 180° Contra-aligned with the First Part of the Route and the Times (tabled in seconds) taken to make these Judgements.

Orientation Error								**Orientation Latency**							
Front				Back				Front				Back			
FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2	FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2
10	0	5	15	5	5	10	60	1.93	2.64	3.8	1.85	2.55	1.69	4.16	6.55
5	20	20	10	10	15	5	5	1.96	4.06	2.13	4.51	1.66	2.5	3.17	6.99
65	40	5	155	25	35	75	95	6.54	3.26	22.41	9.96	3.49	7.86	5.21	8.39
75	15	35	95	140	105	45	0	18.76	13.3	24.61	21.49	26.3	3.89	16.55	25.89
10	95	5	115	10	115	175	175	18.11	5.7	27.3	34.96	26.77	16.07	50.63	30.68
10	10	70	145	0	90	150	80	3.57	4.76	10.21	5.23	3.53	9.62	7.75	6.63
40	5	5	30	25	5	100	85	7.53	1.4	13.89	13.72	3.95	9.93	7.86	13.87
15	20	40	0	15	5	60	5	1.43	1.97	4.75	8.44	3.09	2.93	6.97	4.66
15	25	30	0	0	0	20	10	3.53	5.47	9.4	2.93	2.03	3.04	6.1	4.69
65	20	95	70	80	95	120	80	11.01	6.06	7.03	5.72	17.76	10.07	16.73	17.61
25	5	130	155	95	155	5	85	5.08	4.91	4.55	7.53	7.62	10.87	11.59	6.88
15	15	20	0	5	5	175	5	6.95	12.07	5.18	29.81	16.63	17.98	24.17	16.66
30	25	160	155	130	60	125	140	6.58	4.47	9.54	6.95	4.73	16.84	5.36	3.65
10	15	165	105	25	70	65	180	9.56	8.31	16.89	14.63	23.97	5.23	10.46	6.87
25	5	5	20	5	25	30	5	1.48	1.81	6.26	2.67	3.42	3.73	9.29	14
0	15	0	10	0	10	100	20	4.22	6.93	4.46	4.13	4.44	1.81	11	7.69
15	10	160	170	5	5	10	180	4.29	1.89	5.35	4.24	3.33	2.73	13.92	3.16
5	15	25	50	30	15	85	160	1.37	1.09	6.19	2.38	7.45	2.09	6.47	3.53
170	110	65	40	60	45	55	20	44.73	18.86	26.34	18.02	20.75	20.79	4.59	12.55
10	10	15	15	5	15	20	15	2.43	3.07	1.47	2.72	3	2.28	3.5	2.98

APPENDIX D

Experiment 3: Table 3: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) for Aligned and 180° Contra-aligned Orientation Judgements under the 'Landmark' and 'No Landmark' Conditions. (Landmark Described as 'beyond' the First Section of the Route for Ps. 1, 3, 5, 7, 9, etc., and 'behind' for Ps. 2, 4, 6, 8 etc...)

No Landmark								Landmark							
Front				Back				Front				Back			
FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2	FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2
50	45	85	130	120	0	15	60	65	140	130	155	70	60	60	75
50	75	105	135	5	45	45	160	60	100	80	70	125	65	30	40
0	5	75	25	0	5	30	5	5	20	15	5	5	0	0	95
20	0	0	20	15	20	20	5	10	20	25	5	25	15	75	10
50	50	15	170	20	25	25	65	20	35	50	125	25	15	100	95
0	30	120	95	5	10	90	65	115	105	40	115	100	70	65	95
5	20	100	5	10	5	5	5	5	20	0	15	10	5	10	165
70	40	5	155	0	25	60	130	55	25	155	130	155	40	135	115
0	65	165	170	25	20	165	175	40	5	0	165	10	10	5	10
0	25	25	0	5	0	175	0	15	0	0	15	10	0	0	20
20	5	170	170	45	15	165	110	5	25	170	165	10	10	180	165
15	5	40	120	40	5	100	100	5	20	20	110	105	10	90	65
10	165	65	15	5	170	0	20	20	5	5	15	110	25	20	0
40	30	95	5	60	5	20	10	25	5	10	25	5	30	30	5
65	140	180	170	50	5	125	145	50	65	130	115	0	40	45	40
60	40	180	155	15	20	150	130	50	65	155	140	20	5	165	170
0	20	20	5	5	5	85	10	15	5	10	20	5	50	35	0
10	25	35	10	15	180	70	20	20	40	40	15	15	20	10	35
20	0	80	90	10	20	15	75	35	40	95	75	45	5	165	65
10	5	0	165	10	20	25	175	0	25	20	115	40	10	15	25
140	65	65	50	30	45	120	60	65	40	140	65	40	25	25	35
5	20	20	5	30	10	85	45	20	15	175	25	5	45	20	5
115	140	40	110	50	20	115	50	50	65	155	50	30	135	135	120
30	10	35	25	110	5	25	10	5	30	45	35	70	5	130	15
85	65	155	165	20	45	60	10	100	90	180	155	140	75	75	140
50	165	175	165	155	50	85	0	115	25	155	115	10	60	5	180
25	5	150	20	20	20	25	20	5	25	25	5	20	5	15	20
65	140	140	155	40	65	65	140	170	155	65	50	60	45	135	120
20	25	75	0	45	5	5	60	35	5	10	25	140	30	80	170
50	65	155	50	120	50	45	120	65	40	140	115	40	115	65	50
110	140	40	155	80	65	60	140	10	55	155	135	60	0	55	165
15	10	105	20	5	5	75	10	5	15	20	50	10	5	5	70

APPENDIX D

Experiment 3: Table 4: Raw Orientation Latency Scores

Latency scores (tabled in seconds) for Aligned and 180° Contra-aligned Orientation Judgements under the 'Landmark' and 'No Landmark' Conditions. (Landmark Described as 'beyond' the First Section of the Route for Ps. 1, 3, 5, 7, 9, etc., and 'behind' for Ps. 2, 4, 6, 8 etc...)

'No Landmark'								'Landmark'							
Front				Back				Front				Back			
FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2	FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2
15.77	8.74	6.84	11.57	9.37	4.84	12.55	11.5	6.99	25.54	36.91	5.25	31.93	33.88	4.7	7.29
30.62	6.4	5.63	13.03	8.97	16.3	13.31	32.59	2.34	5.5	85.7	28.48	3.01	2.73	23.77	31.42
15.97	16.77	17.25	16.14	16.09	12.07	21.49	19.89	15.04	9.19	13.27	12.33	9.52	13.85	13.3	9.79
4.6	2.02	5.89	9.59	14.36	11.65	6.73	4.25	3.07	3.68	14.75	18.96	19.26	10.2	19.58	15.33
10.62	6.92	24.81	28.09	20.54	38.43	175.1	21.89	11.75	6.68	14.75	2.05	6.23	34.49	10.05	9.29
3.87	3.17	4.5	7.38	3.73	6.68	4.9	6.84	3.74	2.15	4.9	2.94	1.73	3.37	4.39	6.2
2.13	2.06	10.73	5.68	8.24	2.12	18.93	16.88	2.63	4.55	6.17	9.49	7.43	7.96	9.01	13.22
3.14	3.07	4.13	3.82	4.5	3.68	3.59	4.81	3.54	5.71	9	6.69	4.89	5.59	4.99	4.85
4.57	5.27	2.96	3.49	30.08	11.97	34.04	3.71	8.18	5.83	5.44	4.55	2.54	2.97	4.88	22.17
4.03	6.72	9.23	8.14	9.08	8.67	3.48	2.98	4.1	4.81	3.07	5.84	2.76	7.36	11.07	4.99
2.55	4.83	5.63	11.76	2.55	10.38	9.25	9.29	5.91	6.72	7.68	13.67	10.27	17.51	5.48	5.27
2.47	4.4	3.96	8.09	1.56	3.84	12.93	15.49	2.44	10.31	8.93	2.9	6.03	2.09	2.52	1
25.57	36.87	13.37	7.82	28.89	21.74	17.37	29.59	13.12	27.97	13.47	16.29	20.68	16.83	19.89	30.31
40.73	36.66	96.67	13.19	44.51	17.97	72.13	24.23	6.08	4.07	9.13	7.98	15.19	9.84	10.94	5.33
6.25	7.52	6.86	12.75	11.52	11.25	10.11	11.48	4.23	9.77	20.94	14.03	16.56	12.45	12.93	11.91
2.67	2.52	7.73	3.37	3.57	14.36	4.76	6.18	2.27	3.65	4.44	3.56	3.68	2.87	13.78	8.89
2.1	6.65	5.2	2.54	2.66	2.11	4.9	8.73	3.83	4.89	5.42	6.76	4.02	8.76	6.99	9.32
2.76	3.06	7.77	3.29	5.49	5.37	4.09	5.08	6.68	4.03	29.69	4.3	10.54	4	6.6	5.91
3.74	3.64	3.97	3.27	3.47	2.36	4.59	14.34	3.16	2.47	24.34	5.49	5.03	2.55	4.84	7.83
3.8	2.61	4.89	7.9	4.48	4.82	20.17	4.78	4.83	3.52	7.47	22.32	6.35	8.73	20.45	20.01
37.46	4.49	3.15	7.33	5.34	5.27	9.78	9.9	3.74	5.18	23.18	7.85	3.11	14.98	20.92	7.08
3.48	3.09	14.29	11.83	1.3	4.77	4.08	20.75	2.42	7.17	15.29	14.66	5.09	21.05	13.9	12.72
6.27	3.67	2.95	6.7	5.75	12.49	6.07	25.39	3.77	7.32	6.98	19.42	3.57	11.52	13.33	4.72
2.69	3.06	4.43	3.77	3.82	7.12	13.71	2.77	4.67	55.63	5.21	6.63	5.81	2.91	11.69	4.99
5.43	6.97	7.42	4.14	2.82	15.73	1.84	4.59	6.23	7.5	3.97	4.92	7.41	5.59	4.97	3.29
6.19	6.42	10.41	12.77	15.68	4.33	23.21	3.76	9.56	7.97	6.03	7.61	6.12	10.49	3.28	6.09
6.69	14.33	21.89	18.63	13.57	31.75	38.56	46.98	11.27	6.65	14.55	13.88	9.52	4.71	15.13	17.86
10.38	5.23	12.7	8.68	7.33	4.45	9.12	6.25	4.62	8.03	5.19	6.59	5.97	11.03	9.88	6.58
4.24	4.76	12.65	5.63	12.28	3.9	4.19	2.83	7.18	5.05	2.67	3.27	21.54	5.15	4.57	3.36
14.19	20.56	35.66	22.39	1.87	42.33	21.92	11.17	21.09	28.69	9.39	7.31	32.12	20.87	24.47	30.13
5.81	11.31	11.33	14.02	11.93	16.07	6.59	12.45	5.93	7.18	11.16	9.03	2.32	8.88	10.06	7.3
3.43	5.76	3.87	3.33	3.31	9.67	3.18	5.89	2.87	3.13	3.31	7.59	3.63	6.21	3.86	6.7

