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Interactions between sources of alignment in human spatial learning

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by

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# Abstract

Without the ability to learn about the world around us, and the relative location of objects within it, we would be unable to make our way from one location or goal to another. This ability to learn spatially and navigate is essential and therefore so is understanding how this is achieved. Traditionally there has been a split between the theory behind how we learn about temporal and spatial relationships. Since Tolman (1948) the generally accepted theory of human spatial learning is that a cognitive map, a mental representation, is developed as an environment is explored. This map is then automatically updated when new information is presented (O'Keefe & Nadel, 1987). Temporal learning however has been considered to be governed traditional associative principles (Thorndike, 1911; Pavlov, 1927), and later discrepancy learning (Rescorla & Wagner, 1972). A particular effect considered to be confined to temporal learning is that of cue-competition, where learning about one cue, or source of information, can compete with learning about another cue such as blocking (Kamin, 1969) or overshadowing (Pavlov, 1927). In a blocking design learning about the relationship between A and X can block later learning about a possible relationship between B and X. In overshadowing only one cue (A or B) is learnt about in relation to X when both are presented at the same time.

The lack of competition effects in spatial learning was considered evidence for differing mechanisms for spatial and temporal learning, and whilst recent evidence has been found that suggests blocking can be found in human spatial learning (Alexander, Wilson & Wilson, 2009; Wilson & Alexander, 2008) most such examples utilise goal directed spatial search tasks. These are vulnerable to the criticisms of Mackintosh (2002) as they may not reflect 16



true spatial learning due to still having potential non-spatial solutions. Therefore it remains to be seen whether competition effects can be found when using unequivocal spatial measures. One area of investigation free of non-spatial explanations is that of spatial alignment effects. Spatial alignment effects refer to more efficient recall about an environment and the objects within it from an imagined perspective aligned with a particular source of information. One particular type is the First Perspective Alignment Effect (FPA) where recall from a perspective that is aligned with the very first perspective experienced is more efficient than others. Such effects are revealed through judgement of relative direction tasks which require the use and application of vectorial learning and measure orientation dependence.

Spatial alignment effects and cue-competition were investigated in the following Virtual Environment (VE) experiments. Experiments 1, 2a, 2b and 2c investigated factors that could influence the presence of the FPA effect. Experiment 1 found that the FPA effect was present regardless of the level of detail in a VE, or type of VE (Indoor or Outdoor) experienced. Experiment 2a, 2b and 2c found that pre-exposure to a VE before training could attenuate the FPA effect, but only if the pre-exposure was relevant. Experiments 3 to 7 investigated whether evidence for competition effects could be found. Both Experiments 3 and 4, using an object array design and human movement respectively, were unable to provide the required alignment effects in isolation. Therefore no evidence for competition effects was forthcoming. Experiment 5 utilised an overshadowing design to see if competition could be found between the first-perspective and symbolic sources of information. No evidence of overshadowing was found but symbolic information was established as a potential source of spatial alignment. Experiments 6 and 7 used a blocking design to again look at competition between the first-perspective and the symbolic. Evidence was found for blocking; when the first-perspective was trained first it blocked subsequent learning about the symbolic. Experiments 6 and 7 therefore provide important evidence of competition effects in the spatial domain, free from alternative associative explanations. This is a key finding as it suggests a similar learning mechanism between temporal and spatial learning despite the differences in knowledge structure.

The results are discussed further in relation to the salience hypothesis of Wilson, Wilson, Griffiths and Fox (2007), the quasi-modular explanation of spatial learning (Jeffery. 2010), the universalist account (Pearce, 2009) and associative learning mechanisms (Rescorla & Wagner, 1972; Mackintosh, 1975).

# Chapter 1

## Introduction

### 1.1 Causal and spatial learning

This thesis addresses the question of whether causal and spatial knowledge are acquired via common or different learning mechanisms. Theories of causal knowledge have a long history within the associative tradition. Cause and effect are hypothesised to be modelled in the mind as associative links between representations of stimuli or events. Hypotheses about the structure of causal knowledge are largely tied to the passage of time. If event A regularly and exclusively precedes event B, it is a likely cause, and is perceived as such (Hume, 1763). However, as Hume pointed out, causation is not necessarily implied by a close temporal relationship. For example, as you travel through dense undergrowth, the sound of running water might regularly precede the sight of water, but the sound is not understood to cause the sight of water. Traditionally, spatial knowledge has been envisaged as having map-like or model like properties, incorporating at least two dimensions concurrently. This kind of representation mirrors the properties of spatial relationships in the real world. Therefore, and to simplify: the knowledge structures hypothesised to underpin causal-temporal and spatial learning are different in that the former models one-dimensional chains of events and the latter models events within a multi-dimensional frame.

A central proposal developed in this thesis is that irrespective of the final form of encoding of causal and spatial knowledge, which might reflect single and multidimensional relationships respectively, the mechanisms of acquisition of these kinds of knowledge does not necessarily differ. Common learning mechanisms could underpin both causal-temporal and spatial learning, even if the resulting representation of the two kinds of knowledge differs. Unfortunately, when hypothesising about spatial learning in particular, theorists have often confused mechanisms of knowledge acquisition and longer term knowledge structures. The proposal developed in this thesis argues that the confusion in theory has centred on whether or not processing some events influences the processing of others. To help to clarify it is appropriate to briefly review the major hypotheses which have guided research in both associative and spatial learning.

## **1.2 How do we learn about the world? Hume and the philosophical background to cause and effect**

The mechanisms that govern how we learn about the world are central to understanding ourselves, other people, and other species. The most fundamental aspect to learning is processing the relationships between events, both in time and space. Processing arrangements of temporal events forms the basis of an appreciation of cause and effect. For example, throwing a stone at a window is anticipated to be followed by breaking glass due to recall of similar previous successive events. Establishing such apparent cause and effect knowledge is essential for survival and meaningful interaction. Hume (1763) suggested that to establish ideas of cause and effect the observed objects or events must be contiguous, both temporally and spatially:

“I find that in the first place, that whatever objects are consider’d as causes or effects, are contiguous; and that nothing can operate in time or place, which is

ever so little remov'd from those of its existence... We may therefore consider the relation of contiguity as essential to that of causation." [Hume, 1763, pg. 377]

A delay between throwing a stone at a window and glass breaking would weaken the assumption that the stone caused the damage. Similarly, if a stone is thrown toward one window but another window breaks, the assumption that the stone has caused the damage is weakened. A further important idea of Hume's was that for 'perception' of cause and effect to be established the relationship between events need not be truly causative. Event A does not have to cause event B for a relationship between the two to gel in the cognitive system: the events simply have to be spatio-temporally contiguous. Assuming causality is essentially a logical fallacy known as *post hoc ergo propter hoc* (after this, therefore because of this). For something to be assumed to be a cause it does not actually have to be a cause. An example might be that even by this early point in the text the word 'cause' has become associated with the word 'effect' for the reader because of repetition, and contiguity in both space (within the same sentence and within a word of each other) and time (is read within seconds of each other). However it would be erroneous to assume that the presentation of 'cause' will lead to 'effect' being presented. The typing, or reading, of one word does not cause the other. A lack of a true causal relationship does not preclude associations between the two according to Hume, and whole chains of concepts can become associated to the point where the presentation or presence of one event can bring to mind another distant event. As Hume said,

"Tho' distant objects may sometimes seem productive of each other they are commonly found upon examination to be link'd by a chain of causes which are contiguous among themselves and to the distant objects; and when in any particular we cannot discover this connexion, we still presume it to exist." [Hume, 1763, pg. 377]

The lack of a need for a causal relationship between A and B in establishing a recalled relationship or association is routinely taken advantage of when studying associative learning

theories in particular. As illustrated in the next section, associations between events that represent causal chains can be studied experimentally even where the experimenter is aware that the events involved are not causally related.

### **1.3 Background to associative learning**

Historically, the formation of associations, or internal links between representations of newly presented stimuli/events, has been studied experimentally in most detail in non-human animal learning. Pavlov (1927) discovered that an innate response to a biologically significant stimulus, such as salivation to the presentation of food, could be elicited by another 'neutral' stimulus through a learning process based on temporal or spatial contiguity. In traditional terminology, the conditioned stimulus (CS) is a neutral signal (or potential cause in Humean terms) and an unconditioned stimulus (US) is a significant event that follows the CS (a possible effect in Humean terms). Pavlov found that repetition of a CS-US pairing led to the response originally elicited only by the significant stimulus (the 'unconditioned response' or UR) being elicited by the presentation of the CS (the 'conditioned response' or CR). In Pavlov's experiments the dogs heard, for example, the ringing of a bell (CS) before the presentation of food (US), and eventually started to salivate (CR) to the sound of the bell regardless of the presence of food. This is an experimentally controlled procedure for studying associative learning, referred to as classical conditioning. The central learning mechanism was assumed to be temporal contiguity between the CS and US. Note that, in line with Hume's analysis, the temporal succession or chain which leads to the CS activating a representation of the US in its absence, and triggering the CR, does not have to be truly causative. The explanation of the basic phenomenon of 'excitatory' classical conditioning, in which a CS occurs before a US, is now accepted to be that Pavlov's dogs salivated when the bell sounded because internal representations or memories of the two events had become associated (Mackintosh, 1983). Of course, in this procedure the bell does not cause presentation of the food.

Thorndike (1911) was another pioneering experimentalist who investigated changes in behaviour dependent on the temporal relationship between stimuli and responses. In his thesis, Thorndike proposed his 'Law of Effect' based on observations of cats in a 'problem box'. He originally intended to investigate whether animals were capable of insight learning, which is the rapid acquisition of a solution to a problem rather than a more gradual increment in ability to produce an outcome. In Thorndike's experiment a cat was placed inside a locked box. To get out it had to operate a latch, using a combination of simple mechanisms. To begin with the cat would unlock the box by chance and then have the opportunity to quickly eat before being placed back into the locked box. Over many trials the cats eventually learned to efficiently unlock the box and escape to the food source. Thorndike observed a gradual learning curve and no sudden improvements in performance that would suggest insight learning. He proposed that the solution was learned in terms of strengthening or 'reinforcing' of stimulus-response associations. Certain accidental movements against a lever were followed by the reward of being able to eat the food outside the box. Eating the food strengthened an association between the available temporally contiguous stimuli and the most recent response, leading to the action becoming more likely to be repeated in the presence of the same stimuli. When repeated on subsequent trials the movement was again followed by food further reinforcing the stimulus-response association to the point where the cat would perform the exact actions required for escape almost immediately upon being placed in the box. As stated by Thorndike:

"Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur." [Thorndike, 1911, pg 244]

The law of effect can be considered a mechanism for stimulus-response (S-R) associative learning, where a particular stimulus becomes connected to a particular response. In the case of Thorndike's problem box, the sight of a particular part of a mechanism becomes associ-

ated with a temporally and spatially contiguous physical response such as the animal rubbing against it, which then results in escape and the opportunity to eat, strengthening a connection between the sight of the mechanism and its operation due to the satisfaction provided by the food. S-R theory became a foundation for the investigation of ‘instrumental’ associative learning, and was subsequently developed by many theorists. For example, inspired by Newton’s laws, Hull (1943) built on the law of effect in an attempt to make a more predictive and mathematically formal rule of learning.

Early theories of both classical and instrumental learning were heavily dependent on a mechanism based on contiguity between events. However, in the 1960s and 1970s it became apparent that more than contiguity must be involved in associative learning (Kamin, 1969; see section 1.4). To accommodate the new findings (discussed below), Rescorla and Wagner (1972) introduced a theory based on contiguity but that also required a discrepancy between predicted and actual events, or more casually, ‘surprise’. The more surprising an event of importance such as a US, the more it provokes processing and the more likely it will be to enter into learned relationships with other contiguous events. Learning proceeds until the important event ceases to be surprising and ‘asymptote’ is reached. Temporal contiguity between learned events is still crucial, but must be supplemented with surprise. This was a very influential theory that became central to investigations of temporal and spatial learning.

## **1.4 Emergence of a split between temporal and spatial learning**

The Humean concept of spatio-temporal contiguity as the basis of learning became widely accepted during the beginnings of Psychology as a science and the early work on associative learning. However, evidence started to emerge that challenged associative theories, particularly the dominant versions of S-R theory. When applied to ‘spatial’, or perhaps more precisely ‘place’ learning, S-R theory proposed that the location of a goal was learned by strengthening a series of mechanical responses that happened to take the subject to a particular site. The location of the goal was not learned in terms of representations of spatial



relationships, but a series of left-right muscular responses when faced with a succession of familiar stimulus configurations. This view was initially challenged by MacFarlane (1930) who found that, on testing, rats could find a previously learned goal location even when navigating towards it required different physical responses to those supposedly strengthened during training. Rats were initially trained to swim through several enclosed alleys to get to a food box; when the water was drained the rats were still able to find their way to the food box while running. If they were navigating simply by S-R associations then the difference in physical response (between swimming and running) should result in an inability to reach the goal. The rats' ability to reach the goal suggested that they had learned something about the location of the goal within the environment: a specifically spatial relationship. Further evidence that provided a challenge to S-R learning came from Tolman and Honzik (1930b) who discovered that if a rat was left to explore a maze without any reward it would still learn about the layout, a phenomenon called 'latent learning'. Rats who had explored the maze previously but without finding food at the end of one of the arms out-performed rats with no previous experience in the maze. According to the law of effect this should not have happened. Without any reward to strengthen associations between stimuli and appropriate responses, nothing should have been learned. However, the rats had apparently learned something that helped them find the goal without the need for reward. Tolman theorized that spatial learning was different to traditional associative learning in that it resulted in a cognitive map. This mental representation of the immediate environment was spatial in character.

“The stimuli, which are allowed in, are not connected by just simple one-to-one switches to the outgoing responses. Rather, the incoming impulses are usually worked over and elaborated in the central control room into a tentative, cognitive-like map of the environment. And it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses, if any, the animal will finally release.” [Tolman, 1948, pg. 193]

This, Tolman theorized, accounted for latent learning: the map was automatically constructed without a requirement for ‘reinforcement’ of responses. Therefore, spatial learning was governed by different rules and processes to that of standard temporal learning as understood at that time. A series of experiments lent further weight to this explanation of spatial learning (Tolman and Honzik, 1930c; Tolman, Ritchie and Kalish, 1946; Tolman, 1948), suggesting, amongst other things, that rats were able to learn ‘place’ over response, and that when learned routes were blocked or made unavailable rats were able to choose the next closest, unlearned, route or appropriate shortcut. Also, MacFarlane (1930) trained rats to locate food in T-mazes or junctions. The food was always in the same location at the end of the same arm, and during training required the same physical response (right turn) to approach. At testing, the arm of the T was rotated so it was located on the opposite side of the choice-point. When approaching from the newly positioned arm of the T-junction the food was on the left. If the rat had learned the place it would turn left as the food was still in the same part of the environment. If however the rat had simply learned the response of turning right towards food then it would turn and approach the wrong part of the maze. MacFarlane found that the rat learned the place rather than the response. This reliance of place learning over S-R was later found to depend on the length of training the rats received (Restle, 1957). Limited trials resulted in apparent place learning, whilst more trials led to behaviour based on habitual S-R connections. Tolman et al. (1946) trained rats in a radial maze to go down one particular alley to find food. When it was blocked a significant number of the rats (above chance) chose the alley that would lead them closest to the goal. Once again, if spatial learning was simply governed by S-R learning then this choice should have been impossible other than by chance. Successful performance suggested learning about the location of the goal in space.

## **1.5 Theoretical accounts of cue competition**

The theory of automatic updating of a cognitive map during exploration was elaborated by O’Keefe and Nadel (1978), and was at odds with the newly emerging evidence from classical

Group	Training	Test	Result
Overshadowing	A <sub>B</sub> -> X	B	Poor Learning
Control	B -> X	B	Good Learning

Table 1.1: Overshadowing Design (Pavlov, 1927)

conditioning that not all events are automatically processed. Early theories proposed that the strength of an association between a CS and a US would grow independently of the presence of other CSs provided the two were temporally contiguous. Therefore, if CS<sub>A</sub> and CS<sub>B</sub> were presented together and followed by a US, each CS would eventually gain maximal associative strength with the US. However, evidence began to emerge that what was learned about one CS could be restricted by the presence of other CSs, a phenomenon known as ‘cue-competition’. This apparent restricted learning of one cue in the presence of another stood in opposition to the automatic updating of the relationship between all stimuli hypothesised within cognitive maps.

Pavlov (1927) was actually the first to describe a form of cue-competition with his overshadowing design. He found that when a dog was presented with two sources of simultaneous information (CSs A and B) to associate with the presentation of food (see Table 1.1) the dog would not necessarily learn about both CSs, or at least learn equally about one as well as if it was trained in isolation. One CS was learned about and associated with the US which then triggered the conditioned response, whilst little was learned about the other CS: one CS was said to have overshadowed learning about the other. This overshadowing was explained in terms of cue salience or intensity by Pavlov. He suggested that if one of the cues was more intense it would therefore be learned about to a greater extent than the other. For example, if a light and tone were presented at the same time, the light might be extremely bright, and the tone very quiet, or vice versa. The less intense cue was learned about when trained alone but not when trained in compound with a more intense cue.

Kamin (1969) discovered a second and extremely influential form of cue-competition known as blocking (see table 1.2). Blocking differed from overshadowing in that in the experimental condition, CS<sub>A</sub> was presented in relation to a US in phase 1, and then a second CS<sub>B</sub> was

Group	Phase 1 (Pre-training)	Phase 2	Associative Strength
Blocking	A -> US	AB -> US	A=1, B=0
Control	X -> US	AB -> US	A=.5, B=.5

Table 1.2: Blocking Design (Kamin, 1969) and associative strength predicted by the Rescorla-Wagner (1972) model

added to the first ( $CS_{AB}$ ) in phase 2. The control condition had similar training in phase 2 of the experiment, providing experience of the same relationship between  $CS_B$  and the US as the experimental group. Learning about  $CS_A$  in the first phase of the experimental condition restricted ('blocked') learning about  $CS_B$  and the US. For example if a rat was presented with a light (A), followed by an electric shock during the first training phase it would eventually learn about the light in relation to the shock and respond in anticipation of the shock when the light was presented. If then a tone (B) was added at the same time as the light during the second training phase, and the same shock again followed, despite many trials when the tone was presented, and was as temporally contiguous as the light, the rat would not respond to B on the test as if expecting the shock. The relationship between the light and the shock blocked learning about the relationship between the tone and the shock. In the control condition, learning about B was greater than in the experimental condition, and learning to A was less than in the experimental condition; associative learning to A and B was similar provided they were of similar salience.

The blocking design is a more convincing demonstration of cue competition than the overshadowing design because experience with B and the US is identical in both experimental and control conditions. As evidence by these finding of Pavlov and Kamin, temporal contiguity is not sufficient to explain these variations in learning because the overshadowed or blocked cue is temporally contiguous with the US in both experimental and control groups. It was not until Rescorla and Wagner's (1972) work on discrepancy learning that the first adequate explanation was developed. They proposed that surprise, or discrepancy between actual and anticipated US, is an essential component of learning. The surprise can be envisaged as linked to rehearsal of events, which in turn affects how much is learned. In the blocking example of the rat and the electric shock, the initial shock causes surprise which provokes rehearsal of

all temporally contiguous events including the light and shock. The CS is a temporally close event to the US; therefore CS and US are rehearsed at the same time and an associative link between the two is strengthened. On the second presentation of the light and the shock, the light will activate the US representation to a small degree; the US is again surprising, though slightly less so than before, and learning and rehearsal of the CS and US continues. This process continues over trials with the US becoming less and less surprising as the CS-US association becomes stronger, until surprise at the US presentation diminishes completely, and learning the CS-US relationship reaches maximum or asymptote. This happens to  $CS_A$  in phase 1 of the blocking design. In the second stage of the blocking design when  $CS_B$  is added to  $CS_A$ , and followed by the US, the US is not very surprising because it is predicted by  $CS_A$ , and maximum or near maximal learning about the US has already been achieved. The addition of  $CS_B$  is not very surprising in itself as it has no biological value: it is the surprise value of the US that is crucial.  $CS_B$  is still a good predictor of the occurrence of the US in terms of temporal contiguity, but as the association between  $CS_A$  and the shock means that the US is not surprising, very little is learned about the  $CS_B$ . The Rescorla-Wagner theory formalized this and presented discrepancy learning as the following (equation 1.1).

$$\Delta V_A = \alpha\beta(\lambda - V_X) \tag{1.1}$$

In this  $\Delta V_A$  represents the change ( $\Delta$ ) in the strength of association ( $V$ ) between the conditioned (CS), in this case cue A, and unconditioned stimulus (US).  $\lambda$  represents the maximum possible strength of the association between the CSs and US (here arbitrarily set at 100), and  $V_X$  refers to the current associative strength between all CSs present on the trial concerned and the US. The difference between  $\lambda$  and  $V$  is the extent to which the stimulus is surprising: the discrepancy.  $\alpha$  refers to the learning rate parameter governing the change in associative strength and is related to the salience of the CS; this normally has a value between 0 and 1.  $\beta$  in a similar fashion refers to the salience of the US. In much current literature  $\alpha$  and  $\beta$  are

combined as a single value represented solely by  $\alpha$ . Looking again at our rat and shock example, and substituting some arbitrary numbers, the formula predicts the learning about the light-shock relationship and the eventually blocking of learning about the tone. For example if we look at the first trial of the light (CS) shock (US) relationship. Here (equations 1.2)  $V$  will initially be 0 as no learning has yet taken place.  $\lambda$  is as mentioned above set to the maximum of 100 and the learning rate at .2. The resulting value of 20, or 20 units is the new associative strength to L.

$$\Delta V_L = .2(100 - 0) = 20 \tag{1.2}$$

The  $V_L$  strength from the first trial can now be added to the equation for the second trial. Following the same steps again (equations 1.3) we see an increase of 16 in the associative strength, leading to a total associative strength to L of 36.

$$\Delta V_L = .2(100 - 20) = 16 \tag{1.3}$$

Less is learned and added to the final associative strength on this trial due to the decrease in the size of the discrepancy between the CS and US (100 to 80). This gradual loss in surprise slows learning so as to form a negatively-accelerated learning curve until asymptote ( $V=100$  or  $\lambda=V$ ). For blocking we can use the same equation but split  $V$  into two for the compound stimuli of light ( $V_L$ ) and tone ( $V_T$ ), making the general equations look like the following (1.4).

$$\Delta V_L = \alpha[\lambda(V_L + V_T)] \tag{1.4}$$

$$\Delta V_T = \alpha[\lambda(V_L + V_T)]$$

If the light has already been pre-trained to asymptote as per the blocking design then it will have a value of 100, and conversely the tone, which has not been learned about at all, will have a value of 0. If we substitute these values in to the equation for what is learned about the tone we can see (equations 1.5) that nothing is learned/added to its' associative strength.

$$\Delta V_T = .2[100 - (100 + 0)] = 0 \tag{1.5}$$

$$V_T = 0$$

The rules of discrepancy learning can also be applied to overshadowing. When the combined associative strength of two stimuli equals 100 then learning will stop. Whether this learning for each stimulus is equal or not depends on their individual learning rates. As mentioned before, the learning rates in the Rescorla-Wagner theory relate to the salience of the stimuli, and if one is more salient than the other then the increase in learning rate will equate to a large increase in associative strength at the end of the trial. For example in the first trial (equation 1.6) where a light and tone, of unequal salience, are presented together differing levels of learning result. In this example the light is more salient than the tone.

$$\text{Trial 1} \tag{1.6}$$

$$\Delta V_T = .2[100 - (0 + 0)] = 20$$

$$\Delta V_L = .4[100 - (0 + 0)] = 40$$

In the second trial (equation 1.7) this imbalance increases further with the tone reaching an associative strength of 28 and the more salient light 56.

Trial 2 (1.7)

$$\Delta V_T = .2[100 - (20 + 40)] = 8$$

$$V_T = 28$$

$$\Delta V_L = .4[100 - (20 + 40)] = 16$$

$$V_L = 56$$

This then continues until the combined associative strength of the light and tone gradually reaches 100 as seen in the following figures of trials 3, and 4 (equations 1.8 and 1.9).