Experiment 4: Table 5: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) for Aligned and 180° Contra-aligned orientation Judgements under the single 'Landmark' Condition. (Landmark Described as 'beyond' the First Section of the Route for Ps. 1, 3, 5, 9, etc., and 'behind' for Ps. 2, 4, 6, 8 etc...)

Orientation Error							
Front				Back			
FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2
5	5	5	0	10	5	10	20
15	5	20	15	10	5	15	0
15	5	20	20	10	15	25	20
65	5	115	165	40	5	75	175
5	5	0	5	5	5	10	5
55	70	120	130	55	45	130	120
0	35	60	90	105	90	90	120
70	35	165	140	65	10	80	80
65	5	160	115	60	125	95	175
20	10	110	155	10	15	20	175
20	0	10	15	25	5	10	10
20	5	0	20	85	10	10	10
10	20	20	25	10	15	50	25
15	15	165	0	10	15	160	15
5	20	15	5	20	5	5	20
10	10	15	80	10	15	15	5
30	5	175	20	5	5	10	10
25	5	5	25	5	10	20	5
30	5	0	30	0	20	35	0
30	5	15	25	90	20	15	170
0	30	115	135	0	0	0	5
25	35	15	15	20	5	20	15
0	30	30	170	15	5	0	25
0	15	20	5	75	10	85	10
35	5	0	30	55	20	40	10
20	5	5	20	5	10	20	0
25	0	5	105	10	25	160	100
20	5	0	15	0	15	15	5
25	0	115	120	50	90	10	25
0	25	160	175	10	0	180	160
10	20	20	5	10	0	90	10
115	15	15	0	60	95	0	75

APPENDIX D

Experiment 4: Table 6: Raw Orientation Latency Scores

Latency Scores (tabled in seconds), for Aligned and 180° Contra-aligned orientation Judgements under the single 'Landmark' Condition.
(Landmark Described as 'beyond' the First Section of the Route for Ps. 1, 3, 5, 9, etc., and 'behind' for Ps. 2, 4, 6, 8 etc...)

Orientation Latency

Front				Back			
FA1	FA2	FC1	FC2	BA1	BA2	BC1	BC2
6.42	3.89	9.91	4.15	11.69	7.53	6.05	5.5
4.21	4.36	2.82	4.2	4.63	6.83	6.66	12.99
7.16	10.72	36.97	23.24	12.69	2.92	14.69	22.71
6.46	2.87	7.32	4.64	5.73	9.96	3.13	3.09
1.93	4.68	4.2	4.27	6.04	3.07	6.93	9.36
24.6	2.22	1.85	2.33	5.85	10.74	2.97	4.3
3.53	13.08	10.03	24.46	5.01	12.53	10.17	9.54
15.5	8.25	9.43	8.33	8.14	8.1	5.13	8.1
7.45	6.69	4.99	5.41	10.6	20.47	3.13	4.12
4.91	14.89	54.94	20.85	11.86	3.73	47.72	6.44
4.39	2.01	14.1	2.43	3.96	2.69	13.38	4.69
10.3	2.5	5.21	19.27	24.83	11.61	13.35	9.29
3.39	3.66	3.21	13.19	5.47	3.26	4.26	4.22
4.67	4.57	7.53	7.99	6.63	13.49	11.53	10.58
3.07	7.86	5.25	11.83	2.07	1.53	14.95	2.5
2.59	2.29	5.22	3.58	4.29	8.71	6.78	8.12
5.45	3.49	7.73	7.83	7.28	10.66	12.34	8.64
4.85	2.07	11.17	2.46	3.25	1.77	11.31	3.04
4.99	3.53	2.47	1.87	3.97	3.33	7.87	2.53
3.21	4.63	6.21	5.83	1.91	2.42	6.01	2.99
4.92	4.33	3.49	16.79	5.57	10.62	35.46	20.97
7.25	3.16	6.45	5.33	3.07	4.29	5.1	6.91
3.61	2.17	10.24	11.29	3.59	3.63	16.06	18.25
2.21	8.17	5.73	6.68	17.93	3.03	18.57	1.56
11.97	2.72	15.3	11.29	12.2	3.9	13.08	4.08
2.19	1.53	3.23	1.62	1.76	2.11	2.94	1.75
26.17	35.57	42.33	41.77	15.11	34.24	17.98	74.72
12.22	7.5	25.11	11.08	12.87	5.66	17.69	9.11
8.28	19.41	14.99	13.47	24.17	10.94	18.03	5.83
3.2	3.07	8.27	3.44	9.9	4.61	8.7	3.99
16.83	4.29	11.85	7.5	2.19	2.14	22.12	2.18
11.3	14.62	7.56	13.27	27.75	6.27	6.72	10.51

Experiment 5: Table 7: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) for Aligned and 180° Contra-aligned Orientation Judgements for Groups North, South, East and West. (Scores averaged across front and back judgements).

Orientation Error							
North		East		West		South	
Aligned	Contra-aligned	Aligned	Contra-aligned	Aligned	Contra-aligned	Aligned	Contra-aligned
150	95	100	110	60	40	5	5
5	20	10	155	100	85	90	100
95	20	90	5	85	105	140	150
30	0	100	100	100	110	130	150
70	120	0	10	10	10	30	50
10	180	10	10	40	60	0	0
20	180	60	85	10	40	65	50
85	100	85	115	80	95	85	75
20	160	10	120	0	15	30	30
105	60	60	110	10	80	140	60
10	10	35	115	120	165	90	60
90	165	130	70	90	20	165	50
85	85	105	95	90	85	100	85
150	50	110	80	50	120	0	10
10	105	15	5	0	0	0	55
25	55	15	20	30	70	160	30
20	170	90	5	140	60	165	20
10	75	110	90	60	175	80	90
60	140	100	80	40	10	85	75
15	165	105	90	10	5	80	100
40	60	60	10	85	55	80	90
90	110	15	20	60	140	80	70
120	95	0	0	95	100	120	80
10	80	100	75	60	50	170	140

APPENDIX D

Experiment 6: Table 8: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) for Aligned and 180° Contra-aligned Orientation Judgments for Groups North, South, East and West under the 'No Cardinal' and 'Cardinal' Conditions. (Scores averaged across front and back judgements).

'Cardinal'								'No Cardinal'							
North		South		East		West		North		South		East		West	
Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra
15	15	136.25	58.75	73.75	76.25	23.75	3.75	7.5	11.25	65	88.75	11.25	110	8.75	176.25
10	10	6.25	3.75	8.75	18.75	58.75	123.75	11.25	62.5	6.25	25	13.75	32.5	60	98.75
17.5	160	13.75	18.75	68.75	101.25	13.75	23.75	15	167.5	13.75	36.25	31.25	156.25	23.75	83.75
6.25	105	6.25	3.75	10	15	6.25	7.5	33.75	98.75	13.75	17.5	43.75	38.75	18.75	37.5
6.25	3.75	48.75	38.75	5	41.25	18.75	12.5	8.75	15	51.25	55	26.25	32.5	25	13.75
10	158.75	7.5	73.75	10	11.25	16.25	8.75	45	127.5	17.5	16.25	7.5	16.25	87.5	100
16.25	16.25	11.25	15	72.5	43.75	12.5	87.5	11.25	31.25	7.5	18.75	46.25	88.75	10	23.75
10	6.25	10	7.5	6.25	33.75	32.5	10	10	23.75	7.5	7.5	11.25	46.25	15	21.25
35	75	52.5	22.5	77.5	121.25	52.5	120	17.5	8.75	41.25	51.25	10	10	37.5	36.25
16.25	93.75	120	60	25	17.5	116.25	115	28.75	20	12.5	112.5	8.75	10	110	77.5
77.5	96.25	11.25	6.25	22.5	15	65	127.5	93.75	113.75	13.75	15	21.25	10	10	50
10	171.25	71.25	66.25	57.5	143.75	70	90	12.5	166.25	16.25	111.25	45	81.25	31.25	112.5
45	26.25	56.25	18.75	43.75	55	63.75	72.5	17.5	10	38.75	10	10	90	10	102.5
125	70	8.75	28.75	35	103.75	51.25	68.75	65	80	6.25	1.25	21.25	75	10	36.25
47.5	36.25	52.5	115	75	82.5	35	120	10	30	12.5	133.75	67.5	67.5	16.25	126.25
88.75	93.75	101.25	87.5	78.75	82.5	83.75	83.75	77.5	78.75	78.75	80	76.25	67.5	87.5	80

APPENDIX D

Experiment 6: Table 9: Raw Absolute Orientation Error Scores

Latency Scores (tabled in seconds) for Aligned and 180° Contra-aligned Orientation Judgments for Groups North, South, East and West under the 'No Cardinal' and 'Cardinal' Conditions. (Scores averaged across front and back judgements)

'Cardinal'								'No Cardinal'							
North		South		East		West		North		South		East		West	
Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra	Aligned	Contra
9.25	4.50	15.25	24.25	4.25	2.75	19.50	24.25	11.50	7.75	16.75	15.50	2.00	5.75	5.25	8.75
8.50	9.00	18.25	16.75	4.75	4.75	23.50	14.50	7.00	12.00	12.00	31.50	4.25	14.00	22.75	15.50
9.75	14.25	3.75	11.00	4.75	3.75	6.50	9.75	7.75	9.00	4.75	12.75	5.00	11.75	4.25	8.50
1.75	6.75	11.50	13.50	3.75	5.25	4.75	3.75	3.00	11.75	9.00	16.00	4.75	5.75	3.25	7.00
5.00	4.50	6.50	11.00	4.25	8.75	3.50	3.25	5.50	3.75	7.50	17.25	3.25	4.00	3.75	5.00
5.25	9.00	5.50	8.88	20.13	13.00	8.25	9.00	9.75	10.25	8.00	11.25	10.25	17.75	11.50	14.50
5.00	10.00	8.00	8.75	8.50	8.50	9.50	12.50	5.75	7.75	14.00	9.25	17.25	24.25	12.75	10.00
5.25	8.00	3.75	3.50	4.25	5.00	5.00	9.50	6.00	12.50	4.50	5.25	2.50	12.75	5.00	6.50
5.62	6.26	13.03	13.81	13.75	13.43	11.79	37.75	4.05	5.29	5.39	19.18	7.71	6.86	12.29	22.47
5.56	11.99	9.51	23.57	3.55	5.34	11.46	10.91	5.61	13.96	4.74	12.42	6.92	7.08	4.32	7.98
18.15	6.81	4.57	4.93	2.69	3.99	13.07	13.55	14.13	13.62	7.24	6.59	2.63	4.06	8.97	11.88
4.86	14.60	12.49	12.78	6.42	7.24	5.60	4.36	6.30	7.32	6.29	18.02	5.27	10.13	4.31	3.92
8.81	12.74	5.67	8.06	4.82	7.98	10.81	5.20	4.84	8.49	6.13	4.72	4.16	5.36	4.01	6.53
8.70	11.41	4.75	6.72	7.97	10.71	8.67	6.62	7.02	9.24	8.42	8.15	5.75	7.39	4.04	4.60
6.98	5.77	25.40	28.54	14.47	12.64	9.74	19.15	10.30	11.63	12.50	13.23	12.73	11.86	6.13	16.11
4.21	11.28	12.32	20.43	4.80	9.24	3.28	4.51	2.79	3.80	2.91	3.71	1.81	8.54	3.31	3.83

APPENDIX D

Experiment 7: Table 10: Raw Absolute Orientation Error Scores (Ps. 1-24)

Absolute Error Scores (tabled in degrees) for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' and 'Enclosed' Conditions.

'Open'						'Enclosed'					
Front			Back			Front			Back		
Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
20	45	15	5	22.5	5	30	15	5	15	22.5	5
50	27.5	5	0	7.5	15	65	60	5	0	7.5	30
5	10	35	5	5	15	10	85	15	5	7.5	5
10	110	50	40	40	120	65	67.5	65	55	62.5	20
110	172.5	175	30	47.5	140	175	160	140	15	77.5	15
75	112.5	15	5	92.5	50	65	142.5	35	10	70	10
45	17.5	130	65	95	105	45	25	20	85	87.5	85
40	2.5	10	95	7.5	10	90	27.5	90	60	82.5	85
5	12.5	10	5	42.5	20	10	12.5	15	20	37.5	80
10	12.5	15	10	17.5	30	10	7.5	10	10	10	45
10	65	20	80	15	5	5	62.5	20	5	145	110
5	12.5	75	40	57.5	15	20	50	115	95	47.5	35
115	22.5	65	65	45	60	50	2.5	80	90	45	15
20	10	20	90	90	55	10	7.5	0	80	35	10
45	20	10	45	2.5	30	20	17.5	10	25	20	10
180	52.5	10	130	47.5	50	135	102.5	115	0	92.5	175
35	62.5	10	85	90	25	25	57.5	120	110	72.5	55
15	25	15	10	35	15	15	17.5	20	15	12.5	10
5	7.5	25	15	12.5	20	5	5	15	0	10	25
10	10	5	15	12.5	30	10	10	5	25	10	45
30	40	170	25	90	175	25	30	170	65	80	170
115	5	35	25	42.5	15	45	142.5	170	70	42.5	90
65	15	5	25	25	20	5	5	5	0	5	10
15	115	25	20	45	80	20	102.5	100	55	170	0

Experiment 7: Table 11: Raw Absolute Orientation Error Scores (Ps. 25-48)

Absolute Error Scores (tabled in degrees) for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' and 'Enclosed' Conditions.

'Open'						'Enclosed'					
Front			Back			Front			Back		
Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
20	20	20	10	12.5	25	10	20	30	10	15	5
5	7.5	10	0	10	10	0	10	10	10	10	15
15	17.5	65	0	55	160	5	7.5	5	5	7.5	5
70	102.5	100	5	40	155	10	80	20	5	82.5	110
10	5	20	15	12.5	5	10	27.5	15	0	20	30
10	10	65	90	80	0	0	12.5	0	10	5	25
45	15	5	20	5	10	25	62.5	0	10	10	5
20	27.5	5	50	17.5	10	115	57.5	10	15	75	115
15	10	5	5	10	15	20	5	5	10	70	95
10	12.5	10	65	25	10	30	97.5	50	90	125	70
15	7.5	25	15	102.5	70	5	2.5	65	90	20	30
160	105	5	165	90	50	5	80	155	10	90	115
5	12.5	5	10	20	10	15	15	0	20	5	5
30	25	10	5	87.5	10	30	17.5	15	10	25	5
90	27.5	55	15	30	15	30	7.5	10	5	62.5	80
20	50	5	25	5	5	95	67.5	15	15	30	55
10	7.5	30	10	15	70	10	5	20	10	10	0
30	87.5	30	5	42.5	145	30	72.5	50	15	47.5	5
10	82.5	120	0	55	160	0	72.5	170	20	80	130
5	10	20	0	50	20	20	97.5	150	20	137.5	65
80	42.5	65	25	95	90	145	75	115	125	87.5	35
85	90	10	175	175	65	110	20	5	5	155	10
170	127.5	125	85	80	145	130	105	10	145	60	80
25	15	10	10	52.5	5	160	50	55	30	57.5	5

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Experiment 7: Table 12: Raw Orientation Latency Scores (Ps. 1-24)

Latency Scores (tabled in seconds), for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' and 'Enclosed' Conditions.