Trial 3 (1.8)

$$\Delta V_T = .2[100 - (28 + 56)] = 3.2$$

$$V_T = 31.2$$

$$\Delta V_L = .4[100 - (28 + 56)] = 6.4$$

$$V_L = 62.4$$

Trial 4 (1.9)

$$\Delta V_T = .2[100 - (31.2 + 62.4)] = 1.28$$



$$V_T = 32.48$$

$$\Delta V_L = .4[100 - (31.2 + 62.40)] = 2.56$$

$$V_L = 64.96$$

By the end of trials the light has been learned about to a greater extent than the tone despite them being presented at the same time. The Rescorla-Wagner theory explains overshadowing in much the same way that Pavlov (1927) suggested; as being a result of cues with differing intensities or saliencies. The novel idea in the model is that the total amount of associative strength is limited, such that multiple associations cannot concurrently continue to be strengthened until they reach full strength.

The Rescorla-Wagner model is not the only model proposed to account for blocking and overshadowing and which makes new predictions. Mackintosh (1975) suggests it is not how surprising the US is that is key to learning, but changes in attention to the CSs. He proposes that animals always attend fully to USs, and attend to stimuli that are better predictors of the US than those which are poor predictors of the US. All CSs are attended to initially depending purely on their physical salience, but subsequently attention increases to those that are better predictors and actively declines to poor predictors. To attend to the better predictor there must first be a comparison of cues to determine which is the better predictor, i.e. which has the greatest associative strength. In the blocking design Mackintosh theorized that during the first trial of phase 2 when  $CS_A$  and  $CS_B$  were presented together there would be no blocking to  $CS_B$ . Both CSs should be attended to provided both are physically salient enough. On this trial  $CS_B$  would be learned about equally in experimental and control groups. On the second trial of phase 2 though, when the full associative strength between  $CS_A$  and the shock is compared to the small associative strength between  $CS_B$  and the shock,  $CS_A$  is subsequently attended to more and  $CS_B$  attended to less. In this case, despite some learning

to  $CS_B$ , it is still not as good a predictor of the shock as  $CS_A$  which has been presented repeatedly beforehand. What has been learned about  $CS_A$  now blocks further learning about  $CS_B$  because it is no longer attended to. This comparison was formalised by Mackintosh (equation 1.10 and 1.1).

$$\Delta\alpha_A \text{ is positive if } |\lambda - V_A| < |\lambda - V_X| \quad (1.10)$$

$$\Delta\alpha_A \text{ is negative if } |\lambda - V_A| \geq |\lambda - V_X| \quad (1.11)$$

Here  $\Delta\alpha_A$  represents the change in attention to a particular CS (in this case A). There will be a positive change for cue A if the discrepancy between  $\lambda$ , the maximum associative strength to the US (as before), and the current associative strength for A, is smaller than the discrepancy between  $\lambda$  and the current associative strength of the other presented cue(s) (in the example, B). In other words, as A has gathered more associative strength than B, then more attention will be paid to it in further trials. If the reverse were the case (1.11), and A had less associative strength than B there is a negative change in attention to A.

## 1.6 Associative learning versus cognitive mapping

Learning theories based on temporal experiments were not seen as having necessary implications for spatial learning. Tolman's idea of an updating cognitive map was at odds with the S-R theory of his day, and with the later idea of competition for learning resources. O'Keefe and Nadel (1978) took Tolman's concept of the cognitive map and developed it further in the context of neurological findings. They described two systems that determine spatial abilities, the taxon and locale systems. The taxon system is associative in nature and comprises orientation learning and guidance learning. Orientation learning was in essence S-R learning, whereas guidance learning was closer to classical conditioning; a landmark or feature

would be associated with the goal, and the organism would be guided towards the goal by this association. The taxon system was therefore described as being devoid of uniquely spatial knowledge. True spatial learning was considered to be processed by the locale system, a cognitive map like representation that included spatial interrelationships. Changes in the environment from one exploration to the next would result in a mismatch between real world and map which would lead to automatic updating of the cognitive map. They cited place cells as supporting evidence for a map-like structure: cells within the brain that activate when the participant (typically a rat) was at a particular location. Specific cells increase in activity in specific locations lending weight to an almost literal brain mapping of the environment: a representation of spatial information coded in neurons in which the co-ordinates correspond to external co-ordinates. Evidence for this was found within the hippocampus of rats during single neuron studies. When O'Keefe and Nadel elaborated the theory of cognitive maps they considered the locale system to be immune from cue-competition. Further evidence for hippocampal involvement in spatial learning has been found by Doeller, King and Burgess (2008) in humans. Jeffery (2010) also presents a review of evidence for head orientation cells which may be part of the locale system originally proposed by O'Keefe and Nadel, or a related spatial learning module. These are cells that correspond to a specific head orientation within an environment rather than a specific location. These developments helped to preserve the notion of a cognitive map as independent from the laws of temporal associative learning.

An important elaboration of cognitive mapping theory can be found in the work of Cheng (1986) and Gallistel (1990) who investigated the use of geometric spatial structure during spatial learning, and suggested a separate 'geometric module' for processing spatial learning. Nothing in temporal associative learning finds a parallel to geometric relationships. Animals use a wide variety of cues in their surroundings to help reach a goal. Geometric information refers to information such as size, shape and arrangement or structure of and within the environment which can be used as a frame of reference to determine correct headings or the location of goals. For example the location of a hidden platform may be learned about in relation to its' proximity to a corner in the environment, consisting of two long walls meeting

at 90° (Cheng, 1986; Cheng & Gallistel, 1984; Gallistel, 1990). A large amount of evidence for the use of geometric cues or information comes from animal experiments, often on rats or chicks. Evidence for whether geometric cues are being used often comes from experiments which first train animals in the location of food relative to various environmental properties (geometric, featural, distant landmarks, etc.) and then remove or manipulate sources of information to observe what effect this has on performance (usually percentage correct choice in area of goal search). From the results of such experiments it is generally found that animals can use a variety of sources of spatial information, and that when one is removed others can be used, or that when certain ambiguities appear (due to the removal of features that differentiate walls, or the rotation of structures/shapes) systematic errors occur (Gouteux, Thinus-Blanc & Vauclar, 2001; Vallortigara, Fergulio & Sovrano, 2005; Vallortigara, Zanforlin & Pasti, 1990). Similar findings have also been apparent in human studies, usually with young children (Hermer & Spelke, 1994, 1996; Learmonth, Newcombe & Huttenlocher, 2001).

A key finding in this sphere is that while humans and other animals demonstrate the ability to use information other than geometric cues this does not mean they do not learn about geometry or are unable to use it. Indeed often when geometric information is presented at the same time as other types of information, such as colour, in what is essentially an overshadowing design, when the cues are tested in isolation accuracy remains good. For example Kelly, Spetch and Heth (1998) found that after presenting geometric and featural information together in relation to a target corner to pigeons, when one cue was removed for testing, use of the remaining cue remained high as evidenced by accuracy. A lack of overshadowing can be seen in other experiments (Sovrano, Bisazza & Vallotigara, 2002, 2003; Tommansi & Vallotigara, 2000). Furthermore a lack of evidence for blocking involving geometric cues has been noted in studies such as Wall, Botly, Black and Shettleworth (2004) in which pre-training the location in a square in relation to a beacon did not block learning about the location in relation to geometric information in rats. This is in line with Gallistel's (1990) proposal of a geometric module for spatial learning that is immune to associative

learning effects.

The idea of a geometric module, or even just separate modules for different aspects of the cognitive map has led to a wide array of theories on how they are integrated. One theory on integration can be found in Jacobs and Schenk (2003; see also Jacob, 2003 for a review). They suggest that three maps are involved and combined in their parallel map theory, one traditional integrated map, one coding for orientation and vector information and one sketch map containing traditional and topographical elements. The directional map which codes for vector information is considered to be 'coarse' and grid-like, using distant landmarks to help establish gradients and vectors. The sketch map consists of smaller local representations that may not necessarily be connected with other local representations. These are then both combined into the integrated map to develop an overall cognitive representation where not only can information about specific areas be accessed but vectors between them and distant features processed. In a similar fashion to O'Keefe and Nadel these distinct maps are linked by the authors to specific areas within the hippocampus. A similar system of integration was also suggested by McNaughton, Battaglia, Jensen, Moser and Moser (2006).

## **1.7 Indications of cue competition in spatial learning**

Most spatial learning studies have not revealed unambiguous evidence of cue-competition. However Wilson and Alexander (2008; see also Alexander, Wilson & Wilson, 2009) found evidence that cue-competition could indeed occur in spatial learning in humans. Wilson and Alexander's (2008) experiment used a virtual environment comprising an asymmetric enclosed space, within which there were one or more landmarks. The landmarks and walls were not adjacent to the goal, an invisible platform, so it could not be located simply by approaching a landmark or specific corner. Wilson and Alexander suggest that locating the goal was based on vectors in relation to environmental features such as the walls or landmarks. When one particular cue was used in pre-training to find a goal, this led to blocking

of subsequently introduced cues that could be used to find the goal, an example of blocking. In Alexander et al. (2009) a similar finding was made with the pre-training of a specific 2D shape (A) on the floor of an enclosure in relation to the hidden goal location blocked learning about a subsequently added shape (B) when A was initially presented with other auxiliary shapes. If spatial learning involved a cognitive map that updated automatically and made use of all information there should be no competition between these cues. No differences in performance would be anticipated when it came to finding the platform. The results however suggest that cue-competition in spatial learning can occur under certain conditions, and therefore that spatial learning and temporal learning mechanisms are not necessarily that dissimilar. This was further supported by a range of experiments, in rats, reviewed by Pearce (2009) which is discussed in the following section in regards to the 'Universalist' theory of learning or a global learning mechanism.

## **1.8 Universalist versus quasi-modular explanations of spatial learning**

As outlined above, one general learning theory is that we have a global or universal learning mechanism that applies to both temporal and spatial processing. Pearce (2009) reviewed a large number of experiments and was largely able to find parsimonious associative explanations for both types of experiment in which cue competition could be found, and even in some where expected cue competition was not found. He concluded that, regardless of any differences in the structuring of temporal and spatial knowledge, the mechanisms governing their acquisition are the same.

The opposing view is summarised succinctly by Jeffery (2010). This is the quasi-modular explanation of learning and addresses evidence for cue competition in some experiments and its relative absence in others by assuming spatial learning can be broken down into several distinct modules. Some of these modules such as the geometric (Cheng 1986; Gallistel, 1990) may be immune to cue competition and follow module specific rules. Whereas the

module involved with novel shortcut use, preferred orientation, local/global landmarks and other cues may fall under the scope of associative learning mechanisms and the related cue competition. The inter/intra modularity in spatial learning can perhaps be seen most clearly in studies focused on the geometric module. For example Doeller and Burgess (2008) found competition between landmarks in a virtual environment based study with humans but no competition between the boundary (geometric feature) of the virtual environment used.

If the universalist explanation of Pearce (2009) is correct then further investigation should reveal evidence of cue competition regardless of the type of spatial learning. If however further investigation reveals aspects to spatial learning and spatial experimental paradigms that are immune to the effects of cue competition then this would weaken the Universalist viewpoint. Such evidence would instead provide further support of the opposing view of quasi-modular spatial learning.

## **1.9 Cue competition in other areas?**

Cue-competition is an essential component to temporal or causal learning. The original occurrences of cue-competition (Kamin, 1969; Pavlov, 1927) posed difficult questions that then led to refinement of the mechanisms involved in temporal learning (Mackintosh, 1975; Rescorla & Wagner, 1972). Whilst traditionally cue-competition was considered to be confined to temporal learning there is some evidence that cue-competition operates in the spatial domain, whether between individual landmarks or geometric features, and there is evidence that sometimes cue-competition does not operate in the spatial domain. Competition between landmarks and other features have been shown in humans (Alexander et al., 2009; Chamizo, Anzar-Casanova & Artigas, 2003; Doeller & Burgess, 2008; Wilson & Alexander, 2008) and non-humans (Chamizo, Manteiga, Rodrigo & Mackintosh 2006; Pearce, 2009; Rodrigo, Chamizo, McClaren & Mackintosh, 1997). There is even evidence for competition between aspects of geometric information, irrespective of the supposed operation of a geometric module (Pearce et al., 2006). The problem is that much of what is described as ‘spatial’ learning

can be accounted for by mechanisms that do not involve true spatial learning (Mackintosh, 2002). Much of the evidence for cue-competition in the spatial domain can in fact be explained as a result of the taxon system being utilised (O'Keefe & Nadel, 1978). For example, finding a hidden platform in a variation of the Morris Water Maze (Morris, 1981) can be explained in terms of guidance to a landmark with which the goal has become associated, or view point matching. Mackintosh argues that on existing evidence, even the use of novel shortcuts could also be explained in the same fashion. If this learning depends on classical and instrumental conditioning and does not require true spatial learning, then the presence of competition ceases to be surprising or even relevant to the area competition and spatial learning. A major difficulty in determining whether an underlying learning mechanism similar to that of associative learning operates in the spatial domain is unequivocally demonstrating that true spatial learning is being investigated when competition like effects are found.

Further research on competition effect within the spatial domain requires a move away from tasks with potential associative solutions to those that unequivocally require true spatial learning. A truly spatial aspect to human learning and memory is spatial alignment effects which, as discussed in more detail in the following chapter, are preferences for certain headings and orientations when making spatial judgements from memory. These judgements are based on preferences for particular sources of spatial information. The measures used to detect alignment effects are based on spatial information in the form of angular judgements about objects within the environment. This kind of information is by definition truly spatial. As developed in the next chapter, this thesis proposes that if evidence for competition between sources of alignment effects could be found, this would be the strongest evidence of cue competition in truly spatial learning.



# Chapter 2

## Alignment Effects And Spatial Reference Frames

### 2.1 What are spatial reference frames?

Usually spatial learning is defined and investigated in relation to goal localization. However, goals can be located using many strategies that do not necessarily involve a spatial solution (Mackintosh, 2002; see section 2.5). Therefore, the results of goal localization experiments cannot be unambiguously interpreted as reflecting truly spatial learning. To investigate competition between sources of truly spatial knowledge, another spatially-based task is needed. One aspect to spatial learning that must appeal to purely spatial knowledge is the frame of reference that people adopt when recalling a learned space. Spatial reference frames are mental constructs of space that utilize specific sources of information. They are a system of arranging information from preferred perspectives for efficient encoding or recall. They do not normally call upon all available spatial information, but a sub-set of information which potentially makes recall more efficient. It could be said that using a particular frame of reference is more efficient, or at least takes less processing, than actively trying to remember and hold all salient environmental perspectives mentally. Shelton and McNamara (2001) define a spatial reference frame as:

“a relational system consisting of located objects, reference objects, and the spatial relations that may obtain between them. The reference objects may be any objects whose positions are known or assumed as a standard and include the observer; landmarks; coordinate axes; the planes defined by the walls, floor, and ceiling of a room; and so forth” (Shelton & McNamara, 2001, pg.2)

As reference frames are by definition spatially based perspectives of an environment, they conform to an aspect of true spatial learning. There are several types of spatial reference frame. The three most commonly researched are egocentric, intrinsic and allocentric. The egocentric frame of reference relies on information taken from a first person perspective such as retinal co-ordinates. It is largely based upon personal spatial orientation (Easton & Sholl, 1995; McNamara, Rump & Werner, 2003; Mou, McNamara, Valiquette & Rump, 2004; Sholl & Nolin, 1997) and is body-centred (Bryant & Tversky, 1999; Franklin & Tversky, 1990). The intrinsic frame of reference is based on the arrangement and properties of objects within the environment. For example the common orientation of chairs in a lecture hall indicate where the front of the room is considered to be (Kelly & McNamara, 2008; Mou, Fan, McNamara & Owen, 2008; Mou & McNamara, 2002) or an arrangement of objects can define a vector (Easton & Sholl, 1995). It is also possible for the intrinsic frame of reference to refer to a single object rather than an arrangement. Using a chair as an example again it is possible to refer to a referent as being ‘behind’ the chair though it may not be behind the observer. The allocentric frame of reference relies on the structure and generally more distal overall layout of the environment, and has been hypothesised to be orientation free, although this is controversial (Coluccia, Mammarella, De Beni, Ittyerah & Cornoldi, 2007; McNamara et al., 2003; Mou et al., 2004). Of all the frames of reference the allocentric is somewhat similar to that of geometric module discussed previously in terms of the features used and are sometimes described as being geocentric.

## 2.2 How are reference frames indicated?

Which reference frame is being used to recall a particular environment is usually inferred experimentally through alignment effects. Participants are asked to make imagined judgments of relative direction (JRD's) after experiencing an environment. These often take the format of, "Imagine you are standing at object A. Directly ahead/behind you is object B. Point toward object C." Participants usually use some form of pointing device to indicate the direction of the target object relative to their imagined location. The discrepancy between their estimation and the actual direction in degrees is then recorded, and often the time taken to make the decision is also recorded. Using different imagined locations and facing orientations it is possible to see whether participants are more efficient when imagining themselves in certain orientations, as well as whether they are better able to make 'forward' or 'backward' judgments (that is, with respect to their imagined location and facing direction). Typically, these judgements are defined as either aligned with a particular perspective (at  $0^\circ$ ), misaligned (rotated from this perspective, often at  $45^\circ$  or  $90^\circ$ ) or contra-aligned which is a special form of misaligned judgement (rotated  $180^\circ$  from the aligned perspective). These differences between efficiency of judgements, when significant, are referred to as alignment effects; they show a preference for particular imagined alignments over others: that is, orientation-dependence. These preferences may allow the experimenter to infer a particular reference frame. For example better judgements when aligned with the structure of a rectangular room might indicate a geocentric or allocentric frame of reference, where as better judgements when aligned with the forward view of an environment may indicate the adoption of an egocentric frame of reference.

Alignment effects and the frames of reference they reflect have been investigated in various ways. Two of the most common experimental designs either utilise some form of object array or exploration of a route. For example a key study with regard to frames of reference and object arrays is that of Easton and Sholl (1995). They found evidence for an egocentric or a body-centred frame of reference being used when there was a lack of regular structure to an array of objects. In their first experiment participants viewed an object array and were

later asked to make rotational and translational judgments about the objects. The further both rotational and translational judgments were from the actual view the larger the error and latency reported. This finding was replicated for rotational judgements, which are equivalent to JRD's, throughout the study whether the object array was irregular in arrangement or not. Even when there was a regular object to object arrangement that could potentially be used as an intrinsic frame of reference the rotational judgements were more efficient for the original viewed heading. Overall the evidence supported the idea that a body centred frame of reference is used in conjunction with an intrinsic or allocentric frame. This finding was supported by Mou, McNamara, Rump and Xiao (2006) who hypothesised that objects were located using an egocentric frame of reference when the information that formed a possible allocentric frame of reference was of low fidelity.

The use of object arrays to investigate alignment effects and frames of reference has a long history: the important Easton and Sholl study replicated the even earlier design of Reiser (1989), and is still very common. This is because object array based experiments can be very precise when it comes to the definition and investigation of sources of spatial information. In the Sholl and Easton study for example the object array design lent itself to the investigation of both an egocentric frame of reference based on the experienced views, and any potential intrinsic frame of reference use based on the regularity and shape of the object array. In many of the studies that have followed it has been possible to also include investigations of frames of reference based on the structure of the environment within which the object array is viewed by changing the shape and size of the test setting (Nardini, Atkinson, Braddick & Burgess, 2008; Shelton & McNamara, 2001).

An alternative to object arrays is route, or exploration, based investigations. These usually involve the exploration of a route within a novel environment, and perhaps are a more dynamic, or realistic, method of investigating spatial learning and alignment effects than the abstract and often statically viewed object arrays. For example a study by McNamara et al. (2003) utilized a real-life, large, park. Participants were led along a route and taught the location of several objects along the way. Half of the participants followed a route which was aligned

with the walls of a large building, and the other group followed a route that was misaligned (by 45°) with the building walls. When making JRDs, participants who had taken the aligned route were more accurate at making judgments which were aligned/parallel to the building and also when the imagined test orientation headed towards a distant lake. For participants in the misaligned group JRD accuracy was better for judgments towards the lake. The authors suggested the evidence demonstrates a use of the environmental properties to define a frame of reference but with influence of an egocentric perspective due to the preference for the distant lake. Not only do exploration based experiments allow for a realistic, and therefore potentially more valid investigation of spatial learning, but as clearly seen in the results of McNamara et al. (2003) they facilitate the investigation of sources of alignment and related reference frames. Though both types of experimental design are investigated in this thesis the majority of the presented experiments are based on the exploration design. Attempts to replicate array-based effects met with little success (see Chapter 5).

### **2.3 The First Perspective Alignment effect (FPA)**

The First Perspective Alignment effect (FPA) refers to significantly more accurate judgments when participants imagine themselves in alignment with the very first experienced perspective, or direction of travel, within a novel environment than those that are misaligned or contra-aligned with the first perspective. This can occur despite extensive exploration of an environment with equivalent exposure to multiple directions. The FPA effect has been shown to be a strong and reliable with the procedures to be described. Therefore, this form of alignment effect was identified as a potential effect to use in cue competition designs in addition to that reliably obtained from the influence of intrinsic structure. However, at the start of the current research project a full understanding of the conditions that produce this effect had yet to be established. The experiments in this thesis first definitively established the conditions that produce the FPA effect; then, utilised the reliability and strength of the FPA effect to investigate competition between alternative sources of alignment.

The occurrence of the FPA effect is well documented, especially when using secondary media such as verbal route descriptions and virtual environment (VE) learning. For the purposes of this thesis, secondary media can be considered those that do not include first-hand experience of a real-world environment, and instead rely on descriptions or computer simulation.

Whilst previous studies such as Easton and Sholl (1995) and others had indicated a preference for egocentric frames based on initial views of environments and arrays, a key study in the investigation of the FPA is that of Wilson, Tlauka and Wildbur (1999). They asked a group of participants to imagine a map like view of a U-shaped route (see Figure 3.2 in Section 3.2.1), and a second group was asked to imagine walking that route. Despite previous real-life findings (Presson, DeLange & Hazelrigg, 1989; Sholl, 1987) revealing a lack of preferred orientation or alignment effect when exploring a route, a FPA effect was found when this exploration was text based. The FPA was also present in the map description group. In Wilson et al.'s following experiment, the 'size' of the text environment was increased by adding more detail and making it less abstract in an attempt to ensure participants would imagine walking along the route in a first-person/egocentric view rather than from an above, map like, view. Though not all of the participants maintained an egocentric view of the textual environment the remaining participants did show a FPA effect. The way in which the textual information was presented was altered for the final experiment. Three groups either, read a text description of the environment, listened to an audio version, or experienced the environment as a VE. The FPA effect once more appeared in the text and audio groups but not in the VE group. A subsequent comparison of the groups error data suggested that verbally acquired spatial information is processed differently to visually acquired spatial information. This study was one of the first of many to note the frequency of the appearance of the FPA effect, and some of the inconsistencies in its appearance between presentation types. It also began to move the investigation of the FPA towards VE use.

Wilson and Wildbur (2004) built on Wilson et al. (1999) by using only VE's. First they replicated the essential features of the text experiment in an attempt to see whether this FPA effect in text could apply to VE's. Participants explored a U-shaped route around two dif-

ferent VE's. The two VE's both contained connected streets but one was more open to the surrounding area, while the other was enclosed. The participants took a JRD test after the exploration of each VE, and the order in which the VE's were explored was counterbalanced across participants. There was a FPA effect when participants were tested after the first exploration of a VE. Data from the second tested VE revealed an attenuation of the FPA effect. The second experiment closely examined this attenuation of the FPA effect between VE's by omitting the relevant test after the first exploration. This resulted in a FPA effect suggesting strongly that the testing in Experiment 1 after the first VE had an attenuating effect. This may have been due to the experience of the first test aiding participants in attending to other salient information at relevant locations throughout the VE other than the first perspective. The study demonstrated not only that the FPA effect could be expected in VE's under the right circumstances, but also that differences in procedure could attenuate the effect.