'Open'						'Enclosed'					
Front			Back			Front			Back		
Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
7	25	7	8	9.5	12	5	17.5	11	5	12	8
7	22.5	4	17	8.5	11	8	13	3	5	10	12
3	10	8	6	15.5	8	8	8	7	12	5.5	10
2	18.5	12	5	39.5	13	34	17	18	55	17	13
6	5	6	12	7.5	5	6	7	4	7	5.5	8
12	18	7	7	15	18	15	16.5	21	12	17.5	9
5	4.5	10	7	12.5	7	4	3.5	4	6	4.5	7
11	9	8	7	13.5	8	11	14	12	6	11	14
6	8	6	6	9.5	4	5	6	6	3	10.5	9
3	3.5	2	2	3	2	3	3.5	3	3	2.5	6
6	7	5	10	8	7	3	7	6	4	6	3
4	6.5	6	5	6.5	9	5	8	24	5	16.5	14
8	7.5	4	9	7	7	4	10	8	6	6.5	3
5	8.5	9	6	11.5	9	7	10.5	7	8	19	3
6	8.5	6	16	15	12	5	4.5	6	5	7	3
4	4	2	2	4	6	4	3	3	6	2.5	21
21	27.5	4	19	9	8	22	12.5	15	11	12	15
8	17	6	4	14	5	3	8.5	5	6	15	3
6	6.5	7	7	10.5	8	5	7	5	6	6.5	8
6	8.5	7	7	11.5	15	8	6.5	13	7	11	13
5	22	38	8	19	34	10	20	14	10	19.5	12
4	4	4	6	3.5	4	2	14.5	5	4	9.5	4
4	7.5	4	3	9.5	8	5	6.5	4	6	6.5	7
2	3	3	3	4.5	4	2	3.5	3	5	2.5	5

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Experiment 7: Table 13: Raw Orientation Latency Scores (Ps. 25-48)

Latency Scores (tabled in seconds), for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' and 'Enclosed' Conditions.

'Open'						'Enclosed'					
Front			Back			Front			Back		
Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-ligned
4	5.5	9	4	6	5	3	4.5	5	3	4.5	4
8	10.5	6	11	10	13	4	7.5	4	10	8	5
3	3.5	3	3	7.5	3	2	3.5	4	16	3.5	3
8	4.5	4	4	9.5	6	10	5	9	6	9	3
5	6	5	3	7.5	7	2	6	4	6	6	4
14	12.5	5	15	5	6	6	16	3	2	18.5	3
4	4	2	3	4.5	3	4	5.5	3	4	4	5
2	19.5	16	7	22.5	8	2	10	10	21	20	40
27	41.5	46	24	26.5	19	33	29.5	19	35	10.6	37
6	18	3	4	11.5	24	8	18	5	8	24.5	27
2	10	7	7	15.5	25	3	5.5	3	22	19	8
4	4	2	8	8	4	11	6.5	4	3	10.5	11
17	17.5	11	6	8.5	9	5	5	7	4	8.5	6
8	6	6	5	10	7	7	16	6	5	15.5	5
6	6	7	5	8	9	5	4	6	6	6.5	8
2	7	3	3	9.5	5	5	5.5	4	4	6	8
8	13	9	8	13	8	6	7.5	7	7	7	7
18	17	40	3	20.5	4	23	48	2	5	14.5	10
2	4	2	3	4.5	2	3	6	3	19	6	3
16	21	2	12	17.5	14	17	26	35	7	26	5
21	13	6	9	11	12	8	22	18	8	8.5	4
3	5.5	2	7	7.5	5	8	14	2	8	15	4
5	13.5	9	5	4	10	8	4.5	3	8	5.5	3
3	18	5	9	16.5	3	15	7.5	11	3	18	27

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Experiment 8: Table 14: Raw Absolute Orientation Error Scores (Ps. 1-24)

Absolute Error Scores (tabled in degrees) for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' or 'Enclosed' Condition.

Orientation Error

TEST ENVIRONMENT	Front Aligned	Misaligned	Contra-aligned	Back Aligned	Misaligned	Contra-aligned
Enclosed B	5	62.5	5	120	2.5	10
Open B	30	130	125	65	60	125
Enclosed A	85	45	155	50	40	145
Open A	10	10	20	5	12.5	50
Enclosed B	15	5	10	25	17.5	20
Open B	0	95	55	30	12.5	100
Enclosed A	20	52.5	85	0	117.5	25
Open A	25	20	10	10	12.5	5
Enclosed B	0	25	30	20	12.5	60
Open B	15	40	25	0	85	10
Enclosed A	5	90	25	15	17.5	80
Open A	20	30	100	15	60	40
Enclosed B	55	22.5	65	55	32.5	30
Open B	10	12.5	20	5	25	30
Enclosed A	50	12.5	15	60	155	25
Open A	20	50	5	50	37.5	5
Enclosed B	20	10	20	20	20	5
Open B	5	42.5	5	25	7.5	20
Enclosed A	5	27.5	20	5	15	5
Open A	5	77.5	15	5	12.5	10
Enclosed B	10	17.5	25	10	62.5	35
Open B	25	42.5	35	70	25	150
Enclosed A	105	77.5	160	5	62.5	90
Open A	40	10	35	165	95	135

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Experiment 8: Table 15: Raw Absolute Orientation Error Scores (Ps. 25-48)

Absolute Error Scores (tabled in degrees) for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' or 'Enclosed' Condition.

	Orientation Error					
	Front			Back		
TEST ENVIRONMENT	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
Enclosed B	20	27.5	5	15	87.5	0
Open B	10	17.5	5	65	42.5	100
Enclosed A	50	10	5	10	27.5	10
Open A	25	10	10	0	77.5	5
Enclosed B	135	125	130	85	105	180
Open B	15	62.5	20	5	42.5	90
Enclosed A	55	17.5	100	10	45	15
Open A	155	155	130	130	130	15
Enclosed B	35	47.5	5	30	80	95
Open B	20	97.5	80	75	35	15
Enclosed A	5	7.5	10	10	15	5
Open A	25	30	50	5	57.5	35
Enclosed B	20	15	10	65	20	10
Open B	30	25	55	25	22.5	25
Enclosed A	75	47.5	5	10	112.5	10
Open A	20	20	5	50	52.5	85
Enclosed B	10	10	20	5	15	25
Open B	85	75	20	5	57.5	95
Enclosed A	5	52.5	80	10	10	50
Open A	10	12.5	40	0	17.5	50
Enclosed B	15	2.5	25	15	87.5	5
Open B	15	5	25	20	52.5	30
Enclosed A	25	27.5	5	25	5	15
Open A	25	115	5	125	40	95

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Experiment 8: Table 16: Raw Orientation Latency Scores (Ps. 1-24)

Latency Scores (tabled in seconds) for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' or 'Enclosed' Condition.

	Orientation Latency					
	Front			Back		
TEST ENVIRONMENT	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
Enclosed B	24.18	25.19	12.06	7.59	17.44	7.36
Open B	8.35	8.43	18.35	12.67	14.79	9.41
Enclosed A	19.14	13.74	12.97	10.85	25.02	24.63
Open A	1.39	2.59	2.45	1.74	7.34	6.94
Enclosed B	16.59	16.09	5.15	8.43	13.42	9.05
Open B	12.26	16.74	4.46	12.28	9.21	5.67
Enclosed A	7.89	4.14	5.81	10.59	6.52	1.59
Open A	4.36	7.80	11.31	7.27	7.46	20.64
Enclosed B	12.66	8.97	5.19	9.83	10.08	7.03
Open B	3.42	7.10	10.27	7.99	7.02	7.03
Enclosed A	10.05	18.71	14.15	21.92	29.68	24.17
Open A	4.03	4.09	8.07	4.77	5.15	4.22
Enclosed B	6.60	5.60	8.22	9.16	15.98	6.77
Open B	5.78	12.82	3.80	3.68	6.82	3.99
Enclosed A	2.07	4.46	11.68	21.57	23.70	14.63
Open A	4.73	17.39	10.67	6.33	11.50	7.63
Enclosed B	2.42	4.63	3.01	3.39	5.59	4.35
Open B	10.84	13.27	9.74	3.87	12.82	12.00
Enclosed A	4.07	3.70	5.83	2.10	7.78	10.24
Open A	8.95	10.51	1.97	12.33	11.27	17.47
Enclosed B	9.38	9.00	6.74	4.87	8.41	3.61
Open B	7.20	13.83	5.66	11.02	22.69	4.52
Enclosed A	6.34	14.81	2.85	6.37	13.68	2.65
Open A	4.39	9.82	6.22	8.30	16.95	12.26

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Experiment 8: Table 17: Raw Orientation Latency Scores (Ps. 25-48)

Latency Scores (tabled in seconds) for Aligned, 90° Misaligned and 180° Contra-aligned Orientation Judgements under the 'Open' or 'Enclosed' Condition.