A further development comparing VE's to real-world exploration in regards to the FPA effect was made by Wilson, Wilson, Griffiths and Fox (2007). This experiment systematically investigated whether differences in size and type of environment would have an effect on the presence of the FPA effect in primary (real-world) and secondary media. In previous real-world studies the FPA effect had only been found when the environments were relatively small or room sized (Palij, Levine & Kahan, 1984; Shelton & McNamara, 2001). A larger environment would perhaps lead to the reliance on spatial information other than that of the first perspective and may instead promote an allocentric and orientation free frame of reference, explaining the difference between the presence of the FPA between different scaled environments in the literature (McNamara & Valiquette, 2004; Shelton & McNamara, 2001). This experiment also attempted to explain the differences and inconsistencies in results between real-world and other media when looking at alignment effects (Richardson, Montello & Hegarty, 1999; Rossano, West, Robertson, Wayne & Chase, 1999). In the first experiment three groups either explored a U-shaped route around an enclosed corridor, saw a video of the corridor being explored or experienced an audio description of a walk round the corridor. An FPA effect was present in all groups. This was predicted for the audio and video groups

consistent with previous studies (Wilson et al., 1999; Wilson & Wildbur, 2004). The presence of the FPA effect in the real-world exploration differed from the Richardson et al. (1999) results where they found a difference in alignment effect in primary and secondary media: after real exploration along the corridors of a building no alignment effects were present, however when exploring a VE or using a map to learn the route, alignment effects were found (see also Rossano et al., 1999). Size of the explored environment as a variable was explored in the second experiment. The structure of the corridor-route remained the same as that of Experiment 1 but it was scaled up by taking place in a larger building. No FPA effect was found in the errors but it was present in the latencies. The enclosed nature of the route was changed for Experiment 3, and participants explored a route around the outside of a building. The FPA effect was attenuated in the results. This led Wilson et al. (2007) to suggest what they called the salience hypothesis to explain the differences in FPA results, not only in their own paper but between the various types of experimental media, scale and real-world settings in the literature (see section 2.4).

Further evidence for the dominance of the first perspective in object array based experimental designs can be seen in Mou et al. (2004). Although the study dealt mainly with whether acquired spatial information was updated by locomoting through an environment, a preference for the first perspective was found even when the participants were tested in the location physically opposite their initial view. The structure and shape of the room in this experiment had no effect on spatial learning. The lack of influence of the room structure was contrary to previous studies such as Shelton and McNamara (2001; see also Shelton & McNamara, 1997a, 1997b). They conducted seven experiments on alignment effects when viewing a real-world object array. Over the course of the experiments Shelton and McNamara (2001) found evidence of a preference for the first perspective over secondary, tertiary and novel views; essentially a FPA effect. When the learned view, even the first view, was misaligned with the structure, participants performed no better when imagining themselves aligned with it than with a novel perspective. However when the structure did not provide an alternative source of alignment the FPA effect returned.



As can be seen from the above studies the FPA effect is present in many different settings and experimental designs such as route based exploration and the viewing of object arrays. Whilst there are some inconsistencies over its' occurrence in certain situations (real-world versus the virtual, and indoor versus outdoor) the strength and reliability of the effect under well defined circumstances makes it a promising alignment effect with which to begin investigating spatial competition. The question that needs addressing first, however, what specific conditions determine whether the FPA effect will occur? From a methodological standpoint it is difficult to devise experiments where participants do not have a first perspective of the environment, and consequently be unaffected by the FPA effect. The first part of this thesis establishes the factors that influence the presence and the attenuation of the FPA effect in preparation to use it as an experimental tool to investigate cue competition.

## **2.4 Issues with the FPA**

Though potentially an interesting and useful source of alignment encoding to use in the investigation of competition between different sources of spatial information, the use of the FPA effect as it stands is not without problems. As already evident from the previously mentioned studies there is a tendency for the FPA effect to be found predominantly in secondary media, but a relative paucity of support for it in real-world studies (Nori, Grandicelli & Giusberti, 2006; Presson et al., 1989; Richardson et al., 1999; Rossanno et al., 1999; Sholl, 1987; see also Experiment 3 Wilson et al., 2007). This could potentially mean that the FPA effect is actually a phenomenon largely confined to VEs and other secondary media, and that its inconsistent appearances in real-world settings are due either, to problems with experimental characteristics such as scale and available distal features, or more complete spatial information (e.g. vestibular) in the real-world. While VE's are useful tools for investigating spatial learning, that usefulness is limited if the findings are limited to secondary media.

As hypothesised by Wilson et al. (2007) one potential explanation for the disparity of results between the real-world and virtual (also indoor versus outdoor, and small versus large-scale

environments) could be that of the available detail which could influence the salience of the initial perspective. Wilson et al. found a difference in the strength of the FPA depending on the environment in which training and testing was carried out. In one of their experiments when participants were tested in an open outdoor, real-world, environment the FPA was not present. However when participants were tested in an indoor, real-world, corridor the FPA effect was present. Wilson et al. suggested this difference was due to the differences in the salience of the available detail between the two types of environments. This salience hypothesis states that when environments are impoverished there is a lack of salient information that can be used to form anchor points (as described by Couclelis, Golledge, Gale & Tobler, 1987). According to the anchor point hypothesis of Couclelis et al., instead of mentally representing an environment as one continuous space or map, as Tolman suggested, we instead utilize a series of anchor points or nodes of spatial information. These anchor points, instead of being universally available cues such as landmarks, could be personal organizational frames of reference applied to the environment in various locations. These anchor points could comprise of local spatial information as well as be used to organize and define wider spatial information. For example a person may form an anchor point based around the location of their own front door. The structural information of the nearby street, the vector of traffic, the orientation of the house itself and even distant visible landmarks would all help to define the anchor point. This information may even form preferred alignments or orientations. Another anchor point could, of course, be based at the person's place of work and the structure of the environment there, the available cues and other information could again create another frame of reference to be used spatially. These points within the environment would link together structurally to create an understanding and impression of the whole. This can perhaps be seen in studies where subjects (human and non-human) are only able to make correct novel shortcut choices when they have experience which connects subspaces within the environment (Stanton, Wilson & Foreman, 2003; Wilson, Carter, Woulfe & Southall, submitted). The segmented properties of the anchor points though would not necessarily form a complete and accurate map, at least in terms of contiguous information, and instead would

potentially be distorted across (though not within) the anchor points.

In relation to the Wilson et al. (2007) salience hypothesis and the FPA effect, it could be that the preferred alignment is based on an anchor point at the start of exploration or exposure to the first experienced perspective. Participants may use their initial perspective and heading to determine their own 'conceptual north' and define and organize the structure of the environment as a whole. When there is little other distal information to be used as an alternative, then this initial first perspective anchor point may be relied on heavily. However when there is more environmental detail, or exploration of the surroundings, there may be opportunities to form alternative anchor points that define other preferred alignments or contain salient spatial information that can be used instead to form an allocentric representation. An increase in the availability and use of other salient cues and information should then attenuate the FPA effect. This is a promising hypothesis that could explain many of the inconsistencies in the presence of the FPA effect mentioned, and warrants investigation before the focus of the thesis moves on to that of competition effects.

## **2.5 Research Aims**

Evidence for cue-competition in spatial learning designs is becoming increasingly available (see Pearce, 2009 for a review). What is not clear is to what extent human or animal participants are using truly spatial information to solve the experimenter defined tasks. The evidence for cue competition is limited by the body of evidence showing that certain aspects of spatial learning appear to be immune from cue-competition effects (Cheng & Newcombe, 2005) and therefore potentially subject to different learning mechanisms. Even the recent withdrawal of support for a completely impervious geometric module in favour of increasingly associative explanations (Cheng, 2008) has not undermined the suggestion of a quasi-modular approach to spatial learning (Jeffery, 2010). The quasi-modular theory of spatial learning, that different modules acquire spatial information differently, can potentially explain the inconsistencies in

the literature but there is perhaps an even simpler explanation. As mentioned previously, it may be that learning is governed by the taxon system which is suggested to be associative in nature rather than spatial (O'Keefe & Nadel, 1978). For example, many of the experiments where cue-competition is found use a hidden platform design based on the Morris water maze (Morris, 1981), and navigating towards the correct area may not require spatial information. If the location of the platform is indicated by the presence of a nearby landmark, then rather than learn about the location of the platform relative to the landmark the subject may simply approach the landmark until their view of it matches the view they saw when previously at the platform. In associative terms they would have associated a view of cue A (the landmark) with the goal and the more congruent their current view of the landmark was the more strongly it would bring to mind the concept of the goal. Finding cue-competition effects would not be a surprise in this case as only associative learning is required, no spatial information or learning has been required.

With sufficient ingenuity, this criticism (Mackintosh, 2002), can be applied to the majority of studies that have revealed cue-competition. In some case the criticism may strain credulity, but even in experiments designed to try and overcome this problem some doubt still remains. For example in the Wilson and Alexander (2008) experiments a distant landmark was used on the assumption that vectors to the goal would have to be learnt rather than the goal location simply having proximity to the landmark. Vectors fall securely into the spatial domain as they comprise distance and direction information. Unfortunately, in Wilson and Alexander's experiment locating the goal may still have been achieved without reference to a learnt vector, instead due to orientation and detail of the major landmark participants may have aligned themselves with its face, i.e. the participant may have located the platform simply by knowing that when they faced one side of the landmark so it appeared a certain relative size, then they were adjacent to the platform. Even shortcutting studies where participants have to navigate by using previously untrained novel shortcuts between goals can be similarly criticised (e.g., Foo, Warren, Duchon & Tarr, 2005; Stanton et al., 2003; Wilson et al., submitted). Participants in these experiments may not be using a cognitive map, or using other spatial

information to take a novel shortcut and navigate successfully. They may have been trained to navigate from A to B, and then from A to C and be asked to navigate from B to C but this does not mean that spatial information is being used. Once again they may navigate to C by attempting to approach a previously learnt view of C; one learnt during the original A to C training.

These criticisms mean that there remains a lack of sound evidence for competition within the spatial learning domain, and therefore uncertainty as to whether there is a similar learning mechanism for both temporal and spatial learning. Addressing this issue is the main focus of the thesis and is addressed by using a design and dependant variable that can be considered truly spatial in character. In designs similar to that of Wilson et al. (2007) and those that use JRD's no specific goal locations are used and during the test participants do not navigate towards goals. These tests simply reveal preferred alignments when making spatial judgements from memory. These preferred alignments and frames of reference may or may not be acquired using learning mechanisms similar to those underpinning associative learning but they still comprise spatially represented structures. The preference for one imagined alignment over another cannot, it is argued in Chapters 7 and 8, be explained in non-spatial terms. If competition effects can still be found using such spatial measures that will lend further support to the concept of a common type of underlying learning mechanism, as well as undermine the concept of a constantly updated cognitive map. A lack of competition between spatial learning sources would suggest that in truly spatial learning, mechanisms in common with associative cue-competition learning do not apply. However before the main research aim can be explored using the FPA effect, this alignment effect needs further experimental clarification.

The pervasiveness of the FPA effect makes it an ideal source of alignment to create research effects. It is clearly detectable across a variety of designs such as active exploration (Wilson et al., 1999; Wilson et al., 2007), passive exploration and descriptions (Wildbur & Wilson, 2008; Wilson & Wildbur, 2004) and even from the viewing of object arrays (Mou et al., 2006; Shelton & McNamara, 2001). However, it is appropriate to have a more complete un-

derstanding of the effect if it is to be used to make inferences. The problem to be addressed in the first instance is the inconsistencies in the presence of the FPA effect across different media. While the FPA effect is often present in text and verbal descriptions (Wildbur & Wilson, 2008; Wilson & Wildbur, 2004), and reasonably reliable in VE's (Wilson et al., 1999; Wilson et al., 2007), there is a comparative lack of FPA effect in outdoor real-world exploration (Richardson et al., 1999; Rossanno et al., 1999; Wilson et al., 2007, Experiment 3). If these discrepancies are due to a qualitative difference between real-world experience and secondary media then inferences about alignment effects in VE studies may not be applicable to real-world spatial learning. The following chapters in the thesis first test the salience hypothesis and other related explanations for the differences in FPA results across different media and settings. Once these fundamental issue have been discussed the focus of the thesis moves onto the area of competition between different sources of spatial alignment.

# Chapter 3

## **Investigating the Saliency Hypothesis: No attenuation of the FPA effect with differing levels of detail or VE type**

### **3.1 The FPA Effect Saliency Hypothesis**

The saliency hypothesis was put forward by Wilson et al. (2007) as an explanation for the disparity in the presence of the FPA effect between certain real-world experiments, and between real-world and secondary media such as VE's. The FPA is commonly found in verbal/audio descriptions (Wildbur & Wilson, 2008; Wilson & Wildbur, 2004), video viewing (Wilson et al., 1999) and VE exploration (Wilson et al., 2007) but less so in actual real-world settings (Richardson et al., 1999; Rossano et al., 1999, Wilson et al., 2007 Experiment 3). The saliency hypothesis suggests that the reason why the FPA is present in secondary media is because of a lack of alternative salient anchor points to the first perspective. Anchor points, as originally suggested by Couclelis et al. (1987) are, primary nodes or reference points that anchor distinct regions in cognitive space. Rather than a complete cognitive map the mental representation would be a collection, or collation, of individual anchor points and the spatial information contained in them. In relation to the Wilson et al. (2007) saliency hypothesis it could be that the FPA is based on an anchor point. Participants may use their initial per-

spective and heading to determine their own conceptual north and define and organize the structure of the environment as a whole. When there is little other information to provide alternative orientations or supplements this initial perspective anchor point may be relied on heavily. However when there is more spatial detail, or greater opportunity for exploration of the surroundings, there may be opportunities to form alternative anchor points that define other preferred alignments or contain salient spatial information that can be used instead. An increase in the availability and use of other salient cues and information should then attenuate the FPA effect. Some potential evidence for this being the case may be seen in Wilson et al. (2007) when the results from Experiment 1 and 3 are compared. For Experiment 1, participants explored a real-world environment alley which was considered enclosed. The walls around the route the participants explored limited the amount of distant information that could be seen and therefore utilized. In this enclosed environment, even though it was set in the real-world, a FPA effect was found. In Experiment 3 the participants explored an equivalent route around a large outdoor building and there were no walls surrounding the route to limit the amount of available information. In this case there was no FPA effect; the change from enclosed environment to open had attenuated the FPA effect. According to the anchor point, or salience hypothesis, this was because more information and detail was available in the open environment that could be used to create equally, or more salient, anchor points than the anchor point formed at the point of the first perspective. When the environment was enclosed though such salient information was limited and first perspective would be relied on more. If this is the case not only would differing levels of general detail affect the presence and strength of the FPA effect but so should changes in the type of environment explored; enclosed or open, indoor or outdoor. This would explain some of the results in the Richardson et al. (1999) paper where after real exploration along the corridors of a building no alignment effects were found. However when exploring a VE or using a map to learn the route, alignment effects were found.



## 3.2 Experiment 1

The following experiment attempted to assess the salience hypothesis by manipulating both the level of available detail within the VE as well as the type of VE experienced. Building on the designs of Wilson et al. (2007) the Experiment 1 involved participants exploring a similar U-shape route and then being tested, through JRD's, on target objects pointed out to them during exploration. To test the salience hypothesis, the VE's differed in detail (impoverished, rich) and type of surroundings (indoor, outdoor) (see Figure 3.1). Rich VE's had a wealth of detail in the form of objects and surface textures and were as visually close to a 'real' environment as is possible using the current VE editor and engine. Impoverished VE's in contrast contained the bare minimum of surface textures and objects other than the targets objects for the JRD test. The indoor VEs were enclosed corridors and outdoor VEs comprised a route around the outside of a building. This allowed for a continuum of available detail from the theoretical maximum (Rich Outdoor) to the minimum (Impoverished Indoor).

According to the salience hypothesis, increasing detail should equate to increasing amounts of salient spatial information to form alternative anchor points of equal or greater salience to the first perspective. According to the salience hypothesis VEs high in detail and open or outdoor should show no FPA effect. Where as VE's which are relatively impoverished, and enclosed or indoor, should show a clear FPA effect. Potentially, the strongest FPA effect should be found in impoverished indoor VE's. As such the experimental hypothesis was that the level of available detail (Impoverished Indoor, Impoverished Outdoor, Rich Indoor, Rich Outdoor) would systematically affect the presence and strength of the FPA effect.



Figure 3.1: First person views of the VE's used in Experiment 1 taken from the start of one possible route. Upper two panels: Rich Outdoor and Impoverished Outdoor. Lower two panels: Rich Indoor and Impoverished Indoor. The brush and trolley pictured in each case served as two of the target objects.

### 3.2.1 Design

Participants actively explored a U-shaped route within either an impoverished outdoor virtual environment (VE), an impoverished indoor VE, a rich outdoor VE or a rich indoor VE. The rich outdoor VE consisted of a selection of buildings and outdoor objects. The rich indoor environment was a rectangular corridor with indoor objects. The impoverished outdoor VE has the same central building but no other buildings or objects other than those for testing. The impoverished indoor VE had the same dimensions as the rich corridor but contained no objects other than those for testing. For the participants in the indoor groups, the U-shaped route was around the corridor itself, which was matched in dimension/size with the outdoor building (see Figure 3.2). There were eight possible versions of the route to control for: the combination of tested objects, the effects of route length (four routes had the first leg as the shortest and four routes had the last leg as the shortest) and turn direction (four routes had only 90° left turns and four routes had only 90° right turns).

The independent variable was the type of VE explored (Rich Outdoor, Rich Indoor, Impoverished Outdoor or Impoverished Indoor). The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency to make the JRD's (in seconds).

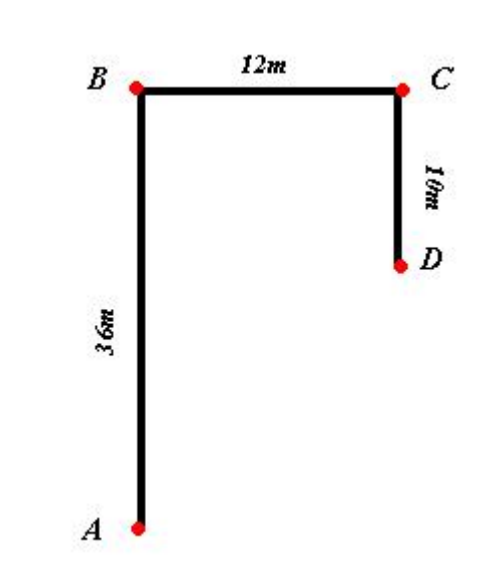


Figure 3.2: Example of U-shaped route taken. Letters indicate placement of objects.

## 3.2.2 Method

### 3.2.2.1 Participants

The participants were 96 undergraduate students who took part in partial fulfilment of a course requirement. Their mean age was 21.3 (range:18 - 58) and of these 24 were men (5 in Impoverished Indoor, 5 in Impoverished Outdoor, 6 in Rich Indoor and 8 in Rich Outdoor). They were pseudo-randomly allocated to one of four groups (n=24) with the constraint that approximately the same number of men served in each.

### 3.2.2.2 Apparatus

All desktop VE's for this thesis were created using the Hammer editor for the Half Life 2 Game Engine. All VE's were presented via an Intel Pentium Desktop computer with SVGA graphics, displayed on a 17-inch LCD monitor. The 4 arrow keys/cursors were used for navigation. The Up (↑) and Down (↓) key controlled forward and backward motion respectively. The Left (←) and Right (→) key rotated the direction the participant was facing. Walking speed was set at the in VE equivalent of 2.86 metres per second, the participants field of view

within the VE was set at 75° and the time taken for a complete 360° standing rotation was approximately 4 seconds. The controls and the details of movement were the same throughout all experiments.

Practice and test questions (JRD) were presented using a Java based pointer program for this and all experiments. The program recorded both the decision latency and the angle error in the orientation judgement. The decision latency was recorded from the moment the test question was presented to the moment when the pointer was de-selected. The mouse (left mouse button) was used to select the pointer and move it to the estimated position of the target object (see Figure 3.3).

The Rich Outdoor environment was based on the real-life outdoor environment used by Wilson et al. (2007, Experiment 3). Participants were asked to follow a path adjacent along 3 of the exterior walls of an oblong building located at the centre of the environment. The environment contained several other buildings and appropriate objects (trees, cars, benches, bicycles etc). Translating to an 'equivalent scale', the building was 36 metres by 12 metres by 9.6 metres. Six objects were placed around the route. These objects marked the points A, B, C, D and W, X, Y, Z (see appendix A). The objects were a newspaper, a bucket, a concrete block, blue barrel, trolley and a brush.

The Impoverished Outdoor VE had the same central building but no other buildings or objects other than the target six.

The Rich Indoor environment had comparable dimension to that of the outside building. The inner wall was a rectangular block 36 metres by 12 metres by 9.6 metres. The width of the corridor was 3 metres to allow the participant room to move. The environment contained several other appropriate objects (doors, radiators, shelves, chairs etc). The same six target objects as in the outdoor VEs were placed around the inner wall of the corridor at the same relative locations.

The Impoverished Indoor VE had the same dimensions but contained no objects other than the target six.

*Imagine you are standing at the ?*  
*Directly behind you is the ?*  
*Point to the ?*

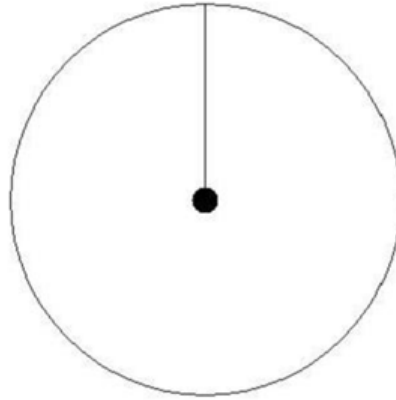


Figure 3.3: Example of the pointer and format of the JRD questions

The practice environment was a 68.2 metres by 68.2 metres by 10.5 metres enclosed space containing four, set apart, objects (Arch, Column, Platform and Walls) (see Figure 3.4).

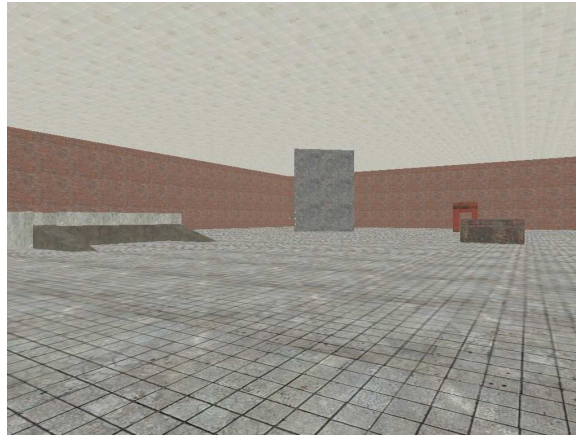


Figure 3.4: First person view of the practice VE. The four practice test objects can be seen; the platform, the column, the arch and the low walls (from left to right).

### 3.2.2.3 Procedure

Participants received a practice exploration and pointing task to familiarise them with the procedure, followed by exploration of the target U-shaped route in one of the four VE's (Rich Outdoor, Rich Indoor, Impoverished Outdoor or Impoverished Indoor), and an alignment test.

For the practice phase participants explored the practice VE. The four objects were pointed out to the by the experimenter and named. Once the participants were confident of the location and names of the objects the VE was removed and a practice JRD test was given. The practice JRD test consisted of four judgements, 2 forward-facing (i.e. in front of the participant's imagined view) and 2 backward-facing, on the four practice objects.

During exploration of the main route, the experimenter verbally directed the participant, pointing out and naming each target/test objects as they passed. This was done a total of three times (start to end, end to start, start to end). Then the participant retraced the route a further three times, except this time they (rather than the experimenter) pointed out and named the objects as they passed. This was to ensure the participants were attending to, and would recognise, the correct target objects. Finally the participants explored a further three times, but did not have to point out any of the objects. The number of times the route was explored differed slightly from related studies (e.g., Wildbur & Wilson, 2008; Wilson et al., 2007). Pilot work determined that the number of explorations was not crucial to the obtained

results (see appendix B).

After the exploration was finished, the VE was removed from the computer screen and the pointer program was loaded. The participants were required to make 12 judgements using the pointer, comprising a random mix of 4 x aligned, 4 x 90-degree misaligned, and 4 x 180-degree contra-aligned trials (with respect to the first direction of travel); these trials also comprised a mixture of 6 forward-facing (from this point on 'forward') and 6 backward-facing (from this point on 'backward') judgements, with 6 judgements on the first and 6 on the last parts of the route. Judgement accuracy and decision latency were recorded.

### **3.2.3 Results and Discussion**

An alpha value of .05 was used for all analysis in the thesis. For all ANOVA based analysis in the thesis the Greenhouse-Geisser correction is applied unless otherwise stated. The error data for the JRD's in this experiment, and all others in the thesis, were derived by subtracting the participant's angle estimates of the object location and direction from the actual object location angle, and converting the value into an absolute figure.

The error data for Experiment 1 (see Figure 3.5 and 3.6) were entered into a 4 X 3 X 2 X 2 mixed ANOVA with the combination of level of detail and VE type (Impoverished Indoor, Impoverished Outdoor, Rich Indoor and Rich Outdoor) as the between-participant factor and alignment (aligned, misaligned and contra-aligned with the first part of the route), judgement direction (forward, backward) and route section (first, last) as the within-participant factors.

There was a main effect of alignment ( $F(2, 184) = 15.03$ ,  $MSE = 2853.36$ ,  $p < .001$ ,  $\eta_p^2 = .14$ ) which reflects the lower error found for aligned judgements compared to both misaligned and contra-aligned across all groups. A main effect of judgement direction was also found ( $F(1, 92) = 12.00$ ,  $MSE = 1603.82$ ,  $p < .001$ ,  $\eta_p^2 = .11$ ) due to lower error in forward judgements than backward judgements (see Figure 3.6). There was an alignment x judgement direction interaction ( $F(2, 184) = 5.11$ ,  $MSE = 1625.50$ ,  $p = .007$ ,  $\eta_p^2 = .05$ ). The interaction between



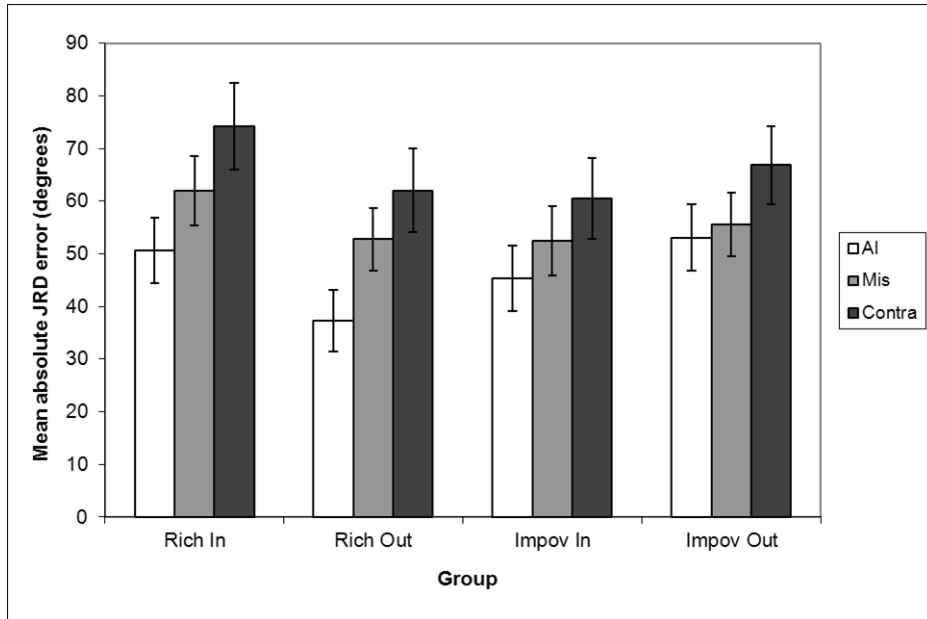


Figure 3.5: Experiment 1. Mean absolute angle errors for aligned, misaligned and contra-aligned judgements across the four groups. Error bars represent one estimated standard error above and below the mean.

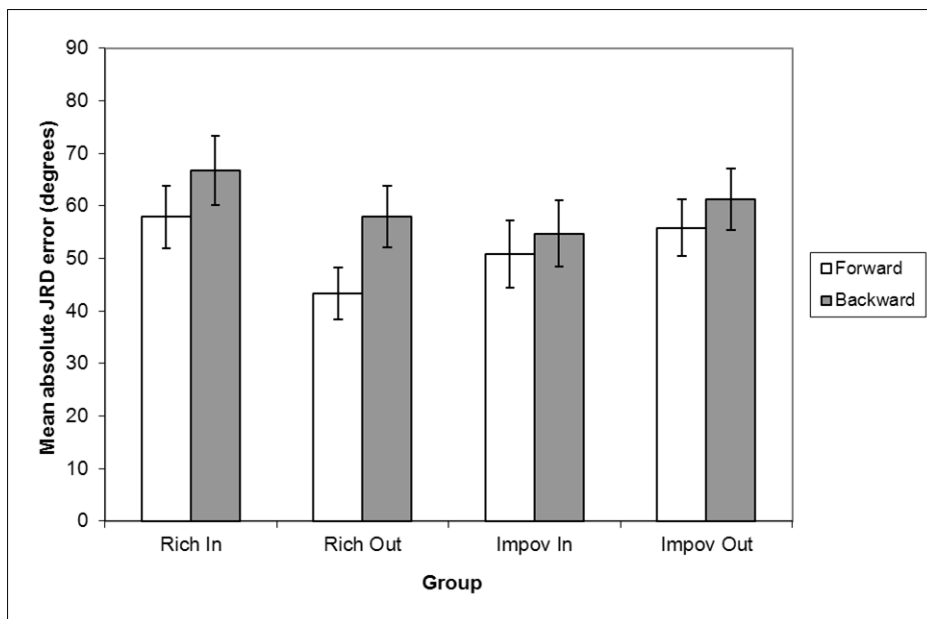


Figure 3.6: Experiment 1. Mean absolute errors for 'forward' and 'backward' judgements across the four groups. Error bars represent one estimated standard error above and below the mean.

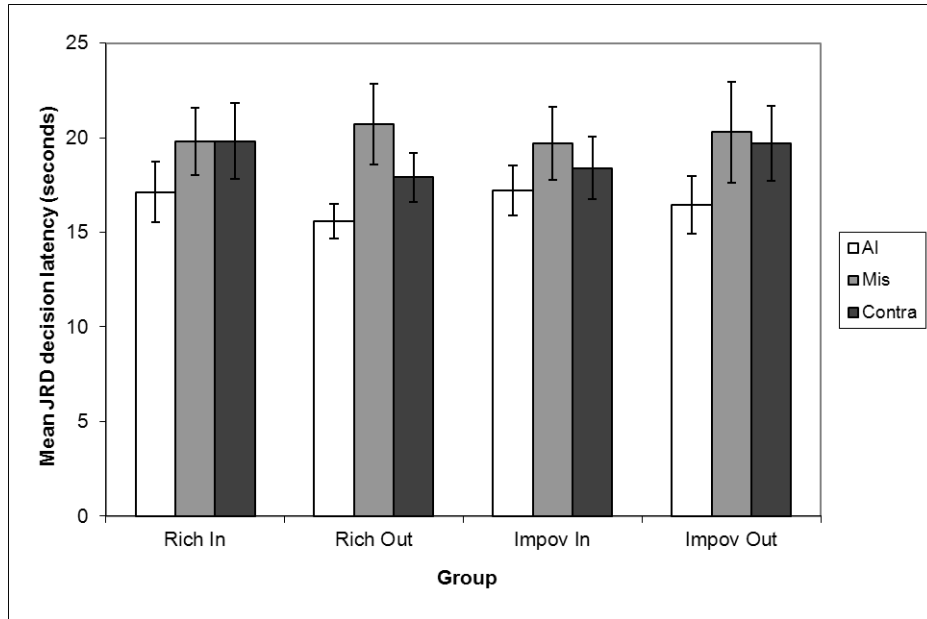


Figure 3.7: Experiment 1. Mean decision latency for aligned, misaligned and contra-aligned judgements across the four groups. Error bars represent one estimated standard error above and below the mean.

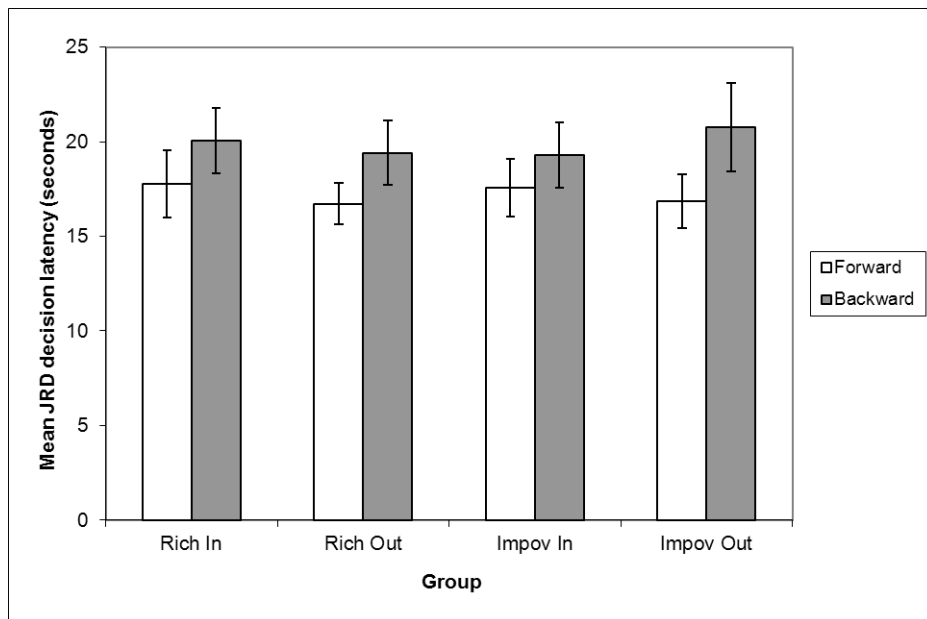


Figure 3.8: Experiment 1. Mean decision latency for forward and backward judgements across the four groups. Error bars represent one estimated standard error above and below the mean.

alignment and judgement direction is a consequence of less overall error in forward judgements when aligned but little difference between forward and backward judgements when contra-aligned.

The latency data for the JRD's in this experiment, and all others in the thesis, were derived from the time taken, in seconds, between the presentation of the question and the release of the left-mouse button upon answering. The latency data (see Figure 3.7 and 3.8) were analysed in the same way as the error data.

There was a main effect of alignment ( $F(2, 184) = 11.83$ ,  $MSE = 119498.94$ ,  $p < .001$ ,  $\eta_p^2 = .11$ ) which reflects faster decision latencies for aligned judgements compared with both misaligned and contra-aligned across all groups. There was a main effect of judgement direction ( $F(1, 92) = 16.12$ ,  $MSE = 125664.27$ ,  $p < .001$ ,  $\eta_p^2 = .14$ ) as demonstrated by generally faster decision latency for forward judgements compared to backward across all the groups. There was also an alignment x judgement direction interaction ( $F(2, 184) = 4.05$ ,  $MSE = 86893.54$ ,  $p = .021$ ,  $\eta_p^2 = .04$ ). The interaction between alignment and judgement direction is a consequence of faster overall decision latency in forward than backward judgements when aligned but little difference between forward and backward judgements when contra-aligned.

The above results suggest that the levels of detail and VE type have no affect on the presence and strength of the FPA effect; this is true in both error and latency data.

Further analyses of each individual groups' error data were performed using a 3 X 2 X 2 within-participant ANOVA in all cases, with alignment (aligned, misaligned and contra-aligned with the first part of the route), judgement direction (forward, backward) and route section (first, last) as factors.

In the Rich Indoor VE there was a main effect of alignment ( $F(1, 23) = 8.38$ ,  $MSE = 3205.23$ ,  $p = .008$ ,  $\eta_p^2 = .26$ ) due to the mean aligned error ( $M = 50.62$ ;  $SE = 6.18$ ) being smaller than the mean misaligned errors ( $M = 61.95$ ;  $SE = 6.5$ ), which in turn was smaller than the mean contra-aligned error ( $M = 74.29$ ;  $SE = 8.22$ ). There was also an alignment x judgement

direction interaction ( $F(1, 23) = 6.64$ ,  $MSE = 1162.43$ ,  $p = .017$ ,  $\eta_p^2 = .22$ ). The interaction between alignment and judgement direction is a consequence of less overall mean error in forward ( $M = 43.79$ ;  $SE = 5.26$ ) than backward ( $M = 57.45$ ;  $SE = 8.59$ ) judgements when aligned but the reverse between forward ( $M = 80.14$ ;  $SE = 10.66$ ) and backward ( $M = 68.43$ ;  $SE = 7.90$ ) judgements when contra-aligned.

In the Rich Outdoor group there was a main effect of alignment ( $F(1, 23) = 6.50$ ,  $MSE = 4545.50$ ,  $p = .018$ ,  $\eta_p^2 = .22$ ) as the mean aligned error ( $M = 37.21$ ;  $SE = 5.82$ ) was smaller than the mean misaligned error ( $M = 52.75$ ;  $SE = 5.95$ ), which in turn was smaller than the contra-aligned error ( $M = 62.04$ ;  $SE = 7.97$ ). There was also a main effect of judgement direction ( $F(1, 23) = 9.40$ ,  $MSE = 1208.08$ ,  $p = .005$ ,  $\eta_p^2 = .29$ ) as the mean forward judgement error ( $M = 43.33$ ;  $SE = 4.95$ ) was smaller than the mean backward error ( $M = 58$ ;  $SE = 5.84$ ).

In the Impoverished Indoor VE there was a main effect of alignment ( $F(1, 23) = 6.86$ ,  $MSE = 1587.36$ ,  $p = .015$ ,  $\eta_p^2 = .23$ ) as the mean aligned error ( $M = 45.38$ ;  $SE = 6.2$ ) was smaller than the mean misaligned errors ( $M = 52.43$ ;  $SE = 6.66$ ), which in turn was smaller than the mean contra-aligned error ( $M = 60.44$ ;  $SE = 7.6$ ). There was also an alignment x judgement direction interaction ( $F(1, 23) = 4.91$ ,  $MSE = 1059.26$ ,  $p = .037$ ,  $\eta_p^2 = .17$ ). The interaction between alignment and judgement direction is a consequence of less overall mean error in forward ( $M = 39.16$ ;  $SE = 6.87$ ) than backward ( $M = 51.6$ ;  $SE = 7.27$ ) judgements when aligned but the reverse between forward ( $M = 64.64$ ;  $SE = 9.8$ ) and backward ( $M = 56.25$ ;  $SE = 7.47$ ) judgements when contra-aligned.

In the Impoverished Outdoor VE despite the mean aligned error ( $M = 53.08$ ;  $SE = 6.25$ ) being smaller than the mean misaligned error ( $M = 55.48$ ;  $SE = 6.03$ ), which in turn was smaller than the mean contra-aligned error ( $M = 66.83$ ;  $SE = 7.41$ ) there were no significant effects or interactions.

The latency data for the individual groups were analysed the same way as the error data. In the Rich Indoor VE despite the mean aligned latency ( $M = 17.11$ ;  $SE = 1.59$ ) being faster than the mean misaligned latency ( $M = 19.81$ ;  $SE = 1.76$ ), which in turn was the same as the mean

contra-aligned latency ( $M = 19.81$ ;  $SE = 1.99$ ) there were no main effects or interactions.

In the Rich Outdoor VE there was a main effect of alignment ( $F(1, 23) = 5.34$ ,  $MSE = 48737.52$ ,  $p = .030$ ,  $\eta_p^2 = .18$ ) as the mean aligned latency ( $M = 15.58$ ;  $SE = 0.92$ ) was faster than the mean misaligned latency ( $M = 20.72$ ;  $SE = 2.13$ ), which in turn was slightly slower than the mean contra-aligned latency ( $M = 17.90$ ;  $SE = 1.29$ ).

In the Impoverished Indoor VE there was a main effect of judgement direction ( $F(1, 23) = 4.76$ ,  $MSE = 74449.35$ ,  $p = .039$ ,  $\eta_p^2 = .17$ ) as the mean forward judgement latency ( $M = 17.5$ ;  $SE = 1.52$ ) were faster than backward judgment latency ( $M = 19.29$ ;  $SE = 1.72$ ). There was also an alignment x judgement direction interaction ( $F(1, 23) = 12.28$ ,  $MSE = 40721.85$ ,  $p = .002$ ,  $\eta_p^2 = .34$ ). The interaction between alignment and judgement direction is a consequence of faster overall mean latency in forward ( $M = 14.22$ ;  $SE = 1.65$ ) than backward ( $M = 20.16$ ;  $SE = 1.48$ ) judgements when aligned but little difference between forward ( $M = 18.65$ ;  $SE = 1.58$ ) and backward ( $M = 18.14$ ;  $SE = 2.17$ ) judgements when contra-aligned.

In the Impoverished Outdoor VE there was a main effect of alignment ( $F(1, 23) = 5.45$ ,  $MSE = 95340.66$ ,  $p = .029$ ,  $\eta_p^2 = .19$ ) as the mean aligned latency ( $M = 16.42$ ;  $SE = 1.52$ ) was faster than the mean misaligned latency ( $M = 20.28$ ;  $SE = 2.65$ ), which in turn was slightly slower than the mean contra-aligned latency ( $M = 19.71$ ;  $SE = 1.98$ ). There was a main effect of judgement direction ( $F(1, 23) = 6.84$ ,  $MSE = 50132.24$ ,  $p = .015$ ,  $\eta_p^2 = .22$ ) as the mean forward judgment latency ( $M = 16.85$ ;  $SE = 1.41$ ) in the outdoor group was faster than the mean backward judgment latency ( $M = 20.76$ ;  $SE = 2.35$ ). There was also a main effect of route section ( $F(1, 23) = 5.05$ ,  $MSE = 28286.24$ ,  $p = .035$ ,  $\eta_p^2 = .18$ ) as judgements made on the first part of the route were faster ( $M = 18.61$ ;  $SE = 1.9$ ) than judgements made on the last part of the route ( $M = 19$ ;  $SE = 1.81$ ).

The individual analysis of the groups supports the initial conclusion that there is no effect of VE type and detail on the presence of the FPA effect. The majority of the groups demonstrated a clear FPA effect in either or both error and latency. Those groups that did not show a significant alignment effect had a pattern of data similar to that of a FPA effect, and did

not show an alternate alignment effect or pattern of data that would directly contradict the initial conclusion. It is also worth noting that if the misaligned data has been omitted from the analysis, as it has been in recent studies (Wildbur & Wilson, 2008; Wilson et al., 2007), then a significant FPA effect in the impoverished outdoor group may have been obtained. It may be that the misaligned data, due to its intermediate position between the aligned and contra-aligned judgement data causes noise in the analysis and leads to insensitivity in the analysis and lack of significance in some cases.

According to the salience hypothesis (Wilson et al., 2007) an increase in the amount of available spatial information, either through the level of detail available or whether the surroundings are open or enclosed, should attenuate the FPA effect due to the opportunity to form salient anchor points and orientations other than the first. Clearly in the results for Experiment 1 this was not the case. There is an overall alignment effect in both error scores and latencies, and there is no interaction between alignment and group. The further individual analysis of the groups shows a largely present FPA, and in the error scores the one group it is not significantly present the apparent attenuation does not support the salience hypothesis. A lack of FPA effect in the impoverished outdoor group is not congruent with the salience hypothesis (unlike an attenuation in the rich outdoor group would be) and it could be suggested that the attenuation in this case is a consequence of noise in the data.

The lack of definitive support for the salience hypothesis aside, there are other interesting effects to note. Firstly the effects of judgement direction (sometimes as part of interactions with alignment) noted in the initial error and latency analysis suggest that participants were more efficient at pointing at target objects in front of their imagined perspective at test than 'behind them'. This suggests that not only were the participants actually envisioning themselves physically in the environment, but that an egocentric frame of reference was, to some extent, being favoured. If participants had simply imagined a map like overhead representation of the environment, or had used an allocentric frame of reference then no difference between judgements forward and backward of the viewing locality would have been expected. A significant effect of route section was found in some cases, testifying further to the importance

of the first perspective. Judgements made on the first section of the route were more efficient than the later experienced route section. However, regardless of this effect of route section the data suggest that the first perspective defines a principal reference vector applied across the entire VE, not just the first section of the route. The effect of route section in this case does not contradict the overall alignment effect, and is not a major finding with respect to the current hypotheses.

At this point in the analysis it is worth pointing out that no evidence of a trade off between error scores and latency has been found. High errors do not seem to be a function of fast decision latencies, and lower errors do not seem to be a function of longer latencies. This has been found by Easton and Sholl (1995, Experiment 1) as well, and may suggest that the two measures are independent. Whilst error scores clearly reflect spatial ability, or what has been learnt about the relational properties of the VE, this need not be the case for the latency data. It may be that latency data reflect a different aspect of the participant's experience, such as confidence or certainty. The latency data will still be collected and analysed in following experiments to both see if a trade off can be established and to avoid the same criticism levelled at past studies that did not find the FPA effect when only using one measure (Richardson et al., 1999). However unless a trade off can be established, or the two measures directly contradict each other (i.e. both show two different significant alignment effects), the error data will be given priority during the discussion of further analyses.

The aim of Experiment 1 was to investigate whether the differences in the presence of the FPA effect in previous experiments were due the salience hypothesis. The lack of any influence of manipulating the detail level and VE type suggests acceptance of the null hypothesis, that the availability of spatial detail does not influence the FPA effect. This does not mean that the salience hypothesis has been completely refuted. Nor does it mean the difference in FPA effect between different media is due to a qualitative difference between them. These issues are furthered investigated in the following chapter.

# Chapter 4

## **Investigating the Saliency Hypothesis: Attenuation of the FPA effect**

### **through pre-exposure to the VE**

#### **4.1 The Saliency Hypothesis: Anchor Points**

The results from Experiment 1 did not support the saliency hypothesis as outlined by Wilson et al. (2007). Despite systematic variation in the amount of detail that was available in VEs which could hypothetically be used to form alternative anchor points to the first perspective, or provide an allocentric frame of reference, the FPA effect was fairly uniform between VEs. This suggests that the original hypothesis does not offer an explanation for the differences in results concerning the FPA effect across different media. However, there is an alternative account of the results.

While the level of detail and surrounding distances were manipulated, it could be that the additional details that were provided in some conditions were not experienced adequately by the participants. The participants only explored a route around the building or along the corridor, and all the distant additional detail, while visible, may not have been adequately processed by the participants. Some experiments have found a difference in the use of local and distant cues or landmarks (Steck & Mallot, 2000), generally finding a preference for the



local over the distant (Geiger, Gillner & Mallot, 1997). In this case the available local information may have overshadowed the more distant cues restricting the formation of alternative anchor points or other possible frames of reference. The task of exploring only the route may have, in effect, blinkered the participants to the wider environment. This is particularly relevant when considered the anchor point hypothesis. There is evidence that exploration is required to facilitate spatial judgements even when the majority of the environment is visible. Hamsters (Chapuis, Durup & Thinus-Blanc, 1987) and humans (Stanton et al., 2003; Wilson et al., submitted) were only able to select correct novel shortcuts if exploration had provided connecting experience between two previously trained routes. In a kite-shaped path structure with distant landmarks, participants were trained to travel between two platforms or rooms (Red to Blue for example), and then they were trained to travel between two others (Green to Yellow). Groups that only had this experience performed badly (chance and below) when attempting to select a correct novel shortcut (Red to Yellow) despite the availability of distant stable landmarks. Groups that had connecting experience through additional training (exploration of Red to Green or Blue to Yellow) performed significantly better and were able to make the correct novel shortcut choice. This suggests that experience of exploring a connecting route allows previously separated sub spaces to be integrated. Simply being able to see the other areas and paths was not enough, exploration was required. Considering the anchor point hypothesis (Coulcelis et al., 1987) the above evidence suggests it may be necessary to actually explore to establish or link anchor points. The distant information and detail provided in Experiment 1, especially in the rich outdoor VE, may not have been used to establish anchor points because the area outside the U-shaped route was not explored but merely viewed.