Orientation Latency

	Front			Back		
TEST ENVIRONMENT	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
Enclosed B	7.77	11.96	11.31	10.61	10.68	9.50
Open B	13.49	22.53	43.02	3.79	13.08	10.83
Enclosed A	4.99	18.88	4.87	4.16	9.18	7.37
Open A	1.60	2.85	2.70	2.17	6.66	3.11
Enclosed B	13.48	12.80	10.39	5.57	8.69	5.74
Open B	6.13	15.47	23.26	5.37	12.72	11.46
Enclosed A	4.27	6.61	4.49	17.64	5.65	3.69
Open A	26.92	28.94	33.63	20.61	22.30	12.78
Enclosed B	25.67	26.37	20.63	8.13	18.49	12.56
Open B	15.96	47.13	3.88	9.18	9.54	7.67
Enclosed A	2.94	6.96	4.63	4.92	8.51	22.53
Open A	1.69	8.62	2.29	2.22	7.93	4.88
Enclosed B	13.14	15.88	7.46	10.22	14.33	4.12
Open B	2.87	8.44	10.07	5.99	7.40	18.37
Enclosed A	7.81	16.82	3.99	3.60	6.83	8.64
Open A	3.32	5.47	4.59	8.13	9.47	8.96
Enclosed B	2.10	2.60	3.61	4.35	7.68	7.45
Open B	10.97	7.84	5.14	5.69	4.53	13.53
Enclosed A	8.17	10.18	8.63	12.07	11.17	10.60
Open A	4.18	9.76	5.48	3.61	5.95	3.13
Enclosed B	6.35	8.52	9.94	4.69	7.96	11.14
Open B	4.50	5.83	24.53	5.67	22.33	6.70
Enclosed A	3.03	7.90	2.40	21.07	5.55	2.03
Open A	4.17	23.49	4.08	11.64	16.84	14.23

Experiment 9: Table 18: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) for Aligned, 90° Misaligned and 180° Contra-aligned Absolute Error Scores under the 'No Judgements' and 'Judgements' Conditions.

Orientation Error

NO JUDGEMENTS			JUDGEMENTS		
Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
30	92.5	10	20	85	55
10	67.5	170	30	25	10
10	27.5	25	40	15	25
15	17.5	15	30	60	10
60	57.5	60	100	100	15
30	47.5	20	20	10	35
10	12.5	40	0	45	25
10	22.5	10	30	10	35
10	102.5	160	140	32.5	50
0	55	155	0	47.5	0
10	25	15	10	5	170
0	15	10	0	82.5	0
20	15	15	10	47.5	10
20	20	35	10	2.5	10
60	40	25	30	52.5	50
10	5	10	10	7.5	25
60	120	115	140	102.5	160
40	20	35	10	22.5	10
60	30	65	40	37.5	40
30	25	10	15	17.5	15
0	40	5	170	22.5	50
60	15	45	90	12.5	0
20	60	15	10	12.5	0
80	110	105	70	132.5	130
10	2.5	10	30	5	35
10	7.5	0	0	5	5
10	42.5	20	20	45	15
10	22.5	10	30	10	25
10	2.5	10	60	15	15
10	102.5	170	20	110	15
40	32.5	40	20	20	15
10	12.5	140	30	30	65

Experiment 9: Table 19: Raw Orientation Latency Scores

Latency Scores (tabled in seconds) for Aligned, 90° Misaligned and 180° Contra-aligned Absolute Error Scores under the 'No Judgements' and 'Judgements' Conditions.

Orientation Latency

NO JUDGEMENTS			JUDGEMENTS		
Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
19.8	19.25	16.8	12.1	13.5	11.4
22.7	32.4	29.3	14.6	22.5	11.3
27.2	20.3	20.6	19.3	22.15	20.4
19	24.7	24	15	20.9	9.8
10.7	15	14.4	28.1	12.4	18.4
44.2	56.25	114	16.6	16	16
24.6	29.35	43	38.7	11.5	11
10.2	16.9	12.1	8.2	26.35	25.3
22.8	23.1	10.6	11.7	16	9.7
16.4	37	24.8	13.8	32.75	20.1
48.9	19.85	58.2	28.1	10.95	9.9
14.3	37.6	41	11.1	13.05	23.8
47.7	24.45	14.4	25.5	14.95	13.5
34.9	41.2	47	12.9	27.9	27.7
114	30.55	21.2	27.3	19.05	24.7
12.8	25.75	15.6	19.8	26.6	24.2
6.9	3.7	3.4	5.2	7.4	6.1
9.7	16.4	13.2	16.7	15.1	16.8
30.5	17.4	13.2	13.5	17.7	11
19.4	15.55	16.2	16.6	9.5	25.2
11.3	11.05	11.2	7.9	20.65	14.9
17.7	23.85	24.9	15.6	27.35	26.9
18.6	15.9	19.3	13	15.75	20.4
18.7	21.25	27.7	38.4	23.75	1
19.6	19.8	10.3	22.1	16.35	13.4
27.8	32.95	21.4	27.5	24.15	41.1
19.4	27.5	24.4	25.5	31.9	13.1
15.8	17.05	19.9	23.8	16.6	35.6
25	18.1	21.5	20.6	26.25	11.9
29.2	24.95	60.5	25.6	41.2	66.2
10.7	14.85	8.7	23.1	22.55	17.5
28	12.8	23.7	24.4	16.55	54.8

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Experiment 10: Table 20: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) for Orientation Judgements to Target Locations that were aligned with the First, Second and Fourth Perspectives on the Array.

Orientation Error

	Front				Back			
Participant No.	First	Second	Third	Fourth	First	Second	Third	Fourth
1	40	55	150	150	55	130	60	75
2	180	120	140	25	0	5	10	15
3	0	15	10	170	15	15	5	0
4	75	10	5	5	100	0	5	5
5	80	5	10	20	10	10	5	15
6	5	0	170	60	5	15	25	40
7	10	15	110	90	10	5	10	20
8	15	35	15	5	20	0	175	5
9	60	5	20	75	60	10	15	105
10	10	10	100	10	35	45	175	15
11	105	20	130	95	0	80	170	105
12	170	170	115	10	95	5	20	15
13	80	100	15	115	5	85	25	30
14	175	5	10	10	0	15	10	10
15	15	100	120	20	20	5	10	20
16	5	20	100	10	10	10	110	15
17	80	10	75	10	10	30	70	50
18	10	0	5	0	15	10	15	20
19	5	15	5	0	5	65	30	5
20	45	150	45	0	10	160	20	15

	Front				Back			
Participant No.	First	Second	Third	Fourth	First	Second	Third	Fourth
21	10	5	5	5	10	45	5	0
22	10	10	90	0	60	15	90	0
23	5	10	35	50	25	5	10	105
24	5	95	75	55	135	80	10	65
25	70	125	110	5	5	20	30	55
26	80	10	95	10	10	45	145	20
27	0	160	90	85	5	170	50	20
28	105	15	85	85	60	15	170	10
29	30	5	10	80	65	30	35	35
30	10	10	5	45	20	20	15	15
31	15	15	10	20	25	120	20	35
32	95	25	90	55	95	100	65	180
33	175	0	15	5	25	10	10	10
34	5	5	10	0	15	10	10	5
35	5	0	5	5	5	15	10	10
36	40	165	20	5	25	10	45	105
37	45	70	85	135	45	15	20	45
38	20	130	30	90	80	5	140	155
39	135	5	0	0	5	10	5	10
40	0	35	15	15	20	35	50	10

Experiment 10: Table 21: Raw Orientation Latency Scores

Latency Scores (tabled in seconds) for Orientation Judgements to Target Locations that were aligned with the First, Second and Fourth Perspectives on the Array.