This explanation could extend to the relative lack of FPA effect in some real-world experiments. The procedure between real-world (primary) learning and learning from secondary media differs considerably. In the real-world, even if participants are truly naïve to the layout and details of the explored route, they still have to be led to the start location. Unless participants are blind-folded and disoriented when approaching the start of the route, the

approaching experience means they can acquire local spatial information. They may form anchor points as they approach, or approaching may allow them to learn about surrounding allocentric cues (other buildings) that may or may not be congruent with the first perspective they experience during the training. As mentioned by Wilson et al. (2007) the outdoor building they used for their third experiment, where no FPA effect was found, was selected due to it being located on the edge of the campus and therefore potentially unfamiliar to most participants. However participants could have still been familiar with the surroundings of the campus, and that lack of true novelty may have led to alternative anchor points being established resulting in an attenuation of the FPA effect. In contrast, participants in secondary media experiments are either instantly transported to the start location in a VE, or they experience a description that involves no approach to their initial imagined start. It may be that participants in VE studies, such as Experiment 1, lack an initial environmental pre-exposure to surrounds that can lead to attenuation of the FPA effect. In essence, the explanation is one of spatial competition: where anchor points are established around a test route, these can compete with the anchor point normally established at the start of the test route.

## **4.2 Experiment 2a**

In Experiment 2a the salience hypothesis (Wilson et al., 2007) was re-evaluated; this time taking into account the potential effects associated with prior experience of the surroundings. In an effort to mimic more closely the procedure typically used in real-world studies, the participants experienced a period of pre-exposure to the surroundings of the route to be tested in the VE prior to training and testing. According to the modified salience hypothesis above, the pre-exposure to the surroundings should allow the formation of salient anchor points that compete with the first perspective on the subsequently explored route. The hypothesis was that the experience of pre-exposure to the surroundings would have an attenuating effect on the presence of the FPA effect.

### **4.2.1 Design**

Participants were shown a passively presented tour of an outdoor built virtual environment before they actively explored a U-shaped route within it. There were eight possible versions of the route to control for: the combination of tested objects, the effects of route length (four routes had the first leg as the shortest and four routes had the last leg as the shortest) and turn direction (four routes had only 90° left turns and four routes had only 90° right turns).

The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency to make the JRD's (in seconds).

### **4.2.2 Method**

#### **4.2.2.1 Participants**

The participants were 24 undergraduate students who took part to fulfill part of a course requirement. Their mean age was 19.66 years (range: 18 - 33 years) and of these 4 were men.

#### **4.2.2.2 Apparatus**

The practice environment used in the Experiment 1 was used in this and all following experiments.

The main experimental environment was the same as the Rich Outdoor environment used in Experiment 1 (also referred to as VEA). Participants were asked to follow a path adjacent to 3 of the exterior walls of an oblong building located at the centre of the environment. Two pre-recorded tours were made comprising two similar explorations of the surrounding environment (between 165 and 246 seconds long). The start of these tours was located away from the route that would later be explored. The tours began with the view rotating from a stationary point before gradually slowing. The tours explored the surrounding environment but never followed the route around the building that would later be explored.

### 4.2.2.3 Procedure

Participants received a practice exploration and pointing task to familiarise them with the procedure, followed by the presentation of the pre-recorded tours, and then exploration of the target U-shaped route around the central building, and an alignment test.

The procedure and details for the practice exploration, main exploration and subsequent JRD test were identical to the previous experiment. The only difference in procedure was the inclusion of the pre-recorded tour. The experience of the tour was passive and only required the participants to watch the tour before continuing on to the main exploration.

### 4.2.3 Results and Discussion

The error data for Experiment 2 (see Figure 4.1) were entered into a 3 X 2 X 2 within-participant ANOVA with alignment (aligned, misaligned and contra-aligned with the first part of the route), judgement direction (forward, backward) and route section (first, last) as factors. Importantly no significant main effects or interactions were found.

The latency data (see Figure 4.2) were analysed the same way as the error data. A significant effect of judgement direction was found ( $F(1, 23) = 4.47$ ,  $MSE = 43049.61$ ,  $p = .046$ ,  $\eta_p^2 = .16$ ) as the mean forward judgement latency ( $M = 15.4$ ;  $SE = 1.5$ ) was faster than backward judgement latency ( $M = 17.7$ ;  $SE = 1.5$ ). No other significant main effects or interactions were found.

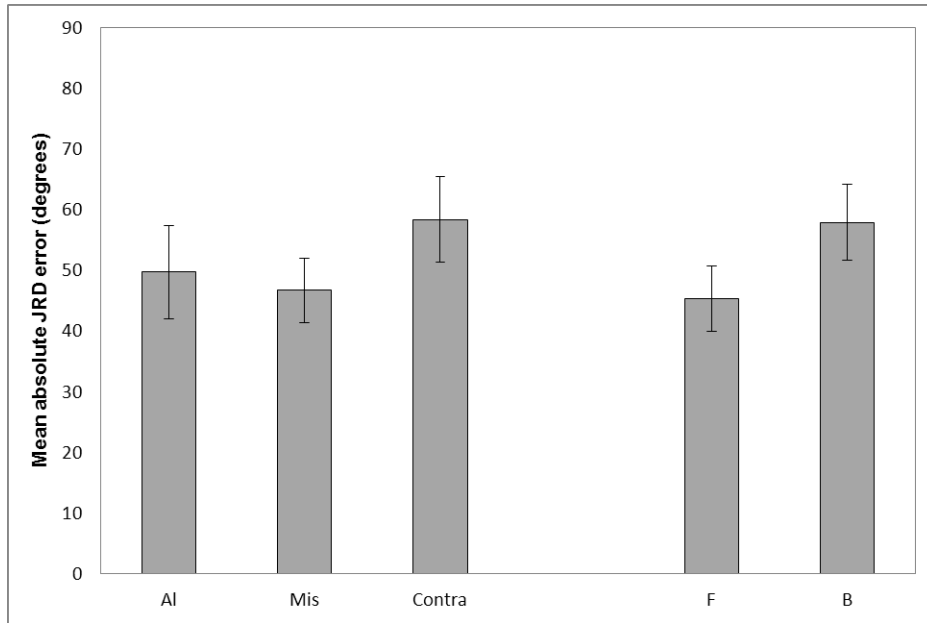


Figure 4.1: Experiment 2a. Mean absolute errors for aligned, misaligned, contra-aligned, forward and backward judgements. Error bars represent one estimated standard error above and below the mean.

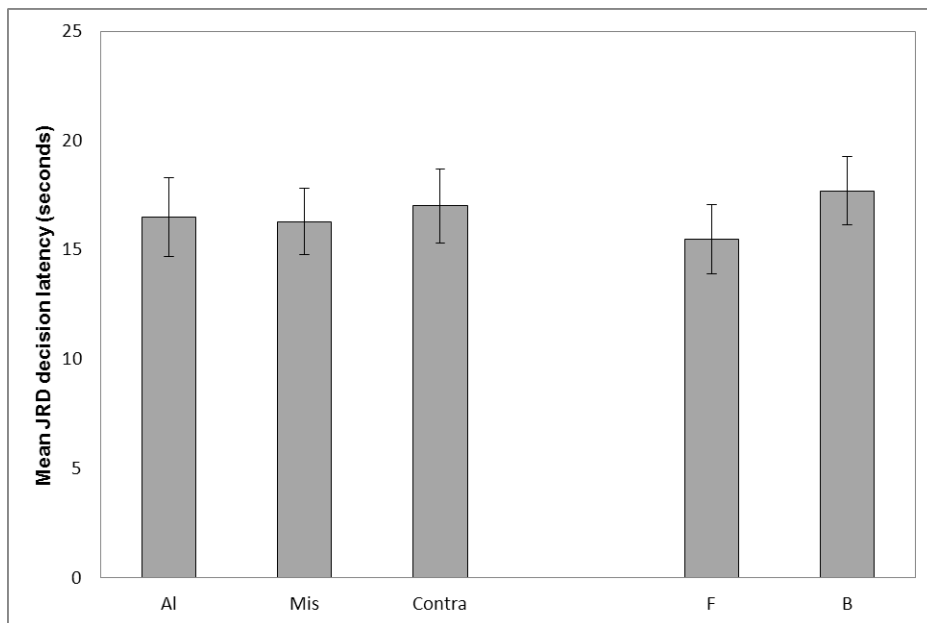


Figure 4.2: Experiment 2a. Mean decision latency for alignment, misaligned, contra-aligned, forward and backward judgements. Error bars represent one estimated standard error above and below the mean.

The clear lack of a FPA effect in both the error and latencies data contrasts with the strong FPA effect found in Experiment 1 and supports the experimental hypothesis based on the amended salience interpretation. The exposure to information about the surroundings of the VE attenuated the FPA effect by allowing other salient anchor points or preferred orientations to be learnt about as well as that of the first perspective. When compared with the average error scores in the previous experiment the misaligned and contra-aligned error scores are reduced (see Figure 3.5).

While the results are compatible with the amended salience hypothesis there is an alternative explanation of the attenuation of the FPA effect. Reduction in the FPA could occur as a consequence of nothing more than the increased time that participants spent observing any VE, perhaps by making them more comfortable with VE experience. The increased exposure provided by the tour may increase the familiarity and ease with which the participants can use and learn about any VE rather than specifically the one in which route exploration subsequently occurs. While real-world exploration is likely to have been experienced extensively by participants, the exposure to VE-based exploration is potentially much more limited. If the FPA effect is linked to the novelty of the exploration experience then extra time spent experiencing VEs in general may reduce novelty and lead to a result more congruent with that of equivalent real-world settings.

### **4.3 Experiment 2b**

Although Experiment 2a found evidence compatible with the salience hypothesis, it is unclear from the results whether the attenuation of the FPA effect was due to the spatial information provided by the tour or merely the extra familiarity with any VE. This issue was addressed in the following experiment by expanding upon the Experiment 2a design by including a further two groups. Alongside a replication of the group which received pre-exposure to the VE they were trained and tested in (VEA), a second group received irrelevant pre-exposure

Group	Pre-exposure to:	Trained in:	Tested on:
A	VEA	VEA	VEA
B	VEB	VEA	VEA
C	VEC	VEA	VEA

Table 4.1: Design for Experiment 2b showing the difference in initial pre-exposure for groups (VE)A who toured the explored VE, (VE)B who toured an unrelated VE of similar level of detail and (VE)C who explored an unrelated and bland VE prior to the tour.

of an equally detailed but differently configured VE (VEB), and the third group received pre-exposure to a bland low detail but differently configured VE (VEC) (see Table 4.1 for design, and Figure 4.3 for examples). This allowed for comparisons between the content of the tour and the level of detail. If, as hypothesised, the pre-exposure to the surroundings of the to-be-tested route is what attenuated the FPA effect by establishing salient anchor points, then attenuation would only be expected in the original group (VEA). The FPA effect should be unaffected in the other two groups (VEB and VEC) as the content of the tour has no relevance to the later training, and no salient anchor points can have been formed. Nor would any difference be expected between the groups VEB and VEC either because, despite the difference in detail, neither contains any relevant information under the salience hypothesis.

An alternative prediction would be that only the extra experience of a VE is required for attenuation of the FPA effect. Therefore, an attenuated FPA effect would be expected in all of the groups as they will all involve an equal amount of pre-exposure.

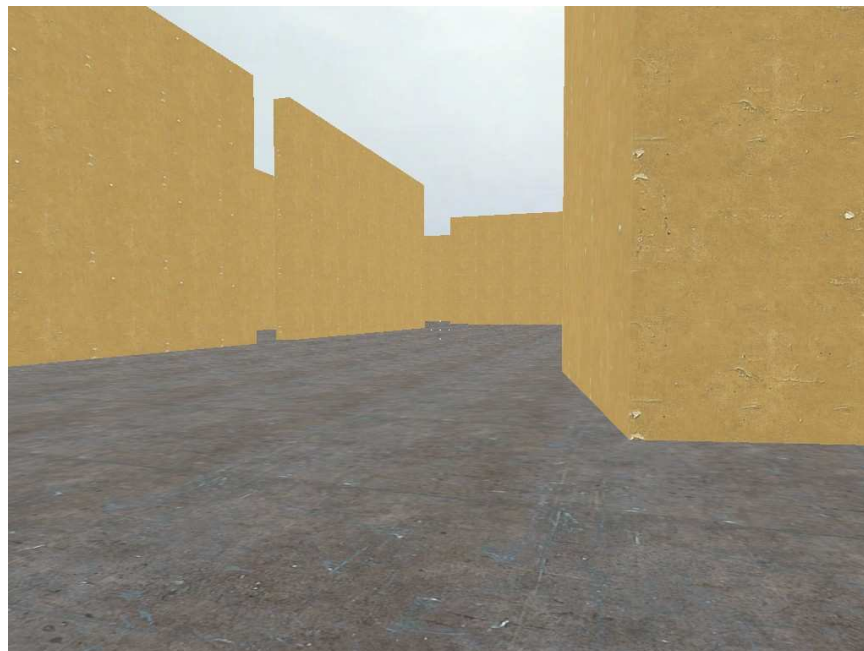


Figure 4.3: First person views of the VE's used for the pre-exposure tours in Experiment 2b. Upper panel: VEB. Lower panel: VEC. (Figure 3.1 shows a view of VEA)



### **4.3.1 Design**

Participants were shown a passive pre-recorded tour of a VE before they actively explored a test route within the outdoor (VEA). The passively toured VE was either the same as subsequently explored (VEA), a rearrangement of that which was later explored (VEB), or a bland version of the rearranged VE (VEC). There were eight possible versions of the route to control for: the combination of tested objects, the effects of route length (four routes had the first leg as the shortest and four routes had the last leg as the shortest) and turn direction (four routes had only 90° left turns and four routes had only 90° right turns).

The independent variable was the type of tour experienced. The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency for the JRD's (in seconds).

### **4.3.2 Method**

#### **4.3.2.1 Participants**

The participants were 72 undergraduates who took part in partial fulfilment of a course requirement. Their mean age was 21.41 years (range: 18 – 55 years) and of these 18 were men. Group VEA contained 5 men, group VEB contained 6 men and group VEC contained 7 men. They were pseudo-randomly allocated to one of three groups (n=24) with the constraint that approximately the same number of men served in each..

#### **4.3.2.2 Apparatus**

VEB contained the same objects and the same sized buildings as VEA but they were presented in a different arrangement and used different textures. VEC had the same building arrangement/structure as VEB but contained no other objects, and only used two textures.

The pre-recorded tours took a similar route (stopping at objects in a similar order) where possible and all lasted approximately between 165 and 246 seconds long.

#### **4.3.2.3 Procedure**

Participants received the practice exploration and pointing task used in Experiments 1 and 2a to familiarise them with the procedure, followed by the presentation of one of the prerecorded tours for either VEA, VEB or VEC. They then explored a U-shaped route around the central building in VEA, followed by an alignment test.

The only difference in procedure between the three groups was the tour experienced. All groups experienced the same practice, main exploration and subsequent JRD test procedure and details; all of which were identical to the procedure in previous experiments.

#### **4.3.3 Results and Discussion**

The error data for Experiment 2b (see Figure 4.4 and 4.5) were entered into a 3 X 3 X 2 X 2 ANOVA with factors of group (VEA, VEB and VEC) alignment (aligned, misaligned, contra-aligned with the first part of the route), judgement direction (forward, backward) and route section (first or last).

There was a main effect of judgement direction ( $F(1, 69) = 7.39$ ,  $MSE = 6612.50$ ,  $p = .008$ ,  $\eta_p^2 = .09$ ) which appears to reflect less error for forward judgments compared to backward across all groups. Importantly no main effect of alignment, other main effects or interactions were found.

The latency data (see Figure 4.6 and 4.7) were analysed the same way as the error data. There was a main effect of alignment ( $F(2, 138) = 10.74$ ,  $MSE = 73303.04$ ,  $p < .001$ ,  $\eta_p^2 = .13$ ) reflecting faster aligned judgements than misaligned or contra-aligned across all groups. No other main effects or interactions were found.

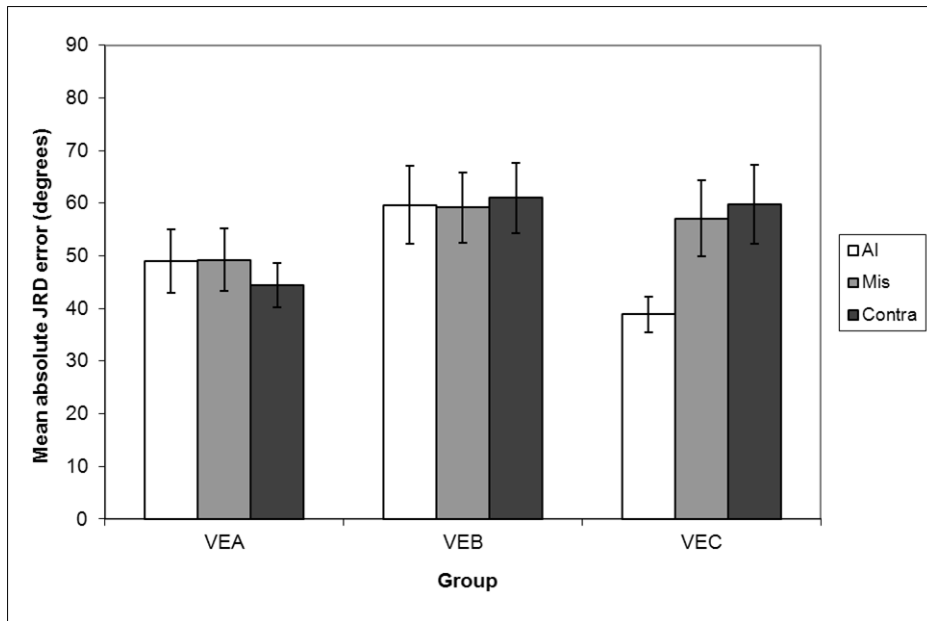


Figure 4.4: Experiment 2b. Mean absolute error for aligned, misaligned and contra-aligned judgements across the three groups. Error bars represent one estimated standard error above and below the mean

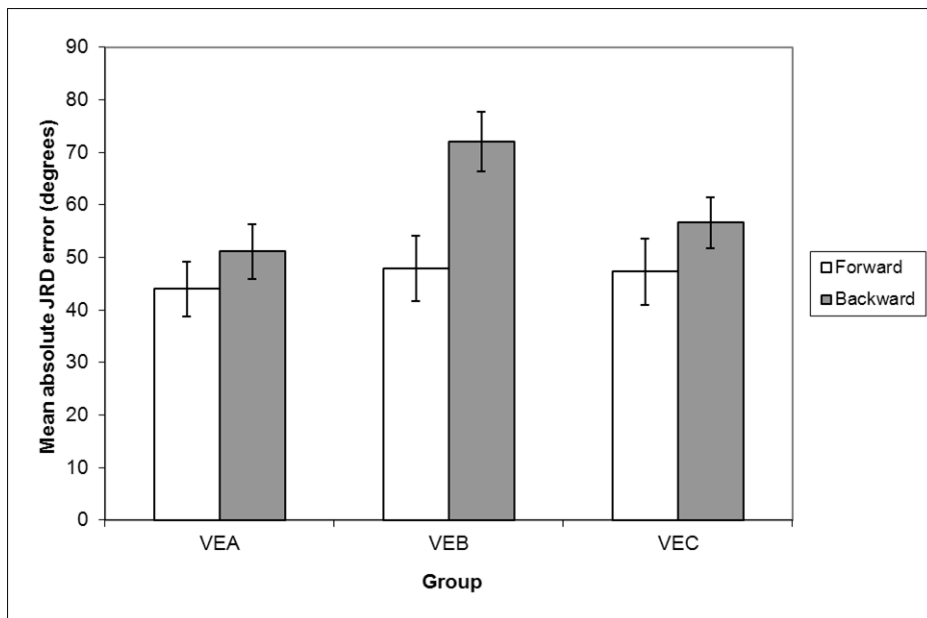


Figure 4.5: Experiment 2b. Mean absolute error for forward and backward judgements across the three groups. Error bars represent one estimated standard error above and below the mean

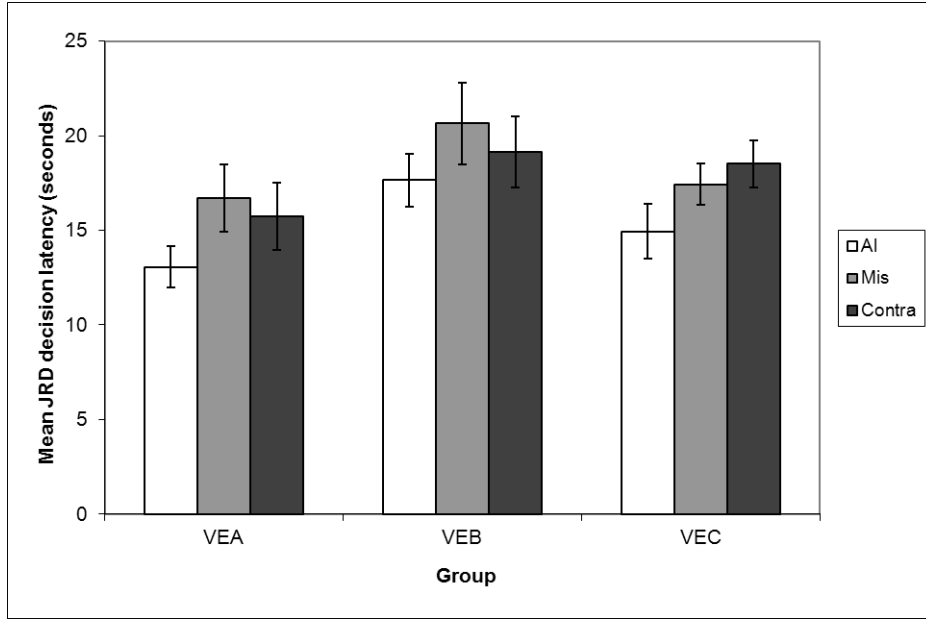


Figure 4.6: Experiment 2b. Mean decision latency for aligned, misaligned and contra-aligned judgements across the three groups. Error bars represent one estimated standard error above and below the mean

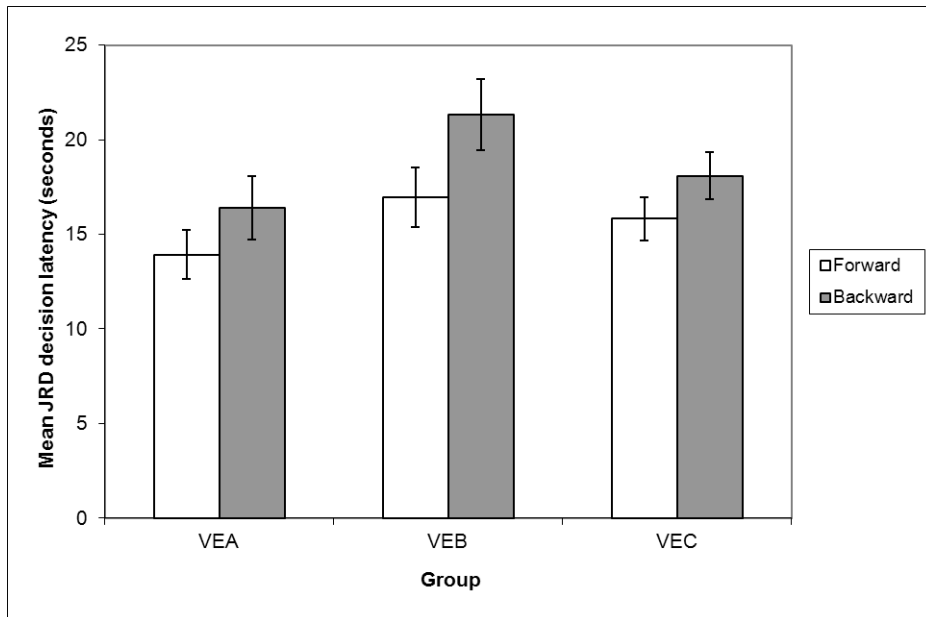


Figure 4.7: Experiment 2b. Mean decision latency for forward and backward judgements across the three groups. Error bars represent one estimated standard error above and below the mean

The overall analysis suggests a rejection of the hypothesis that relevant pre-exposure is required to attenuate the FPA effect, contrary to the predictions of the amended salience hypothesis. This is due to the lack of statistically significant alignment by group interaction, and the lack of a main effect of alignment in the error data, consistent with the interpretation that any VE pre-exposure is sufficient to attenuate the FPA. This would mean that the novelty of the VE experience is perhaps the key factor in the presence of the FPA effect. However looking at the patterns and individual analyses of the data for each group, suggests the need for further investigation.