Orientation Latency

	Front				Back					Front				Back			
Participant No.	First	Second	Third	Fourth	First	Second	Third	Fourth	**Participant No.**	First	Second	Third	Fourth	First	Second	Third	Fourth
1	17.09	8.19	12.3	8.87	4.25	24.37	20.39	2.98	**21**	13.63	1.88	17.11	3.39	2.59	7.05	1.86	3.13
2	15.89	8.31	15.14	46.64	10.68	20.72	15.74	16.87	**22**	26.93	21.43	34.48	25.11	3.88	7.8	17.19	4.71
3	2.24	2.95	4.36	18.99	1.74	2.03	1.65	5.4	**23**	1.64	5.51	10.55	2.93	2.23	2.06	2.59	5.17
4	4.59	9.42	2.76	3.43	5.12	3.92	2.39	1.76	**24**	2.77	5.28	12.57	10.37	5.57	3.96	6.19	6.19
5	4.68	11.13	23.59	14.73	10.56	6.69	8.45	18.49	**25**	21.72	19.28	8.94	5.37	5.72	8.88	1.94	5.03
6	1.79	3.74	3.66	4.26	3.27	2.2	3.97	3.58	**26**	6.15	18.95	14.27	17.45	9.21	24.2	12.23	5.52
7	1.06	8.33	3.11	13.27	1.19	3.02	1.35	3.32	**27**	12.53	9.62	17.5	6.87	1.25	6.12	8.45	3.81
8	2.52	8.09	6.17	10.23	2.69	2.29	45.52	3.21	**28**	4.78	8.9	4.53	2.9	8.75	4.03	3.69	4.09
9	6.86	4.13	6.12	9.27	12.95	15.06	4.97	17.71	**29**	10.5	5.34	6.88	7.53	11.72	6.69	9	11.06
10	3.13	9.29	6.43	18.59	1.89	3.91	11.77	3.46	**30**	4.75	2.94	2.81	2.14	3	1.79	2.84	2.62
11	9.97	10.46	12.84	4.58	4.45	9.62	4.14	5.85	**31**	3.67	7.82	8.56	4.25	4.13	5.03	3.1	4.57
12	12.22	1.47	22.63	9.62	1.87	9.62	14.29	2.59	**32**	3.79	7.06	8.97	8.75	13.81	4.21	7.22	8.44
13	6.14	14.52	5.85	20.17	4.23	7.73	3.93	7.81	**33**	23.47	19.75	10.91	16.68	11.53	4.12	8.16	11.03
14	3.85	12.22	3.53	13.67	5.2	3.91	4.19	1.46	**34**	3.07	6.25	3.25	2.72	2.88	5.12	2.9	8.09
15	4.24	6.65	5.49	2.43	2.71	9.13	5.26	5.31	**35**	6.47	9.1	7.31	6.79	5.82	3.03	6.47	4.94
16	4.77	8.25	14.28	4.26	2.39	7.25	5.68	4.8	**36**	2.25	13.07	7.88	2.75	8.12	6.29	5.93	26.87
17	18.02	3.13	1.4	2.03	2.17	2.01	2.82	1.63	**37**	6.03	3.41	7.56	12.75	6.78	8.31	3.81	5.53
18	6.56	17	2.69	9.93	2.65	13.54	2.83	3.91	**38**	2.69	3.1	2.23	2.11	8.16	3.13	4.72	2.53
19	42.22	12.6	11.33	5.2	12.31	19.12	10.13	2.97	**39**	5.47	9.19	5.94	6.66	2.37	5.97	8.03	3.59
20	11.38	16.53	8.82	10.17	15.56	19.87	11.27	11.98	**40**	3.9	2.78	5.34	3.44	5.19	3.84	3.3	5.47

Experiment 11: Table 22: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) in the 'No Judgements' and Judgements Conditions to targets that were aligned with the First and Second experienced Perspectives and aligned with the Opposite to First and Opposite to Second Perspectives.

No Judgements								Judgements							
Front				Back				Front				Back			
First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-first	Opp-Second
20	10	0	0	20	80	55	25	10	105	10	10	15	20	90	10
5	5	5	5	5	0	5	10	0	5	5	0	5	0	0	10
95	5	5	175	165	5	5	5	5	5	5	85	5	5	5	5
50	90	135	140	40	75	70	50	65	5	90	160	65	5	95	110
25	20	90	0	5	20	90	15	175	5	0	25	105	145	0	180
45	135	120	45	110	45	140	30	45	155	170	45	65	135	165	85
40	135	125	50	40	50	65	50	45	135	90	105	115	40	140	55
35	5	0	45	55	45	10	25	0	5	0	0	5	30	0	5
0	5	0	20	75	5	0	15	95	0	10	10	10	5	15	10
10	10	25	100	15	10	80	10	170	20	10	170	10	170	170	170
15	10	160	75	15	25	120	15	15	0	35	45	135	25	15	25
5	5	0	5	0	5	10	10	15	5	15	5	15	0	20	5
0	15	10	20	5	0	10	15	30	15	5	15	5	15	15	0
20	15	20	140	140	170	20	70	170	25	10	170	80	10	170	170
0	10	5	10	5	5	15	0	10	20	15	25	0	0	0	10
10	35	15	0	20	10	30	105	5	20	10	5	30	35	20	5
5	10	10	20	170	10	0	10	0	10	5	25	10	5	10	20
35	10	20	35	30	50	5	15	20	25	10	25	35	15	35	10
170	15	10	10	5	10	80	55	0	0	55	35	10	30	0	45
50	15	65	10	5	105	70	160	10	15	35	5	0	10	30	10
105	5	170	20	5	15	50	5	115	120	85	110	50	10	70	10
90	25	105	180	80	0	95	175	75	5	10	170	85	10	90	165
0	5	45	155	170	10	20	25	60	35	50	35	45	45	40	30
10	25	10	25	25	65	5	80	5	10	5	100	90	75	0	120
35	75	5	0	135	35	35	80	5	15	45	10	10	25	20	160
10	15	5	15	0	10	0	5	5	5	15	20	10	15	5	5
10	10	15	15	0	90	45	170	10	25	5	60	5	175	80	20
5	5	5	5	5	5	65	5	5	5	0	5	5	20	60	10
0	10	0	15	5	5	95	95	0	20	5	10	20	100	95	75
15	0	10	10	30	10	25	5	10	5	10	0	0	10	10	0
5	100	55	10	10	0	5	15	25	5	170	10	10	15	15	175
0	35	5	30	55	55	5	30	5	35	10	65	30	70	5	125

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Experiment 11: Table 23: Raw Orientation Latency Scores

Latency Scores (tabled in seconds) in the 'No Judgements' and Judgements Conditions to targets that were aligned with the First and Second experienced Perspectives and aligned with the Opposite to First and Opposite to Second Perspectives.

No Judgements								Judgements							
Front First	Second	Opp-First	Opp-Second	Back First	Second	Opp-First	Opp-Second	Front First	Second	Opp-First	Opp-Second	Back First	Second	Opp-First	Opp-Second
5	6	5	3	5	6	10	4	5	6	2	3	4	4	3	6
7	7	9	33	8	28	23	12	6	3	5	2	13	9	21	21
6	3	3	3	3	5	5	4	2	1	8	3	4	4	4	3
4	5	5	3	7	3	8	6	4	4	4	3	4	3	3	3
6	11	8	3	12	6	10	14	4	1	4	6	6	8	7	5
19	29	7	14	12	12	18	17	5	19	15	16	8	8	8	13
3	5	20	9	8	6	10	8	7	9	5	5	3	7	6	6
4	3	5	6	5	8	16	6	3	2	2	5	3	8	5	5
3	3	2	7	13	4	7	5	7	10	4	10	30	9	6	14
2	2	5	9	3	2	4	6	15	3	6	4	5	16	1	13
5	16	4	27	10	15	21	6	9	8	11	18	22	9	8	28
5	3	5	17	4	3	4	4	2	7	4	5	5	15	8	5
16	9	12	8	13	21	58	13	23	10	12	15	36	19	31	12
2	2	4	14	15	21	18	10	14	4	21	2	20	9	1	33
6	3	11	6	4	4	6	5	3	5	5	3	15	9	20	11
9	15	14	7	15	23	12	14	13	27	9	14	15	26	19	18
4	3	7	5	6	14	5	6	1	8	3	3	7	5	5	3
5	2	13	8	10	13	21	11	8	9	4	5	6	8	3	9
5	3	8	7	9	4	7	5	5	6	4	8	5	5	6	5
5	2	3	3	4	2	5	4	2	1	1	1	2	1	2	1
1	1	4	4	2	4	2	2	4	2	8	6	3	2	4	4
4	3	2	6	3	4	4	3	3	2	4	4	3	5	2	2
8	6	20	4	8	9	7	8	8	11	11	3	8	9	7	6
7	8	9	13	8	7	20	18	11	16	18	9	13	35	21	7
5	30	19	11	33	15	12	31	6	11	13	7	13	9	9	17
3	4	3	3	3	9	7	2	4	2	3	3	5	3	3	2
50	4	6	37	4	5	10	8	9	5	4	10	3	2	8	5
9	2	5	25	7	5	14	6	3	4	4	4	2	3	4	3
2	3	2	5	3	3	4	4	3	6	3	20	7	5	4	6
2	3	2	4	4	3	3	6	15	3	4	5	4	4	4	4
6	14	5	15	5	6	9	2	2	2	55	6	31	7	11	14
4	7	7	16	7	7	11	8	10	9	10	15	6	19	8	39

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Experiment 12: Table 24: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) in the 'No Judgements' and 'Judgements' Conditions, to Targets that were Aligned, Misaligned and 180° Contra-aligned with the First-Experienced Perspective.