The individual group error data was analysed using a 3 X 2 X 2 within-participant ANOVA with alignment (aligned, misaligned and contra-aligned with the first part of the route), judgement direction (forward, backward) and route section (first, last) as factors. For group VEA, and consistent with Experiment 2a, there were no significant main effects or interactions.

In group VEB there was a main effect of judgement direction ( $F(1, 23) = 30.83$ ,  $MSE = 1351.05$ ,  $p < .001$ ,  $\eta_p^2 = .57$ ) as the mean forward judgement error ( $M = 47.88$ ;  $SE = 6.23$ ) was smaller than backward judgement error ( $M = 71.93$ ;  $SE = 5.66$ ).

In group VEC there was a main effect of alignment ( $F(1, 23) = 5.56$ ,  $MSE = 2259.52$ ,  $p = .007$ ,  $\eta_p^2 = .19$ ) as the mean aligned error ( $M = 38.84$ ;  $SE = 3.38$ ) was smaller than that of the mean misaligned error ( $M = 57.08$ ;  $SE = 7.26$ ) and mean contra-aligned error ( $M = 59.81$ ;  $SE = 7.49$ ). There was also a significant alignment x judgement direction interaction ( $F(2, 46) = 5.31$ ,  $MSE = 1259.68$ ,  $p = .01$ ,  $\eta_p^2 = .18$ ) reflecting lower mean error for forward aligned judgements ( $M = 31.68$ ;  $SE = 4.68$ ) than backward ( $M = 46$ ;  $SE = 7.5$ ), and the opposite for contra-aligned judgements (forward,  $M = 64.18$ ;  $SE = 2.29$ , backward,  $M = 55.43$ ;  $SE = 6.02$ ).

The individual group latency data were analysed the same way as the error data. In group VEA there was a main effect of alignment ( $F(2, 46) = 5.23$ ,  $MSE = 65638.28$ ,  $p = .009$ ,  $\eta_p^2 = .185$ ) as mean aligned latency ( $M = 13.04$ ;  $SE = 1.09$ ) was faster than the misaligned latency ( $M = 16.69$ ;  $SE = 1.78$ ) and contra-aligned latency ( $M = 15.74$ ;  $SE = 1.78$ ). There was a

main effect of judgement direction ( $F(1, 23) = 9.58$ ,  $MSE = 45840.22$ ,  $p = .005$ ,  $\eta_p^2 = .29$ ) as the mean forward judgement latency ( $M = 13.92$ ;  $SE = 1.28$ ) was faster than backward judgement latency ( $M = 16.39$ ;  $SE = 1.67$ ). There was also a significant alignment x route section interaction ( $F(2, 46) = 5.23$ ,  $MSE = 2259.52$ ,  $p = .009$ ,  $\eta_p^2 = .18$ ) reflecting slower mean aligned judgement latency on the first section of the route ( $M = 13.43$ ;  $SE = 1.33$ ) compared with the last ( $M = 12.65$ ;  $SE = 2.02$ ), and the reverse pattern for contra aligned judgements (first  $M = 14.86$ ;  $SE = .06$ , second  $M = 16.61$ ;  $SE = .02$ ).

In group VEB there was a main effect of judgement direction ( $F(1, 23) = 21.7$ ,  $MSE = 64047.75$ ,  $p < .001$ ,  $\eta_p^2 = .48$ ) as the mean forward judgement latency ( $M = 19.94$ ;  $SE = 7.69$ ) was faster than backward judgement latency ( $M = 21.33$ ;  $SE = 9.17$ ).

In group VEC there was a main effect of alignment ( $F(2, 46) = 5.09$ ,  $MSE = 67440.43$ ,  $p = .012$ ,  $\eta_p^2 = .181$ ) as the mean aligned latency ( $M = 14.94$ ;  $SE = 1.46$ ) was faster than the mean misaligned latency ( $M = 17.43$ ;  $SE = 1.1$ ) and mean contra-aligned latency ( $M = 18.5$ ;  $SE = 1.23$ ). There was a main effect of judgement direction ( $F(1, 23) = 5.75$ ,  $MSE = 63839.65$ ,  $p = .025$ ,  $\eta_p^2 = .2$ ) as the mean forward judgement latency ( $M = 15.83$ ;  $SE = 1.14$ ) was faster than backward judgement latency ( $M = 18.09$ ;  $SE = 1.22$ ).

When considering the design of Experiment 2b, VEA is essentially a replication of Experiment 2a. In this replication, there was again no evidence of the FPA in errors. However in contrast to Experiment 2a, a small alignment effect was apparent in latencies. Thus, preexposure to the surrounds of a route only attenuates the FPA effect, principally on angular errors, but does not abolish it completely (note that the direction of effect in errors in Experiment 2a was consistent with an FPA effect, see Figure 4.1). A strong FPA effect was evident in both the error and latency analysis of group VEC and the pattern of results is similar to the general picture in Experiment 1. The individual data pictures from groups VEA and VEC are consistent with the hypothesis of competition between anchor points, established only when the surroundings to be explored are familiar. However this support for the experimental hypothesis of competition from salient sources becomes less clear when considering the results

of VEB, as the findings are not consistent with the predictions outlined in the introduction to Experiment 2b. No evidence of an FPA effect was apparent in VEB. This pattern is consistent with participants having learned alternative anchor points as a result of the tour; however, these would be anchor points in VEB which should not influence learning in the route within VEA. As the anchor points from VEB should not have been relevant to the experience in VEA because their configurations differed. This raises the question of what else may have caused the attenuation in group VEB?

When exploring potential explanations for the lack of FPA effect in group VEB, examination of the raw scores suggested that this pattern may be due to high variance in the participants' error scores. No criteria for the removal of outliers was established a priori, as under the current design and measures generally high variance between judgements is expected when investigating alignment effects. In the case of group VEB though, greater variance and higher average errors (across all judgments) than in other groups were evident in several participants. For example the average overall error score for participants in VEA was 47° and for VEB 59°. The average error range between most and least accurate judgements for VEA was 30° and for VEB 40°. Therefore, the scores of a few participants could effectively mask a FPA effect in the group as a whole. Therefore, there is a possibility that the results from group VEB were influenced by unfortunate random variation. Alternatively, the participants might have been confused by the similarity of the pre-exposed environment VEB and the training environment VEA. The same level of detail in terms of object types and numbers as well as surface textures were used in VEB as in VEA. The participants were not told explicitly that the two VE's were different and this may have lead some participants to erroneously assume that the route they were exploring was part of the environment experienced during the tour, attenuating the impact of the first perspective on the explored route. If this influenced a substantial portion of VEB participants it might have resulted in the increased error and variance in that group. It is not appropriate to develop criteria to modify scores after the experiment has been completed; however, the conformity with anticipated effects found in groups VEA and VEC suggests it is appropriate to address the findings from group VEB in further experimentation.

## **4.4 Experiment 2c**

The problems concerning the data of group VEB in Experiment 2b were explored further on the hypothesis that in Experiment 2b participant in group VEB had assumed that the passively toured VE (VEB) was the same as that subsequently explored (VEA). The design replicated the original group VEB from Experiment 2b and added a small procedural change to the procedure for a second group. Two groups were pre-exposed to a passive VEB tour before training and testing in VEA as in Experiment 2b. One of the groups was explicitly told that the passively toured VE differed from the VE that they would subsequently actively explore. Running these two groups, one with no instructions and one with instructions, would provide evidence on the possible sampling issue in the Experiment 2b leading to the increased variance, as well as the similarity in detail between VEA and VEB. If random variation was an issue in Experiment 2b, the replication in Experiment 2c should provide evidence of an FPA effect in both groups in Experiment 2c, with or without instructions. If confusion between VEB and VEA was responsible for attenuation of the FPA effect in Experiment 2b, the explicit information about the change in VE provided to the ‘new instruction group’ in Experiment 2c should reduce the generalisation between VEs and the FPA should appear in the ‘new instruction group’ only.

### **4.4.1 Design**

Participants were shown a passive pre-recorded tour of VEB before they actively explored the outdoor VEA. The groups differed in the instructions they received before actively exploring VEA. One group (New Instructions) was told that the VE they were about to see and explore, VEA, was completely different to the VE they had just witnessed a tour of (see appendix C for instructions). The other group (No New Instructions) received no such instructions. There were eight possible versions of the route to control for: the combination of tested objects, the effects of route length (four routes had the first leg as the shortest and four routes had the last



leg as the shortest) and turn direction (four routes had only 90° left turns and four routes had only 90° right turns).

The independent variable was the instruction group experienced. The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency for the JRD's (in seconds).

## **4.4.2 Method**

### **4.4.2.1 Participants**

The participants were 48 undergraduate students who took part in partial fulfilment of a course requirement. Their mean age was 19.97 (range:18 – 36 years) and of these 12 were men; 8 in the No New Instruction group, and 4 in the New Instruction group. They were pseudo-randomly allocated to one of two groups (n=24) with the constraint that approximately the same number of men served in each.

### **4.4.2.2 Apparatus**

All apparatus and materials were the same as in the previous experiment, other than the new instruction sheet. The groups differed in the instructions they were given. In the New Instruction group participants were told before exploration that VEA was completely different to the tour presented VEB. In the No New Instruction group participants were not explicitly told of the difference.

### **4.4.2.3 Procedure**

Participants received a practice exploration and pointing task to familiarise them with the procedure, followed by the presentation of a pre-recorded tour of VEB. They then explored a U-shaped route around the central building in VEA, followed by an alignment test.

Procedural details for the No New Instructions group were the same as for group VEB in the previous experiment. For the New Instruction groups participants were told before viewing the pre-recorded tour that the environment they saw would be different to the one they would later be tested in (see appendix C for detailed instructions). All other details were identical to those for group VEB in Experiment 2b.

#### **4.4.3 Results and Discussion**

The error data for Experiment 2c (see Figures 4.8 and 4.9) were entered into a 2 X 3 X 2 X 2 Mixed ANOVA with factors of group (New Instructions, No New Instructions) alignment (aligned, misaligned and contra-aligned with the first part of the route), judgement direction (forward, backward) and route section.

There was a borderline main effect of alignment ( $F(2, 92) = 3.16$ ,  $MSE = 2956.02$ ,  $p = .05$ ,  $\eta_p^2 = .06$ ) reflecting less error for aligned judgements than misaligned or contra-aligned across both groups. There was also a main effect of judgement direction ( $F(1, 46) = 6.62$ ,  $MSE = 1425.07$ ,  $p = .013$ ,  $\eta_p^2 = .12$ ) reflecting the lower error for forward judgements compared to backward across both groups. There were no other significant effects or interactions.

The latency data (see Figures 4.10 and 4.11) were analysed in the same way as the error data. There was a main effect of alignment ( $F(2, 92) = 5.93$ ,  $MSE = 65799.93$ ,  $p = .004$ ,  $\eta_p^2 = .11$ ) again reflecting faster decision latency for aligned judgements compared with misaligned or contra-aligned for both groups. There was also a main effect of judgement direction ( $F(2, 46) = 10.88$ ,  $MSE = 662159.41$ ,  $p = .002$ ,  $\eta_p^2 = .19$ ) due faster decision latency for forward judgements compared to backward across both groups. No other main effects or interactions were found.

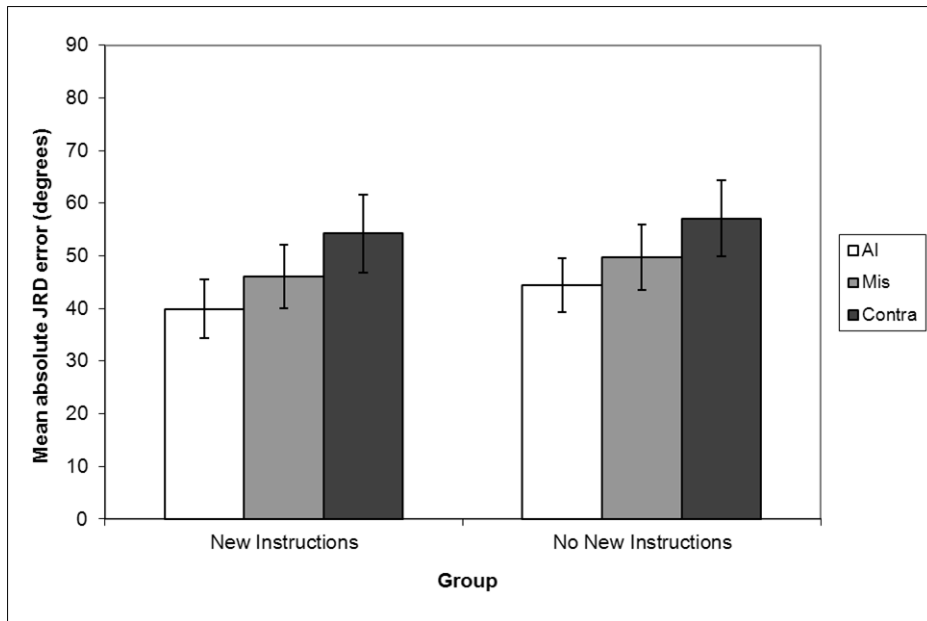


Figure 4.8: Experiment 2c. Mean absolute error for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean

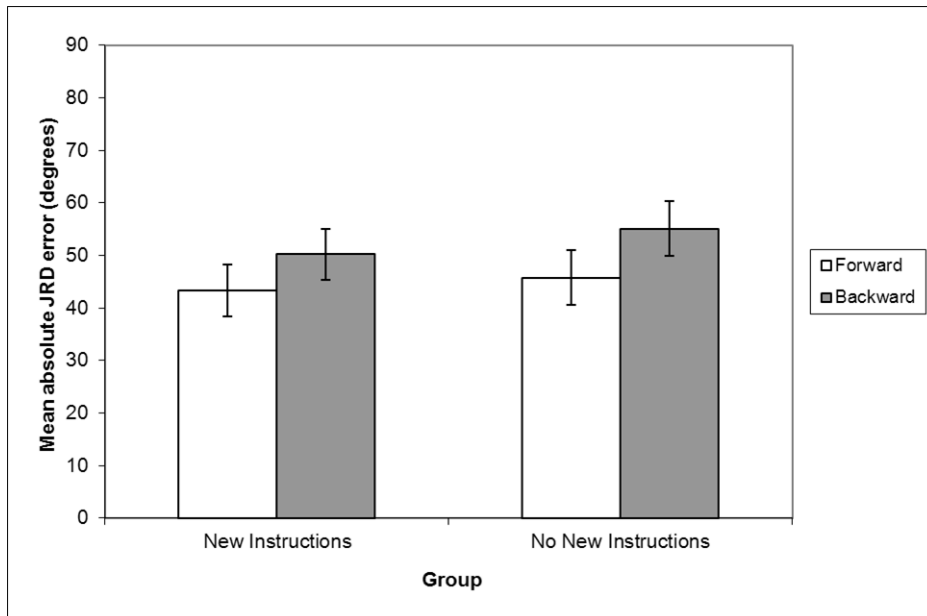


Figure 4.9: Experiment 2c. Mean absolute error for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean

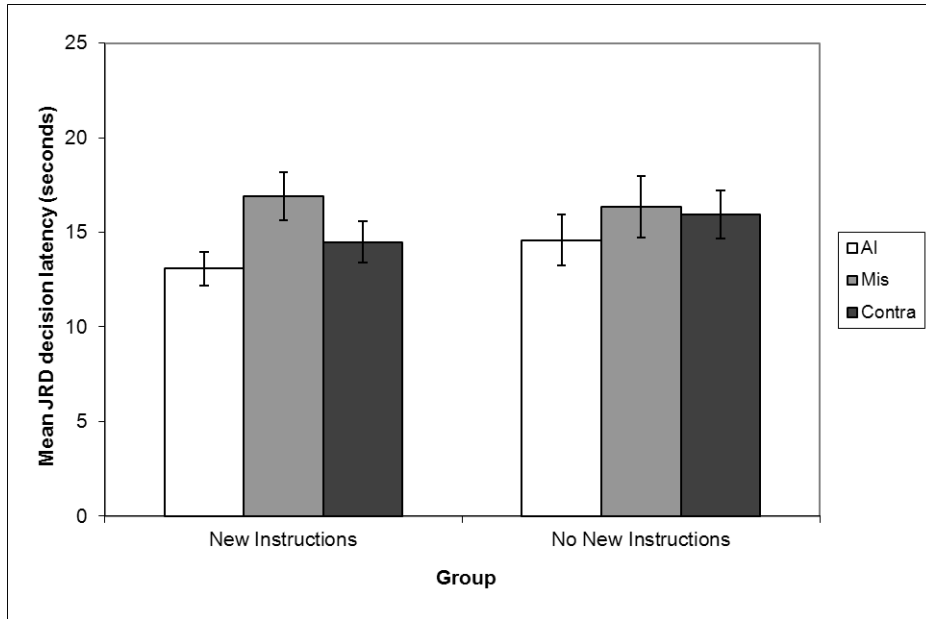


Figure 4.10: Experiment 2c. Mean decision latency for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean

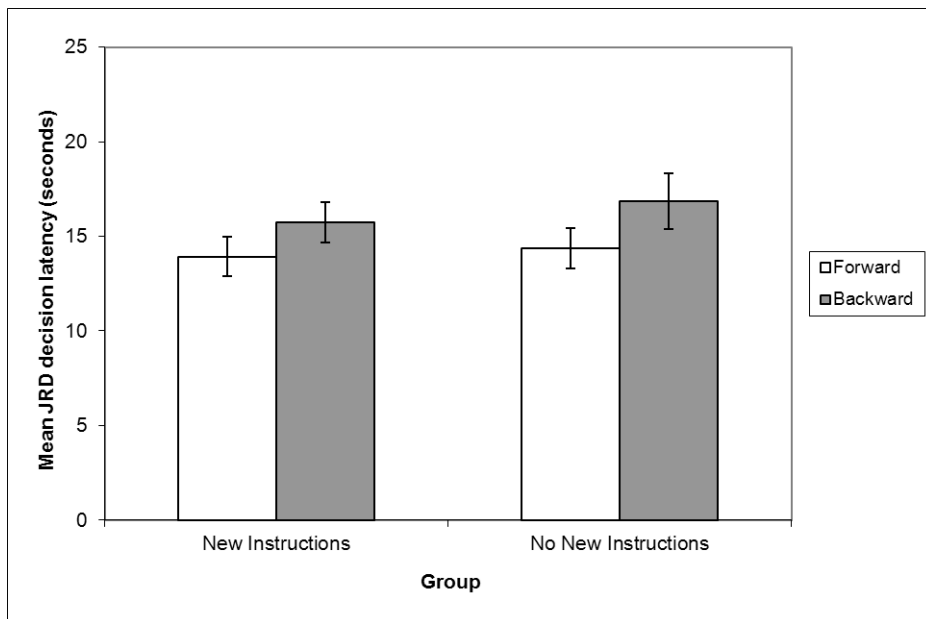


Figure 4.11: Experiment 2c. Mean decision latency for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean

The main effect of alignment, and lack of a significant interaction between alignment and group, suggests that there was no effect of instructions on the FPA effect, failing to support the hypothesis of confusion between the VEs in Experiment 2B. The appearance of the FPA effect in both error and latency in the present experiment suggests that the lack of FPA effect in group VEB in the previous experiment was due to unfortunate random variance. Inferring across experiments suggest support for the original salience hypothesis as the FPA was present in both VEB groups here, and in the original VEC group in Experiment 2c; all groups where the pre-exposure lacked relevant content that could be used to create useful and FPA attenuating anchor points. In confirmation a re-analysis of the data from Experiment 2b, with the substitution of the replicated VEB groups in place of the original VEB was carried out to seek evidence of a group x alignment interaction.

## **4.5 Re-analysis and Discussion**

The analysis from Experiment 2b was re-run with two changes. First the data from the original VEB group was replaced with the data from Experiment 2c. Secondly the misaligned data was not included in the analysis. Although misaligned data was included in previous analyses in the thesis, all subsequent analyses will include only the aligned and contra-aligned data in conformity with recent publications (Nori & Guisbert, 2003; Wildbur & Wilson, 2008; Wilson et al. 2007). This is both for consistency with other published data and to reduce statistical noise caused by the misaligned data. To illustrate: the need for this change can perhaps be seen by expanding on the original analyses of Experiment 2c. With misaligned data included in the mixed ANOVA (2 X 3 X 2 X 2) the main effect of alignment only reaches borderline significance ( $p = .05$ ,  $\eta_p^2 = .06$ ), despite the clear and consistent pattern of data across both groups suggesting a strong FPA effect (see Figures 4.8). When the analysis is re-run without misaligned data (2 X 2 X 2 X 2) the significance of the alignment effect and the effect size is greater ( $p = .027$ ,  $\eta_p^2 = .1$ ) and better represents the data.

The error data for Experiment 2b, substituting the VEB data from Experiment 2c, were en-

tered into a mixed 3 X 2 X 2 X 2 ANOVA with group (VEA, VEB and VEC) as the between subjects factor and alignment (aligned, contra-aligned with the first part of the route), route section (first or last) and judgement direction (forward, backward) as within subject factors.

There was also a main effect of alignment ( $F(1, 93) = 6.38$ ,  $MSE = 2686.79$ ,  $p = .013$ ,  $\eta_p^2 = .06$ ), and a significant alignment x group interaction ( $F(2, 93) = 3.18$ ,  $MSE = 2686.79$ ,  $p = .046$ ,  $\eta_p^2 = .06$ ). The interaction between alignment and group is a consequence of no FPA effect for group VEA and alignment effects consistent with an FPA in groups VEB and VEC. The latency data were analysed the same way as the error data and revealed a main effect of alignment ( $F(1, 93) = 17.1$ ,  $MSE = 65184.68$ ,  $p < .001$ ,  $\eta_p^2 = .15$ ), a main effect of route section ( $F(1, 93) = 4.75$ ,  $MSE = 60273.56$ ,  $p = .032$ ,  $\eta_p^2 = .04$ ) and a main effect of judgement direction ( $F(1, 93) = 13.81$ ,  $MSE = 55197.98$ ,  $p < .001$ ,  $\eta_p^2 = .12$ ).

After the re-analysis of the error data the originally predicted alignment x group interaction appears. The amended salience hypothesis, and the importance of relevant information during pre-exposure are supported. Of course, great weight cannot be attached to post hoc analyses such as this. However, the analyses provides some grounds for suspecting that the lack of FPA effect in the original VEB and its influence on the presented hypotheses can be considered a statistical aberration, as the FPA effect was found in a replication with more participants. Also the difficulty in detecting the FPA effect can perhaps be considered a result of statistical 'noise' when the misaligned data is included.

The results from Experiment 1 and 2 address the concerns arising from the discrepancy in results between different media. The FPA effect is not due to spatial learning differing in virtual environments and the real-world but is rather due to differences in procedure that potentially allow other salient anchor points to be established prior to real-world exploration. The discrepancy that Wilson et al. (2007) found between the results of their Experiment 2, the real indoor corridor with a FPA effect present, and Experiment 3, real outdoor setting with no FPA effect can be re-evaluated: rather than the availability of widely spaced features during exploration providing a basis for alternative anchor points in Experiment 3, the now

modified salience hypothesis provides an alternative. Participants exploring indoors experienced a truly novel environment with no experience of the surrounding space, and therefore established no alternative salient anchor points prior to the experimental task, leading to great reliance on the first perspective. However, participants who explored outdoors had inadvertent prior experience of surrounding spatial information that allowed the formation of alternative salient anchor points, which competed with the first perspective, or led to multiple preferred orientations and alignments. Conclusions from Experiments 2a, 2b and 2c must be treated with caution as they require some cross experiment inference. Unfortunately, the apparent random variation in group VEB in Experiment 2b requires data substitution from the replication with more participants in Experiment 2c. If the inferences from the analysis of the merged data are accepted, the results suggest that prior experience of a space that contains a to-be-tested route can attenuate the FPA that is normally found following exploration of that route, irrespective of the level of detail in the VEs. Even if inferences from the merged data from Experiment 2b and 2c are not accepted, the broad conclusion still holds: participants in Experiment 2a, together with those in Group VEA from Experiment 2b, showed an attenuation of the FPA effect that is otherwise found when training and testing do not involve prior experience of the surrounding environment (Experiment 1). The data from Group VEC in Experiment 2b show this is not due simply to greater exposure to VEs than experienced by the groups showing FPA attenuation; the FPA occurred in this group even with equivalent VE exposure time. The data from group VEB in Experiment 2b do not undermine this conclusion because the pattern of data in this group could not be replicated in Experiment 2c.