No Judgements						Judgements					
Front Aligned	Misaligned	Contra-aligned	Back Aligned	Misaligned	Contra-aligned	Front Aligned	Misaligned	Contra-aligned	Back Aligned	Misaligned	Contra-aligned
10	40	180	0	132.5	170	5	50	25	5	15	5
70	42.5	100	20	115	5	100	42.5	10	20	77.5	30
15	20	0	50	10	10	0	5	10	5	7.5	10
5	7.5	0	10	2.5	0	0	2.5	10	10	30	15
25	7.5	15	20	165	10	0	7.5	5	15	10	15
135	130	5	125	57.5	50	0	10	5	5	90	5
10	135	110	10	35	175	150	112.5	120	70	25	155
90	5	10	10	7.5	15	0	5	5	20	42.5	10
0	52.5	10	175	17.5	80	75	15	10	10	127.5	20
5	0	5	5	5	175	5	7.5	15	5	77.5	10
15	7.5	15	10	12.5	15	10	12.5	35	15	47.5	10
25	20	10	15	17.5	0	10	15	5	30	30	0
0	15	40	0	10	55	0	45	15	5	7.5	10
125	152.5	15	135	137.5	75	0	25	170	5	77.5	95
10	7.5	75	5	15	15	45	22.5	30	40	42.5	30
100	12.5	25	25	5	10	5	10	30	20	5	15
120	57.5	5	170	82.5	10	40	60	5	145	72.5	5
40	72.5	30	10	42.5	65	15	30	20	15	87.5	155
5	20	10	0	55	5	5	12.5	30	5	35	15
5	52.5	15	5	10	5	10	5	20	25	82.5	85
0	47.5	50	20	12.5	170	45	15	10	10	10	5
0	2.5	5	15	5	20	5	80	10	10	10	5
5	50	10	15	40	170	45	65	130	15	45	30
20	12.5	85	5	12.5	15	80	17.5	15	25	35	5
10	5	95	5	10	0	0	7.5	10	0	45	0
10	75	5	20	10	160	15	47.5	60	170	65	100
40	2.5	5	5	30	25	35	27.5	40	25	32.5	25
135	90	105	105	107.5	80	130	27.5	0	165	90	15
50	115	170	35	27.5	170	45	107.5	10	140	70	170
30	47.5	5	5	5	10	0	10	5	45	52.5	5
25	7.5	5	0	10	15	40	30	25	45	35	20
20	40	25	160	82.5	40	85	30	5	145	55	20

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Experiment 12: Table 25: Raw Orientation Latency Scores

Latency Scores (tabled in seconds) in the 'No Judgements' and 'Judgements' Conditions, to Targets that were Aligned, Misaligned and 180° Contra-aligned with the First-Experienced Perspective.

No Judgements						Judgements					
Front			Back			Front			Back		
Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned	Aligned	Misaligned	Contra-aligned
11.48	18.03	24.80	5.67	10.47	12.61	6.57	35.53	7.40	7.33	19.97	5.50
12.63	5.18	3.87	4.70	5.77	4.99	6.61	6.79	3.00	4.39	7.60	5.07
5.93	8.13	4.87	14.84	7.57	5.17	5.51	4.96	6.69	10.07	10.89	2.58
5.67	7.87	9.85	8.84	5.69	3.87	4.77	15.81	3.09	7.18	12.16	6.15
4.41	17.22	18.77	24.29	26.55	20.25	15.75	14.29	6.10	12.41	10.54	7.37
28.13	5.47	2.37	12.53	10.43	14.19	9.48	15.05	10.65	9.24	22.03	24.58
12.66	12.67	25.86	24.93	24.90	40.40	12.84	17.08	19.46	17.13	14.03	73.59
4.80	12.81	3.89	13.36	10.29	9.19	3.49	3.46	6.00	6.57	10.86	8.18
3.83	23.59	5.69	16.23	18.00	31.03	55.63	4.78	11.52	7.45	28.21	23.84
8.56	5.65	10.47	10.15	21.70	4.22	4.24	8.17	6.55	16.64	7.17	20.87
3.21	7.62	8.36	12.97	12.40	15.94	3.88	5.08	2.66	3.94	13.51	4.38
12.80	5.63	2.13	12.48	6.65	17.45	2.55	5.49	4.00	8.47	10.79	20.10
1.69	5.25	3.23	1.33	3.22	4.30	2.13	4.69	7.49	1.98	3.13	2.20
3.18	5.02	3.33	18.27	2.75	21.05	8.33	7.16	8.60	8.23	19.31	17.18
4.78	8.10	2.99	3.13	13.28	23.42	4.12	6.59	8.98	1.53	9.54	17.67
6.07	20.03	7.63	12.92	20.07	9.03	14.17	25.42	20.21	36.58	41.10	71.27
7.84	7.39	3.64	14.28	4.81	2.43	2.62	4.13	3.11	4.15	6.53	3.08
4.16	6.31	2.69	8.22	6.62	6.93	4.67	4.59	16.77	4.93	8.07	7.09
7.47	9.59	5.37	4.45	7.49	4.28	4.41	7.11	8.36	5.69	9.64	7.07
9.65	17.29	4.74	12.68	9.93	8.89	5.88	17.79	15.57	8.77	20.58	102.48
13.23	20.13	26.44	20.89	5.73	10.83	22.95	5.34	6.01	6.91	7.41	9.25
9.62	12.31	6.81	10.28	18.38	25.33	14.07	13.60	11.57	59.30	16.51	31.00
2.39	3.35	1.43	2.09	3.33	5.92	1.94	3.50	2.54	1.52	5.49	5.36
1.77	5.22	0.93	7.53	4.32	6.47	7.03	8.22	9.09	11.13	5.90	22.49
2.29	5.33	2.34	3.64	6.81	7.48	15.24	6.29	2.10	7.59	6.14	5.53
1.55	13.53	14.38	24.67	25.45	4.77	5.03	20.40	4.01	3.60	27.30	5.78
3.09	4.55	4.09	3.25	10.40	11.69	4.27	5.26	4.25	5.50	6.60	15.80
4.32	4.03	7.29	9.29	6.21	7.05	11.19	4.51	3.75	5.40	3.79	6.30
5.29	12.27	2.09	16.06	9.25	2.01	7.00	13.96	3.17	6.10	5.35	8.73
6.34	9.68	5.19	4.43	11.78	3.69	3.33	12.33	9.19	8.38	27.92	7.10
2.33	2.31	1.53	1.46	3.23	8.27	2.73	1.86	2.18	4.17	2.23	1.59
6.27	3.84	1.34	3.89	5.50	2.03	4.29	5.71	5.93	3.73	4.21	3.43

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Experiment 13: Table 26: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were aligned with the First and Second Experienced Perspectives and aligned with the Opposite to First and Opposite to Second Perspectives.

Observer Movement								Array Rotation							
Front				Back				Front				Back			
First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second
170	5	70	0	5	10	170	110	45	45	10	40	160	75	45	25
120	25	35	40	35	90	175	25	10	10	175	165	165	20	10	15
25	10	10	25	15	40	15	15	0	5	0	0	25	15	10	20
20	20	15	20	15	35	20	5	20	45	160	5	25	25	165	35
165	30	5	0	5	15	0	0	0	0	70	5	95	15	0	0
25	25	15	10	20	15	60	10	15	15	10	15	25	15	5	10
5	50	85	165	95	5	45	130	80	10	10	5	10	170	100	15
0	10	0	5	10	10	5	50	5	5	90	100	0	35	0	5
0	70	0	10	10	5	10	5	5	0	20	0	10	5	10	160
10	15	10	15	10	165	10	5	5	10	15	170	15	15	10	170
10	0	0	80	135	15	25	90	10	10	65	40	10	55	10	60
0	0	10	10	10	0	10	5	0	5	5	50	20	20	5	90
20	10	170	70	30	10	120	75	0	20	95	0	5	5	175	75
20	45	170	140	15	10	55	130	55	35	120	75	55	100	160	90
25	10	50	5	65	5	60	55	0	5	0	5	0	5	165	15
60	15	40	25	20	15	55	20	15	15	10	40	10	25	55	20
10	100	180	15	5	15	170	10	70	0	175	120	70	50	135	145
5	0	0	5	0	10	5	5	0	10	0	20	0	10	5	5
5	10	40	5	90	5	40	0	0	0	175	95	10	5	5	0
170	5	15	170	10	0	5	5	0	5	5	50	55	5	5	40
10	10	170	10	0	80	10	10	45	50	50	135	45	45	45	55
80	85	5	5	15	5	85	80	95	40	25	90	0	0	165	5
20	20	105	15	10	95	80	40	75	20	45	45	10	50	10	40
0	0	10	10	0	0	0	10	90	5	5	10	0	0	5	175

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Experiment 13: Table 27: Raw Orientation Latency Scores

Latency Scores (tabled in seconds) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were aligned with the First and Second Experienced Perspectives and aligned with the Opposite to First and Opposite to Second Perspectives.