Thus, the crucial condition required for the FPA effect is that the participant must not have prior experience of the environment to be explored, even at its periphery. This finding is compatible with the description of the ‘first perspective’ alignment effect: the experimenter defined first perspective must truly be the first experience that the participant has with the environment. If it is, the FPA is strong and reliable (Experiment 1). Any prior exposure can reduce the effect.

With this issue clarified, the FPA effect can now be used to explore the issue of competi-

tion effects in spatial learning with greater confidence in its interpretation. This validation and exploration of the FPA effect is of great importance as it not only means one source of alignment for future competition effects experiments has been established, but that investigations of competition can proceed using a truly spatial measure, in the form of JRD's, and truly spatial learning in alignment effects. It is worth speculating that the pre-exposure to the surroundings which attenuated the FPA effect provides an example of competition between alternative anchor points and the first perspective. The pre-exposure phase is similar to the pre-training phase in the standard blocking design (Kamin, 1969). The exposure to the alternative sources of alignment may have blocked learning about the 'first perspective' when it is experienced later during exploration. Further experiments are needed to investigate these possibilities and present definitive evidence for or against the competition effects in spatial learning.



# Chapter 5

## **A lack of competition between movement and the first perspective; and within object arrays**

### **5.1 Object arrays**

Route exploration designs are not the only way to explore alignment effects. A body of evidence presented by Shelton and McNamara (2001) found evidence the FPA effect using object arrays (Experiment 7). In such experiments, an array of objects is viewed from one perspective prior to another (depending on the experiment in question). A JRD test is then performed and potential alignment effects revealed. The object array design lends itself well to the exploration of competition effects. Different views of the array can be put in conflict with each other, as can the intrinsic structure of the array, and even the structure of the surrounding environment or room that contains the array, allowing for the exploration of egocentric, intrinsic and allocentric influences. Of particular interest is the fact Shelton and McNamara (2001) not only found evidence for the FPA effect in object array designs, but also patterns of results suggestive of competition effects. Such patterns suggest object arrays may be a promising methodology to investigate.

In Shelton and McNamara's (2001) first experiment participants experienced three views of

an object array, 0°, 90° and 225°. They found greater accuracy in judgements made in alignment with both the structure of the room (rectangular) and experienced view (0° and 90°). Judgements made from views that were not aligned with the structure of the room were less accurate than those that were aligned, even if they were the first experienced perspective (such as at 225°). This is suggestive of overshadowing of one alignment source by another alignment source. This could be either, according to the 'Pavlovian' (1927) view of more salient information (structure) overshadowing less salient information (perspective); or in accordance with more contemporary (Rescorla & Wagner, 1972) theories of overshadowing in which multiple sources of information reduce what is learned about any one source presented alone, even when the information sources are of similar salience. A similar suggestion of competition can be found in Shelton and McNamara's Experiment 2. Participants experienced a view of the object array, at 0° or 135°. The room was rectangular and provided a global reference frame, and the objects were placed on a rectangular mat. The mat provided a local reference frame and was aligned with the global reference frame. There was an effect of the initial view on judgements: those who experienced the 0° view first were more accurate at imagined judgements aligned with 0° than others, and those who experienced 135° first were more accurate at imagined judgements aligned with 135°. However initial experience of a view aligned with the local and global structure (0°) led to greater accuracy for novel views aligned with this structure; implying learning of the structure that could attenuate the potentially detrimental effect expected of the first perspective on novel misaligned views. Experiment 4 found what might have been competition between local cues (a mat) and global (room structure) with preference for the local cues when the two sets were incongruent. Importantly though in Experiment 7 a clear FPA effect was established using object arrays. Previous evidence for preferred orientation in Experiment 2 was not strictly a FPA effect; it was the only experienced view rather than the first of several which had preferential status. Participants received three views, the same as those experienced in Experiment 1. However in Experiment 7 the object array was in the centre of a cylindrical room so room structure was removed as a possible global reference frame. In doing so they found that viewing order

had an effect on judgements. Though participants experienced all three views at testing the lowest error was found when making imagined judgements aligned with the first experience view; a clear FPA effect.

Due to the design of Shelton and McNamara's (2001) experiments their evidence for competition effects is merely suggestive. Their research was not intended to investigate such effects and consequently the design is not robust enough for conclusions on the presence of competition in alignment learning to be drawn from. While some of the results suggest competition, a properly controlled design was not used, limiting any conclusions. Only the first perspective is presented in isolation in the Shelton and McNamara (2001) experiments. Room structure is never presented in isolation; it is always presented in compound with a set and definite first perspective. With these research findings in the mind Experiment 3 attempted to directly investigate potential competition effects in alignment learning. Changes in the standard object array design were made to clearly identify two different sources of alignment in isolation, and then place them in direct competition.

## **5.2 Experiment 3**

Using an object-array based procedure, an A, B, AB overshadowing design was employed in Experiment 3, in which condition A was the alignment influence of the initial perspective, and condition B was the alignment influence of room geometry.

Three groups of participants viewed an array: one group viewed the array in a static circular room (similar to Shelton & McNamara, 2001, Experiment 6 and 7), while the second group viewed the array in a static rectangular room, and the final group viewed the array in a constantly rotating rectangular room (see Figure 5.1). The stationary circular room group should provide evidence for the FPA effect (condition A) because the absence of surrounding linear structural cues does not provide a ready alternative source of alignment in which to encode the array (cf. Shelton & McNamara, Exp 7). The rotating rectangular room exposed

participants to a linear geometric environment (condition B) while reducing or abolishing the influence an initial viewing perspective. The static rectangular room should provide two sources of spatial alignment effects, the initial perspective and the rectangular framework (AB), which might compete with each other. An important additional design feature for the static circular and static rectangular rooms is that two views were employed, at 0° and 135°, with order of viewing counterbalanced, to assess the influence of the first perspective over another perspective. Importantly, although the spatial overshadowing procedure utilised for Experiment 3 differs from overshadowing in associative learning, formal learning models such as the Rescorla-Wagner model can be applied to spatial and other non-associative learning. As Shanks (2007) has pointed out, 'Rescorla and Wagner themselves were silent on the issue of the representational structures that they thought underlie conditioning—their model is equally applicable to excitatory links as it is to structured representations' (pg 299). Therefore, terms used for competition between CSs in conditioning procedures ('overshadowing' and 'blocking') are used in this thesis to describe related procedural designs and anticipated outcomes without implying a particular underlying representational structure.

If, when presented in isolation, both the initial perspective and the room structure can provide separate sources of alignment, we would expect to see appropriate alignment effects in the static circular (FPA effect) and rotating rectangular room (allocentric) respectively. These two groups provide the control conditions (A and B) against which to assess overshadowing in the static rectangular room group which potentially provides both sources of alignment information (AB). In the static rectangular room group, if there is a preference for the first perspective we would expect to find evidence of a FPA effect, with the most efficient JRDs in alignment with the first experienced perspective over all others. If there is a preference for the allocentric reference frame in this group we would expect to see the most efficient performance in alignment with the walls of the room. This would be evidenced by a saw tooth pattern of responding similar to that found by Shelton and McNamara (2001) in their second experiment. Evidence for a lack of competition would come from evidence for learning about both the first perspective and the allocentric structure, that is equal to that when these aspects

are presented on their own. The experimental hypotheses were: first, in the static rectangular group, the room structure should have an effect on the magnitude of the FPA effect, reducing the efficiency of JRDs in alignment with the first over the second perspective by comparison with the equivalent measures in the static circular group. Second, in the static rectangular group the first encountered perspective should attenuate the saw toothed pattern found in the rotating rectangular group by comparison with the rotating rectangular group.



Figure 5.1: First person views of the VEs used in Experiment 4. Upper Panel: Circular room. Lower Panel: Square room. The Square Rotating Room had the same details as the Square room.

## **5.2.1 Design**

Participants experienced views of an array of objects within either a Circular Room VE, a Square Room VE, or a Square Rotating Room VE. In all three VEs the object array contained the same seven objects in the same relative arrangement. In the Circular, and Square Room groups participants experienced two views of the object array, the second perspective being located 135° from the first perspective. Each view was experienced for approximately 60 seconds.

The independent variable was the type of VE experience (Circular Room, Square Room, Rotating Square Room). The dependent variables were the mean absolute error in the judgements of relative direction (JRD, in absolute degree's) and the decision latency to make the JRD's (in seconds).

## **5.2.2 Method**

### **5.2.2.1 Participants**

The participants were 68 undergraduate students who took part in partial fulfilment of a course requirement. Their mean age was 20.09 (18 - 40). The Circular Room group (n= 28) contained 4 men, the Square Room group (n= 24) contained 2 men and the Square Rotating Room group (n= 16) contained 4 men. The difference in sample size was due to the discontinuation of testing when a lack of either alignment effect individually became apparent. Without clear alignment effects in the control conditions no evidence of competition could possibly be found. This is discussed further in section 5.2.3.

### **5.2.2.2 Apparatus**

The static Circular Room VE had a diameter of that would translate to approximately 7 metres, a circumference of 22 metres and a ceiling height of 7 metres, the object array was placed

centrally. The static Square Room VE was 7 by 7 by 2.5 metres, with the same centrally placed array. The Square Rotating Room comprised the same dimensions and properties as the static Square Room. It rotated by one full revolution every 8 seconds. Seven objects were arranged in the centre of each room (see Appendix D). The objects were a kettle, a pan, a keyboard, a cup, a jar, a wrench and a boot. They were arranged in a regular array similar to that of Shelton and McNamara (2001), with approximately 1 metre between each object.

### **5.2.2.3 Procedure**

Participants were given practice experience in a VE and a pointing task to familiarise them with the procedure. The seven objects they would see were described, and they were asked to repeat their labels. In the static Circular and Square Room groups, participants experienced a view of the object array at either  $0^\circ$  or  $135^\circ$  with respect to the view illustrated in Figure 5.1. After approximately 60 seconds, the view was then changed to a second view point and perspective. The order in which the view points were experienced was counterbalanced across participants within groups. The experience differed for participants in the rotating room as they did not receive two unique views ( $0^\circ$  or  $135^\circ$ ) due to the rotation. To maintain equivalence in procedure when views were changed for the static room groups, the rotating group viewed the room for approximately 60 seconds before the same rotating view was re-loaded for a further 60 seconds.

When viewing was complete, the VE was removed from the computer screen and the pointer program was loaded. The participants were required to make 32 judgements using the pointer, comprising a random mix of 4 judgements (2 forwards and 2 backwards) at 8 possible judgement positions (imagined standing at  $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ ,  $180^\circ$ ,  $225^\circ$ ,  $270^\circ$  and  $315^\circ$ ). Judgement accuracy and decision latency were automatically recorded by the software.



### 5.2.3 Results and Discussion

The data were collated as described as in previous experiments in the series. The error data for Experiment 3 (see Figure 5.2, 5.3 and 5.4) were entered into a mixed 3 X 8 X 2 ANOVA with group (Circular Room, Square Room and Rotating Square Room) as the between-participant factor and judgment position (0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°) and judgement direction (forward, backward) as the within-participant factors. There were no significant main effects or interactions ( $p > 0.05$ ).

The latency data (see Figure 5.5, 5.6 and 5.7) were analysed the same way as the error data, and revealed only a judgement direction x group interaction ( $F(2, 64) = 5.05$ ,  $MSE = 27.32$ ,  $p = .009$ ,  $\eta_p^2 = .13$ ). This was a result of faster forward judgements than backward in the Square Room group, but similar forward and backward judgment latencies in the Circular Room and the Rotating Square Room.

Individual group analyses were performed using a mixed 2 X 8 X 2 ANOVA with viewing order (0° then 135° or 135° then 0°) as the between-participant factor and judgment position (0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°) and judgement direction (forward, backward) as the within-participant factors.

For the Circular Room error data there was a main effect of judgement position ( $F(7, 182) = 3.69$ ,  $MSE = 1556.47$ ,  $p = .01$ ,  $\eta_p^2 = .12$ ), which appears to reflect lower mean error scores for all judgements position of between 0° and 135° in comparison with 180° to 315°. The lack of significant interaction between viewing order and position (or alignment) suggests that it does not matter what view is seen first; there is no effect of the first perspective on the data. This main effect of judgement position or alignment appears to be a preference for judgement positions close to both those experienced rather than a preference for the first perspective experienced. There was a main effect of judgement direction ( $F(1, 26) = 13.25$ ,  $MSE = 1157.18$ ,  $p < .001$ ,  $\eta_p^2 = .33$ ) reflecting lower mean error for forward judgements ( $M = 60.45$ ;  $SE = 2.82$ ) than backward ( $M = 72.15$ ;  $SE = 2.87$ ). The latency data, analysed the same way as the error data, revealed no significant main effects or interactions.

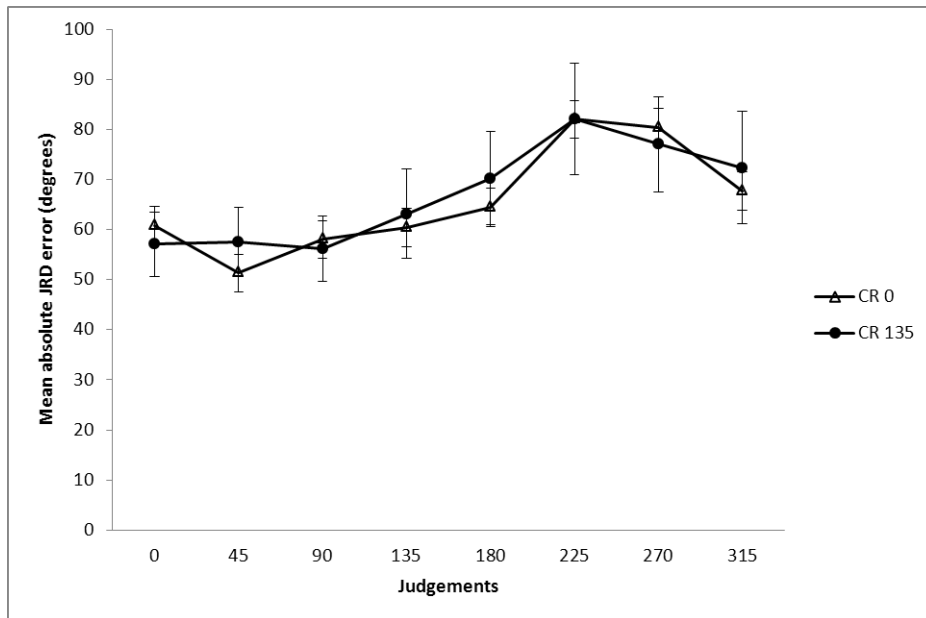


Figure 5.2: Experiment 3. Mean absolute JRD error across all imagined judgement positions for both viewing orders (0° then 135°, 135° then 0°) in the Circular Room group.

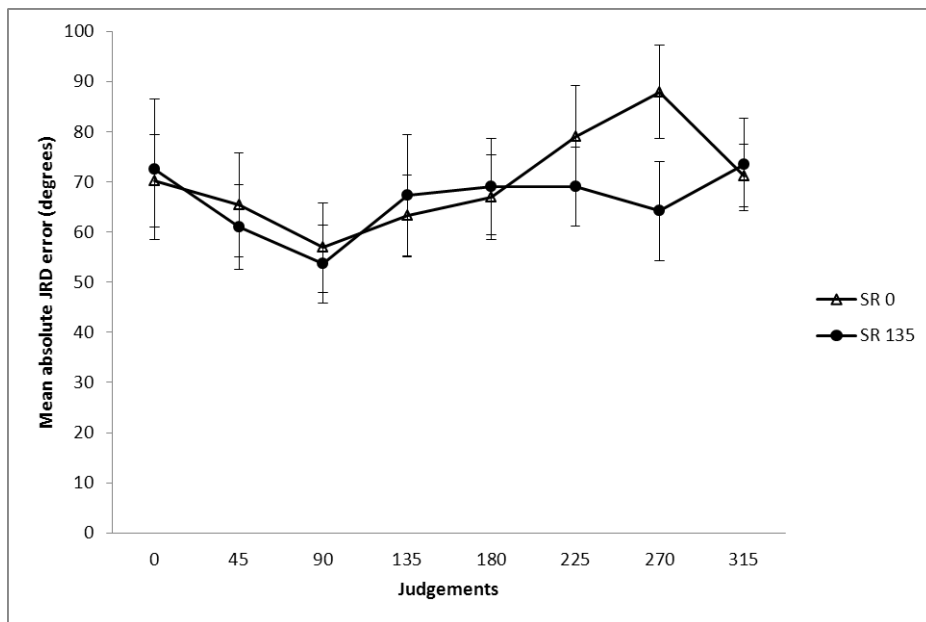


Figure 5.3: Experiment 3. Mean absolute JRD error across all imagined judgement positions for both viewing orders (0° then 135°, 135° then 0°) in the Static Square Room group.

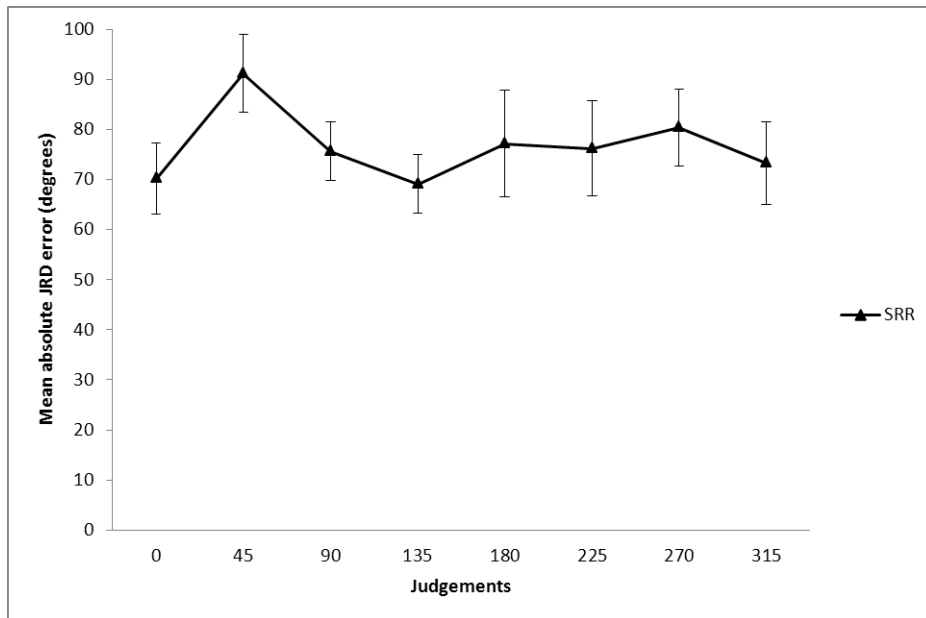


Figure 5.4: Experiment 3. Mean absolute JRD error across all imagined judgement positions in the Square Rotating Room group.

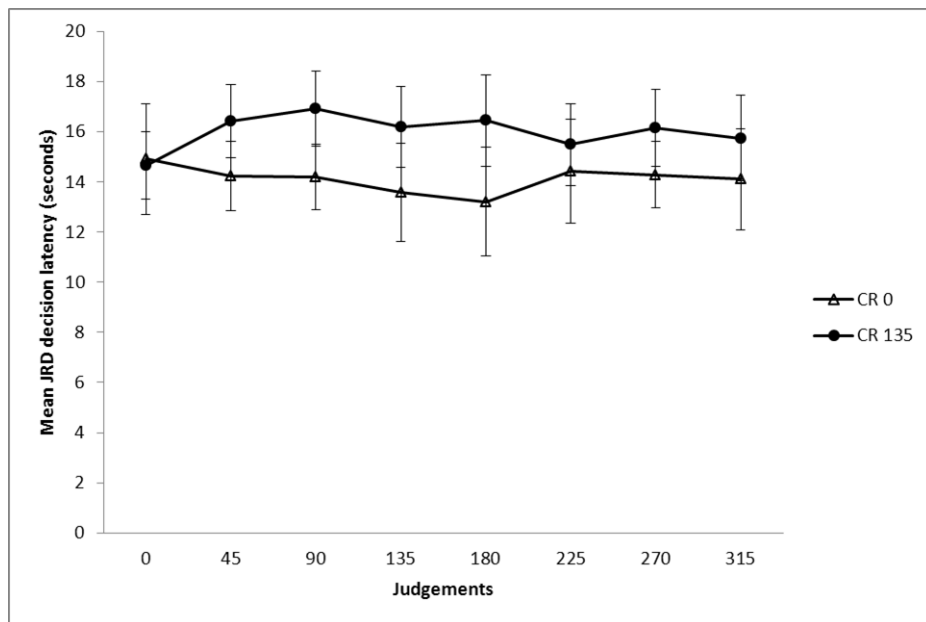


Figure 5.5: Experiment 3. Mean JRD decision latency across all imagined judgement positions for both viewing orders (0° then 135°, 135° then 0°) in the Circular Room group.

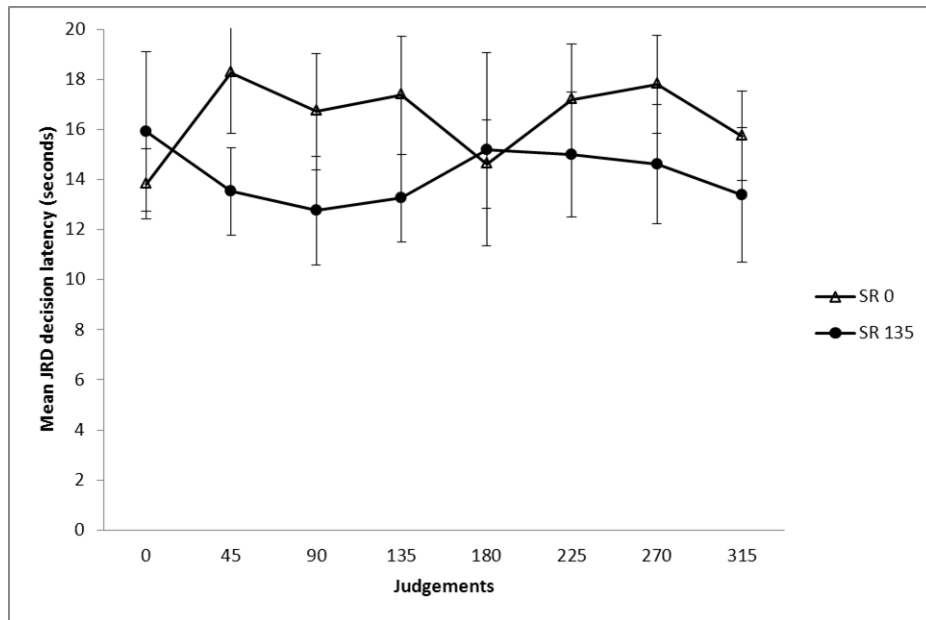


Figure 5.6: Experiment 3. Mean JRD decision latency across all imagined judgement positions for both viewing orders (0° then 135°, 135° then 0°) in the Static Square Room group.

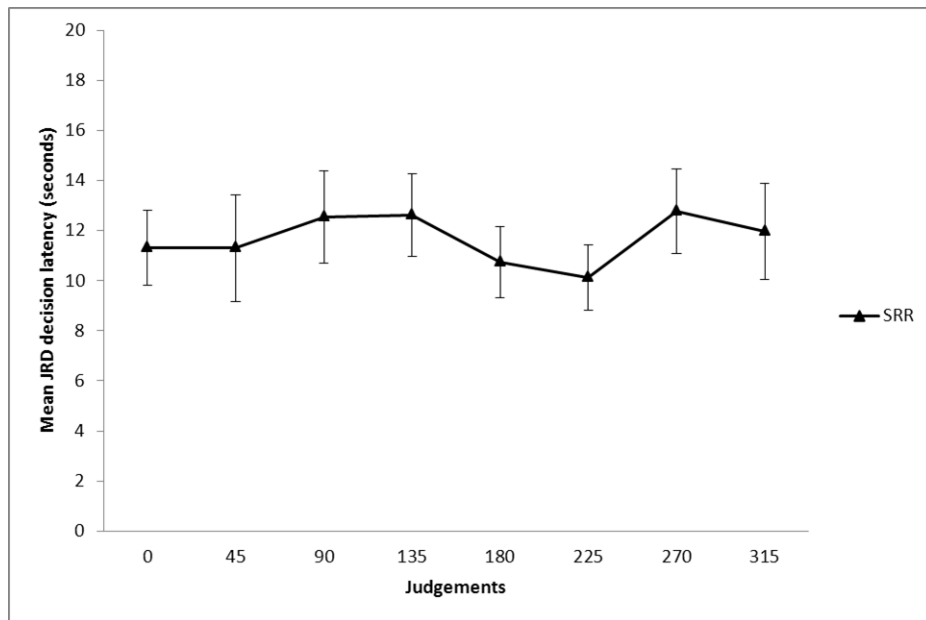


Figure 5.7: Experiment 3. Experiment 4. Mean JRD decision latency across all imagined judgement positions in the Square Rotating Room group.