Observer Movement								Array Rotation							
Front				Back				Front				Back			
First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second
8.47	6.89	6.86	8.35	4.37	4.92	4.58	5.06	3.6	2.7	4.51	11.23	4.97	3.87	6.53	6.08
8.33	16.57	5.81	7.99	8.55	3.32	13.63	3.26	2.09	6.76	6.09	5.2	8.77	19.49	6.41	13.99
11.13	2.65	4.23	17.07	4.61	9.26	12.07	3.89	5.94	8.41	4.13	6.88	10.53	4.84	4.23	14.52
12.12	2.8	3.61	9.17	5.27	2.7	5.95	8.49	1.75	4.27	12.18	4.24	5.58	3.08	8.37	7.22
9.47	2.17	7.37	6.63	2.19	8.71	7.97	9.28	4.51	2.99	3.64	4.77	7.29	5.69	5.63	11.75
9.98	6.88	7.1	2.67	6.86	5.98	2.75	6.91	2.43	5.77	9.9	2.11	6.79	3.75	6.83	7.69
6.49	10.42	3.64	4.16	41.28	5.57	14.49	10.65	4.25	7.17	2.79	20.93	1.9	21.27	18.48	6.59
3.99	2.76	25.95	3.18	14.32	2.41	18.55	46.71	32.81	1.77	3.54	56.82	16.15	13.57	6.26	23.06
4.68	5.54	4.8	7.34	6.73	4.78	6.75	4.82	7.67	6.35	7.05	5.84	6.71	6.98	13.43	9.35
3.59	1.3	7.65	2.13	3.99	6.25	2.67	17	4.79	1.73	2.53	34.12	2.69	1.8	7.55	6.96
12.05	4.37	5.7	12.41	2.6	8.37	21.5	20.28	25.11	3.25	12.47	10.46	11.83	4.6	7.11	12.43
3.58	3.96	20.87	8.03	3.48	17.14	5.05	6.48	13.02	27.03	5.87	6.93	8.16	10.92	6.88	2.07
10.47	12.9	14.86	4.38	16.64	17.94	12.94	3.58	3.65	9.27	17.57	8.26	2.3	12.53	11.25	7.87
14.3	2.99	6.03	8.81	6.18	7.88	4.61	19.73	15.85	25	12.67	13.47	10.78	11.21	2.59	9.82
11.98	14.05	7.06	10.49	9.46	8.64	11.6	11.29	6.3	8.27	6.94	5.03	9.01	8.42	11.75	8.68
6.02	3.01	3.4	3.45	3.77	2.79	4.87	5.83	2.49	1.85	5.83	8.4	6.78	6.36	2.57	9.97
6.72	8.01	23.73	4.33	12.33	17.07	7.36	8.5	12.42	12.59	20.77	14.63	5.57	4.37	6.43	4.73
1.57	2.49	3.17	1.63	2.45	1.37	5.38	2.64	1.49	2.83	7.64	32.17	1.79	26.86	3.77	9.82
5.03	5.28	7	6.49	11.09	5.76	10.69	6.99	5.59	5.64	11.17	12.32	10.89	13.63	9.51	7.12
5.95	5.27	5.17	6.14	10.41	6.21	12.06	4.69	9.57	6.57	3.71	5.33	7.23	3.31	14.07	2.83
34.15	7.83	19.04	2.38	9.62	3.77	40.08	3.38	15.49	39.57	6.35	4.89	4.78	20.73	12.64	15.27
8.49	5.12	5.37	8.58	9.51	10.38	9.04	8.16	9.94	19.93	5.84	39.51	9.17	7.41	14.15	16.43
4.77	18.65	6.59	1.79	11.43	7.45	13.47	10.56	6.29	4.07	23.19	3.62	21.71	34.85	20.75	5.14
7.73	4.67	8.97	20.27	1.78	16.89	19.37	1.24	17.11	3.37	2.71	60.01	14.26	7.59	12.25	4.07

APPENDIX D

Experiment 14: Table 28: Raw Absolute Orientation Error Scores

Absolute Error Scores (tabled in degrees) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were aligned with the First and Second Experienced Perspectives and aligned with the Opposite to First and Opposite to Second Perspectives.

Observer Movement								Display Rotation							
Front				Back				Front				Back			
First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second
10	60	60	0	5	10	35	80	100	10	90	150	85	0	85	5
50	20	5	5	15	15	55	15	0	5	5	25	25	15	15	15
170	10	10	10	10	25	150	10	5	10	0	0	5	180	10	5
5	0	5	0	5	0	10	5	30	50	55	5	35	10	20	10
30	20	40	10	0	15	45	30	5	15	5	15	0	10	15	10
55	20	5	80	15	15	25	165	10	10	95	170	5	10	10	20
0	5	5	5	180	5	60	20	10	15	10	15	5	20	10	10
15	10	85	25	70	0	120	80	85	0	170	5	25	20	170	25
55	10	90	130	10	45	95	65	15	5	85	165	135	25	70	75
60	35	15	50	10	35	65	30	5	80	10	20	10	15	15	0
5	5	0	5	10	5	5	5	15	45	15	30	60	55	40	10
15	5	10	5	5	10	10	10	15	5	20	10	10	0	10	5
15	40	20	10	20	10	20	20	0	0	10	5	5	85	15	5
40	50	80	110	140	30	140	130	100	10	40	135	95	5	90	180
10	10	10	10	50	25	20	20	35	0	10	20	25	20	30	20
10	10	5	20	10	20	45	130	40	15	5	160	110	65	35	30
60	55	55	0	45	5	35	30	85	15	80	100	25	5	20	75
30	35	65	0	10	15	45	110	25	15	75	10	75	25	10	5
100	10	35	175	20	10	10	145	65	160	45	45	40	50	65	70
10	5	120	155	60	170	160	160	35	35	30	10	40	10	65	170
0	10	130	45	15	25	10	5	0	0	170	105	10	80	95	20
5	5	5	5	5	5	5	5	5	50	5	0	15	45	15	5
15	10	5	0	5	25	10	0	15	10	5	10	15	20	10	10
15	10	115	165	30	30	5	165	15	5	20	85	65	20	65	180

APPENDIX D

Experiment 14: Table 29: Raw Orientation Latency Scores

Latency Scores (tabled in seconds) in the 'Observer Movement' and 'Array Rotation' Conditions, to Targets that were aligned with the First and Second Experienced Perspectives and aligned with the Opposite to First and Opposite to Second Perspectives.

Observer Movement								Array Rotation							
Front				Back				Front				Back			
First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second	First	Second	Opp-First	Opp-Second
21	54	20	14	8	15	11	35	27	4	29	25	13	5	9	21
3	5	12	3	5	7	10	6	6	3	10	4	5	3	5	6
3	10	7	26	5	13	33	4	9	14	7	8	12	6	12	14
10	4	4	5	6	4	5	12	11	9	1	12	12	8	6	12
13	9	6	3	3	6	10	3	5	2	3	3	4	3	2	4
4	5	5	4	3	8	3	7	3	3	9	30	5	25	10	17
7	9	10	5	8	13	31	10	7	6	7	9	4	8	7	15
8	2	13	15	15	8	10	9	7	6	5	10	6	6	11	9
12	3	3	2	4	4	2	1	1	2	2	3	3	2	2	5
3	2	2	2	4	15	5	4	3	3	3	5	3	3	3	11
2	16	8	15	8	10	26	41	12	3	15	9	10	4	8	27
2	2	3	5	2	2	3	3	2	4	4	4	3	2	3	5
3	4	2	1	5	1	4	4	2	2	2	2	12	3	2	3
7	5	15	10	6	9	6	4	6	6	11	14	3	5	6	6
2	1	2	2	2	1	1	4	21	1	7	2	1	2	5	2
2	11	5	3	4	6	3	5	7	2	2	16	16	6	4	4
4	4	5	3	13	6	6	14	6	4	4	5	5	4	17	6
8	3	5	4	2	6	6	17	21	7	12	7	10	11	10	15
15	7	23	17	6	19	26	54	34	9	55	25	78	21	16	46
5	3	12	5	2	5	9	13	5	2	10	2	5	5	17	42
24	11	24	3	4	9	5	6	4	3	5	14	4	10	9	10
3	4	2	4	3	5	3	6	3	9	4	4	5	8	5	4
4	5	7	11	26	5	10	19	6	3	4	28	5	11	3	16
5	4	6	3	3	5	6	6	3	2	1	3	3	3	3	4

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