For the Square Room error a main effect of judgement direction ( $F(1, 22) = 13.43$ ,  $MSE = 22.88$ ,  $p < .001$ ,  $\eta_p^2 = .37$ ) was found reflecting smaller mean error for forward judgements ( $M = 66.47$ ;  $SE = 3.21$ ) than backward ( $M = 69.86$ ;  $SE = 3.44$ ). Analysis of the latency data revealed no significant main effects or interactions.

The lack of different viewing orders in the Square Rotating Room group meant that a slightly different analysis was appropriate: an 8 X 2 ANOVA was used, with judgement position ( $0^\circ$ ,  $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ ,  $180^\circ$ ,  $225^\circ$ ,  $270^\circ$  and  $315^\circ$ ) and judgement direction (forward, backward) as within-participant factors. Analysis of the error data revealed no significant main effects or interactions. No significant main effects or interactions were found upon analysis of the latency data either.

Contrary to predictions based on Shelton and McNamara's (2001) findings, alignment effects consistent with either the first perspective or the room structure were not apparent in the present experiment. A main effect of judgement position was found in the Circular Room error data but, as there was no interaction between position and viewing order (i.e. it did not matter whether the  $0^\circ$  or  $135^\circ$  view was seen first) this did not represent an FPA effect. From looking at the data in Figure 5.2 it appears that the judgements around the  $0^\circ$ - $135^\circ$  mark, i.e., those experienced or between those experienced, were better than other judgements. There was a complete lack of an alignment effect in the Rotating Square Room. Based on Shelton and McNamara's (2001) results a saw tooth pattern would have been expected if the structure had been learnt about; more efficient judgements for the positions aligned with the structure ( $0^\circ$ ,  $90^\circ$ ,  $180^\circ$ ,  $270^\circ$ ) than those not-aligned with it ( $45^\circ$ ,  $135^\circ$ ,  $225^\circ$ ,  $315^\circ$ ). As these groups produced no evidence of predicted alignment effects, there were no effects to be attenuated in the static Square Room.

This preliminary exploration into the use of computer-simulated object arrays suggests that they are not suitable for addressing questions relating to cue competition effects, at least with the parameters used here which were based on previous research. They cast doubt on the whether the first-perspective alignment effect is reliable from object-array learning. Though

initial studies such as Shelton and McNamara (2001) found evidence of the FPA effect under certain conditions, later studies such as Mou, Zhao and McNamara (2007) found no such evidence for a FPA effect, or preference for an egocentric frame of reference. Mou et al. (2007) found that participants used lines of symmetry to determine a preferred axis other than that defined by the first perspective. They found no preference or benefit to judgements aligned with the first perspective, in contrast to the findings of Shelton and McNamara (2001), Experiment 7 in particular. They suggested that this was due to procedural differences. In Shelton and McNamara (2001), participants had to point out and name all the objects in the array each time they viewed a new perspective. The first time they saw the objects and had to name them was during their first perspective. Mou et al. (2007) suggest this might have resulted in more learning time directed to the first perspective giving it a privileged status. When the time devoted to learning both views is equal, as in Mou et al. (2007) and Experiment 3 here, no preference for the first perspective is found.

The lack of consistent alignment effects in the Circular and Square Room pose a problem to further research on competition effects. Any further work utilising object arrays would require two new sources of alignment to be established before competition effects could be investigated. In consequence it was decided to explore alternatives based on the route-learning paradigm as the conditions required for a clear and consistent FPA effect have already been found in Experiments 1-2c. All that remains is finding an alternative source of alignment to place in competition with the already established FPA effect.

### **5.3 First perspective versus human movement**

The lack of alignments effects in the object-array based Experiment 3 suggested a return to the previously investigated route exploration design. This thesis has already made some progress in establishing the conditions under which an FPA effect can be found in during route exploration, and has addressed some existing issues in the literature. Chapters 3 and 4 investigated the inconsistency in detecting the presence of the FPA effect in previous studies and clarified why a difference between primary and secondary sources of media/learning had been recorded. The results supported the modified salience hypothesis as an explanation: that the difference between media is due to differences in the typically experienced salient spatial information encountered. When a comparable procedure to real-world learning is used in a VE, comparable results are obtained in terms of the FPA effect. Experiments 1 and 2 also established the conditions that promote the FPA effect, paving the way for studies of competition with other truly spatial sources of learning.

With these clarifications, the following experiments focused on competition between different sources of spatial learning. One of these sources would be the already established FPA effect. However, Experiment 3 suggested that allocentric cues, a natural choice for a second alignment source, do not lead to the expected saw-tooth pattern indicative of allocentric learning in a square delineated environment. One particularly interesting potential source of spatial alignment effects that could be used to compete with other sources such as the first perspective may come from human movement. Human spatial navigation does not occur in a vacuum, and one area that is often neglected in spatial learning studies is social influence. Whilst an arrangement of buildings and objects might suggest allocentric frames of reference or principal reference vectors, the same might be true of coordinated human movement. The importance of certain locations within an environment could be indicated by the volume and harmony of human traffic moving towards them. In the context of a university campus, the flow of human movement is likely to be towards key buildings and facilities such as the library. A common universal direction of movement might be sufficient to define a

principle reference vector, similar to that defined by the first experienced perspective. The mental representation of the environment might become aligned with the direction of congruent movement. Levine et al. (1982) found that map reading is more efficient when in alignment with personal experience; the mental map of the local environment may be aligned with the common direction of travel.

If movement direction could be established as a source of alignment learning, this would open up new directions in spatial cognition research. Humans have been found to follow the eye gaze of others, even when as young as 3 months old (Reid & Striano, 2005; Samuels, 1984) and according to the theory of mind (Frith & Happe, 1994) people constantly make assumptions about the state of mind and intentions of others. The presence of other people, all-facing, looking and moving in one direction may play upon this social aspect of cognition. It may cause participants to attempt to follow their gaze, or assume that the others are moving towards a goal, making a particular direction or vector more salient than another. Janzen, Schade, Katz and Herrmann (2001) found that participants could make judgements just as well from the view point of a distant person (dummy) as they could from their own view point (see also Aromin, 2003). Congruent with the theory of mind, participants seem to be able to envisage themselves in the position and orientation of other humans in the environment. In addition, Morrow, Greenspan and Bower (1987) found that implied movement of characters through a described building had an effect on the accuracy of judgements made about whether certain objects were present in distant rooms; judgements about object presence and location were more accurate if the implied movement of the characters were towards it, or if the character was near it. Similarly, Rapp, Klug and Taylor (2006) found that described movement of characters through space affected the accessibility and accuracy of spatial information near them when the movement was predictable and unidirectional. As in Janzen et al. (2001), and in accordance with the theory of mind, the accuracy of spatial judgements were improved when there was seemingly purposeful and predictable human movement, and the points of view of other people that could supplement the participants own experience, even in imagined settings.



Tversky and Hard (2008) presented participants with images of a selection of objects and then asked them to describe the relationships between the objects. Some of these images also contained a person in the background with a view opposed to the participants. One set of the images contained a person looking at the objects, and another contained the same person reaching for an object. They found that many, though not all, participants were able to adopt the perspective of the other person quite readily. In the second experiment when the participants were asked to describe the spatial relationships between the objects the question was either phrased as to imply action on the part of the person present in the image, such as reaching, or implied no action as it had in the first experiment. When the question called attention to the implied action the amount of participants who described the spatial relationship between the objects from the point of view of the other person increased. Unlike Janzen et al. (2001) and the other previously mentioned experiments the accuracy of the spatial judgments in Tversky and Hard (2008) was not the focus of investigation. The results did however demonstrate an apparent ability to adopt the spatial perspectives of others from the merest of suggestions. This suggests that human action may be an influential source of alignment or orientation.

## **5.4 Experiment 4a**

This experiment was a preliminary investigation into whether a direction of social movement could create a source of alignment that could be used in subsequent experiments to compete with the first perspective. The same rich outdoor VE used in Experiment 2a (VEA) was employed because the presence of the FPA (under normal exploration) has already been established. Coordinated human movement was provided by the use of realistic computer simulated people who moved continuously through the VE, either in a direction that was aligned with the explorer's initial perspective (FPA congruent), or, in a direction 180° misaligned with the explorer's initial perspective (FPA incongruent) (see Figure 5.8). By introducing two potential sources of alignment learning, both human movement and the FPA, the



Figure 5.8: First-person initial view of the VE used for Experiment 4a, which illustrates incongruent human movement, contra-aligned with the explorer's initial perspective.

procedure shares conceptual similarities with overshadowing (Pavlov 1927).

As a preliminary hypothesis, if human movement is congruent with the initial orientation on the environment, the FPA effect should not be disrupted, or it might even be facilitated. However, if movement in the opposite direction to the first perspective engenders a preferred orientation in the opposite direction to the first perspective, the FPA effect might be weakened. This outcome pattern would suggest a spatial equivalent to traditional overshadowing, which is normally explained in associative terms (see section 5.2). The next step would be to incorporate additional controls (see Chapter 6). The essential hypothesis at this point is that the inclusion of human movement incongruent with the first perspective or direction of travel should have a disruptive effect on the presence of the FPA effect.

#### **5.4.1 Design**

Participants actively explored a U-shaped route within an outdoor Virtual Environment. In the VE there were also computer controlled people who walked a route alongside the outside

of the central building. Eight versions of the route were used to control for: the combination of tested objects, the effects of route length (four routes had the first leg as the shortest and four routes had the last leg as the shortest) and turn direction (on the outward leg, four routes had only 90° left turns and four routes had only 90° right turns).

The independent variable was the direction of travel taken by the computer controlled simulated people who moved either congruent with, or incongruent with, the first perspective or direction of travel experienced by the participant. The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency to make the JRD's (in seconds).

## **5.4.2 Method**

### **5.4.2.1 Participants**

The participants were 48 undergraduate students acting in partial fulfilment of a course requirement. Their mean age was 21.1 (18 - 49) years old, and of these 15 were men: 8 in the incongruent group and 7 in the congruent group. They were pseudo-randomly allocated to one of two groups (n=24) with the constraint that approximately the same number of men served in each.

### **5.4.2.2 Apparatus**

The VE used was the same as VEA used in Experiment 2b. The only modification was the inclusion of computer simulated people. There were 36 computer controlled people who walked one of two parallel unidirectional routes past the central building which provided the pathway for participant exploration. The simulated people represented a random mix of sex, age and ethnicity, and all wore the same clothing (light blue jumpsuit). The movement speed of the computer-controlled people through the VE was approximately the same as that of the participants.

### 5.4.2.3 Procedure

Participants received a practice exploration and pointing task to familiarise themselves with the general requirements of the procedure, followed by exploration of the target U-shaped route around the central building, and an alignment test. For half the participants, the direction in which the simulated people moved was congruent with their initial perspective; for the remaining participants the direction in which the simulated people moved was opposite to the direction of their initial perspective. Otherwise, the main exploration and test procedure was identical to that of the exploration of the Rich Outdoor environment (VEA) in Experiment 1.

### 5.4.3 Results and Discussion

The error data for Experiment 4a (see Figure 5.9 and 5.10) were entered into a 2 X 2 X 2 ANOVA with group (incongruent, congruent) as the between subjects factor and alignment (aligned or contra-aligned with the first part of the route) and judgement direction (forward or backward-facing) as within subject factors. This analysis differs from previous experiment as misaligned and route section data were no longer analysed. This was because previous analysis had failed to find any significant effects or interactions of note regard the route section, and this is not an essential factor in establishing the presence of the FPA effect. The misaligned data were not analysed as they simply increased variance in analysis, which may have obscured alignment effects. The misaligned data is reported descriptively but, as previously discussed in Chapter 4, not analysed, which is in keeping with other published studies with which comparisons might be drawn (Wildbur & Wilson, 2008; Wilson & Wildbur, 2004; Wilson et al., 2007). Furthermore Nori and Guisbert (2003) found no significant difference between misaligned and contra-aligned judgement accuracy, but a significant difference between aligned and misaligned, and aligned and contra-aligned.

In the analysis of the error data, there was a main effect of alignment ( $F(2, 46) = 4.29$ ,  $MSE = 2057.46$ ,  $p = .022$ ,  $\eta_p^2 = .08$ ) reflecting the lower aligned error scores than contra-aligned

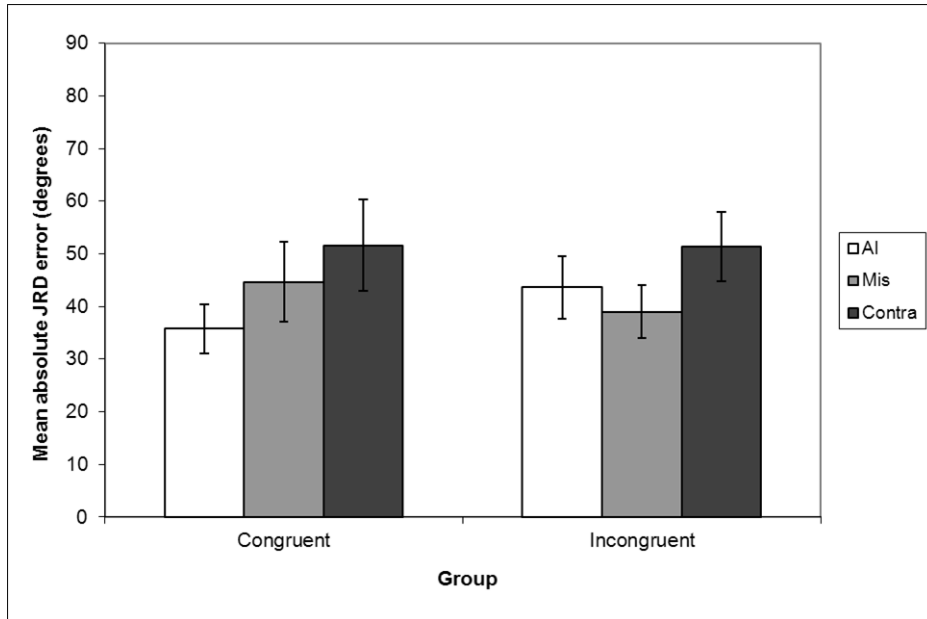


Figure 5.9: Experiment 4a. Mean absolute errors for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

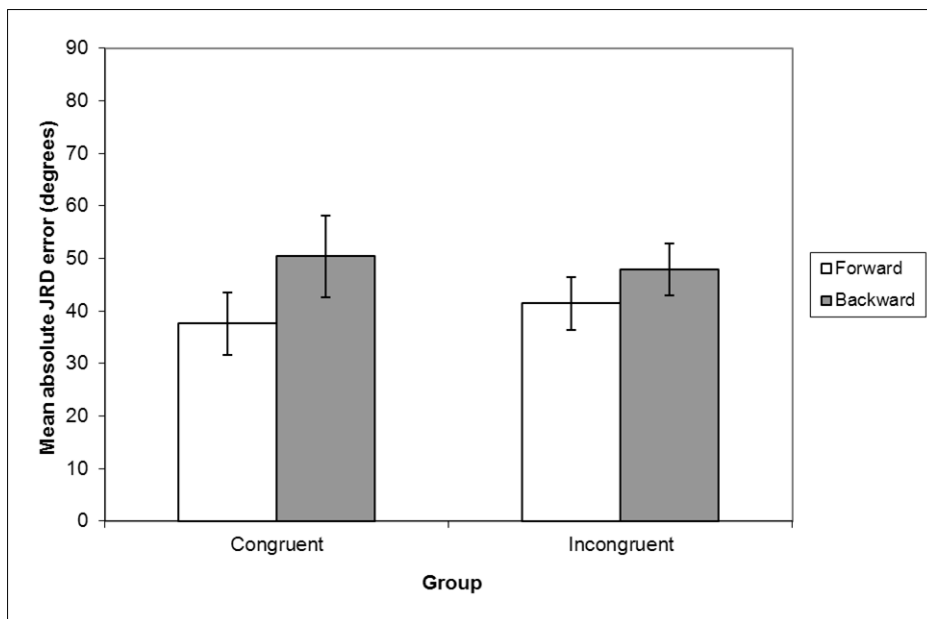


Figure 5.10: Experiment 4a. Mean absolute errors for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

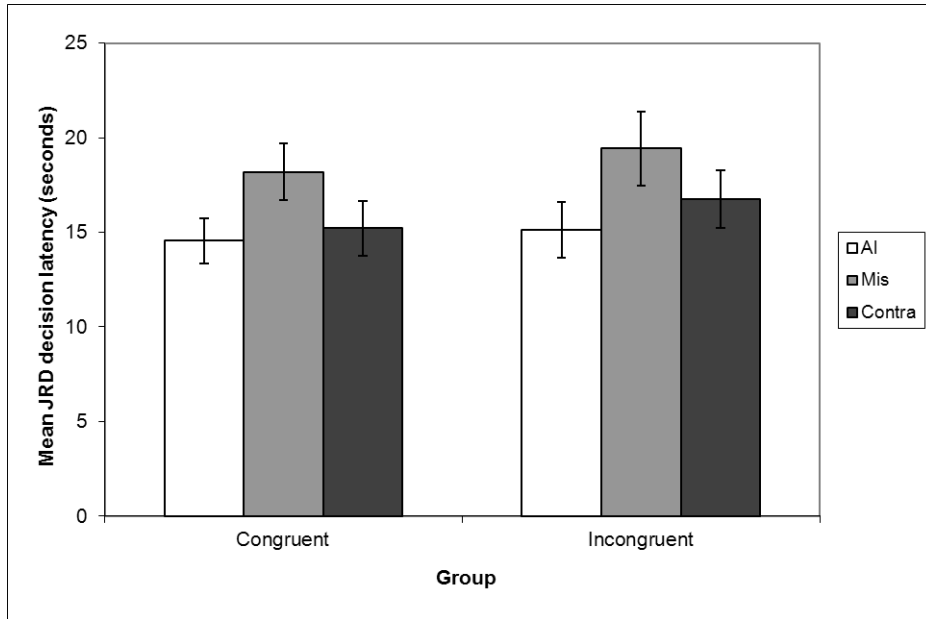


Figure 5.11: Experiment 4a. Mean decision latency for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

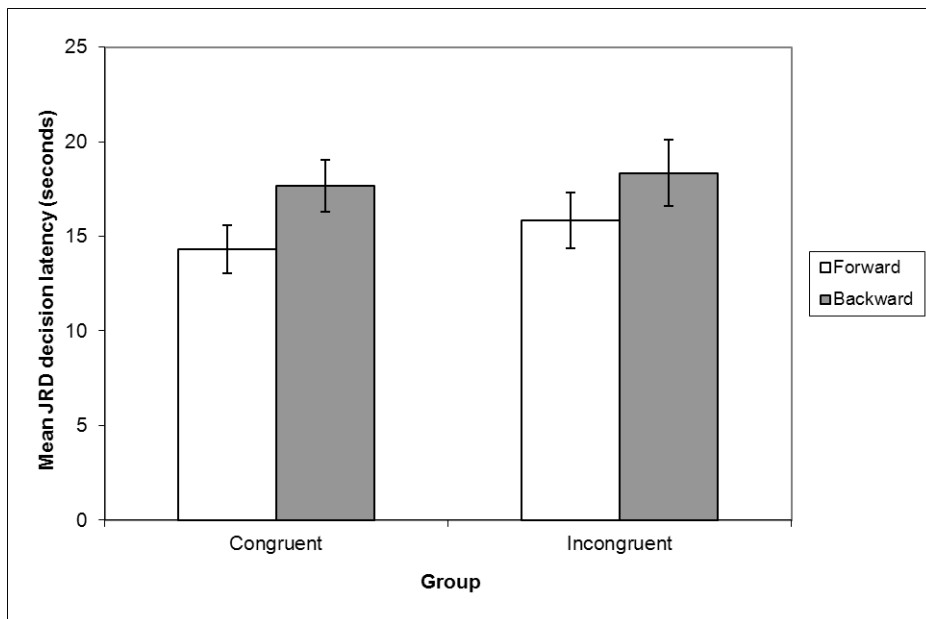


Figure 5.12: Experiment 4a. Mean decision latency for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

in both groups. There was a main effect of judgement direction ( $F(2, 46) = 7.82$ ,  $MSE = 1702.56$ ,  $p < .008$ ,  $\eta_p^2 = .14$ ) similarly reflecting the lower forward-facing judgement error than backward-facing judgement error for both groups. No other main effects or interactions were found.

The latency data (see Figure 5.11 and 5.12) were analysed in the same way as the error data. There was a main effect of alignment ( $F(2, 46) = 19.26$ ,  $MSE = 47459.59$ ,  $p < .001$ ,  $\eta_p^2 = .29$ ) reflecting overall faster decision latency for aligned judgments than contra-aligned. There was also a main effect of judgement direction ( $F(2, 46) = 30.09$ ,  $MSE = 40966.45$ ,  $p < .001$ ,  $\eta_p^2 = .39$ ) reflecting faster decision latency for forward judgements compared to backward across both groups. No other main effects or interactions were found.

The overall alignment effect in both error and latency data, as well as the lack of group interaction on alignment, suggests no effect of human movement on the FPA effect. The null hypothesis can be accepted. The first experienced perspective had a similar influence on alignment learning whether congruent or incongruent with simulated human movement. However, unfortunately the design of the experiment does not allow an inference as to whether this is because the salience of the first perspective overshadowed learning about human movement which would otherwise have been evident in isolation, or whether the only available source of alignment was the first perspective. A full overshadowing design would have included groups to confirm that both the first perspective alone, and human movement alone, could determine alignment effects. Due to limitations in the VEs and procedure it was not possible to separately assess the effects of human movement. Removal of the first perspective would have required disorientation and passive exploration of the surroundings; however, this procedure might have introduced anchor points that indicated reference vectors other than the one suggested by the human movement. That is, the process of eliminating the influence of the first perspective may have resulted in the removal of the influence of the human movement that was intended to be the focus. Therefore, while it is clear the human movement did not influence alignment leaning, it is unclear whether this is due to overshadowing of human movement by the salience of the FPA effect, or whether human movement is limited as a

source of alignment in its own right.

## **5.5 Experiment 4b**

The limitations discussed above mean that it is difficult to remove the influence of the first perspective and present human movement as a source of spatial alignment learning in isolation. Therefore, it is not clear whether human movement had any influence on alignment. To investigate further, a very basic blocking design was employed. In the first phase, attempts were made to increase the salience of the human movement direction (A+) before introducing the free exploration that leads to the FPA effect in the context of continued human movement (AB+). Should this treatment produce a weaker than normal FPA effect (B alone), a more complete blocking design with appropriate control conditions would be warranted (see Chapter 7).

To increase the salience of human movement as a source of alignment in Experiment 4b, participants were ‘primed’ to attend to the direction of travel of the simulated people in a preliminary training phase. Participants were shown a brief pre-recorded tour of a novel VE where they witnessed people walking towards a building. The recorded tour followed the simulated people into the building where an interesting event occurred (flares were ignited and an individual waved at the participant, see Figure 5.13). This brief pre-training (similar to phase 1 of a blocking design) was an attempt to encourage participants to subsequently attend to the direction of human movement while exploring a novel environment for the first time. Participants then experienced training in the rich outdoor environment (VEA) with an incongruent direction of human movement. It was hypothesised that attending to the direction of movement might attenuate or block the influence of the first perspective during exploration, reducing (blocking) the FPA effect by comparison to that found in earlier studies reported in this thesis which did not have the preliminary training (Experiment 1; Rich Outdoor group, see Figure 3.5).



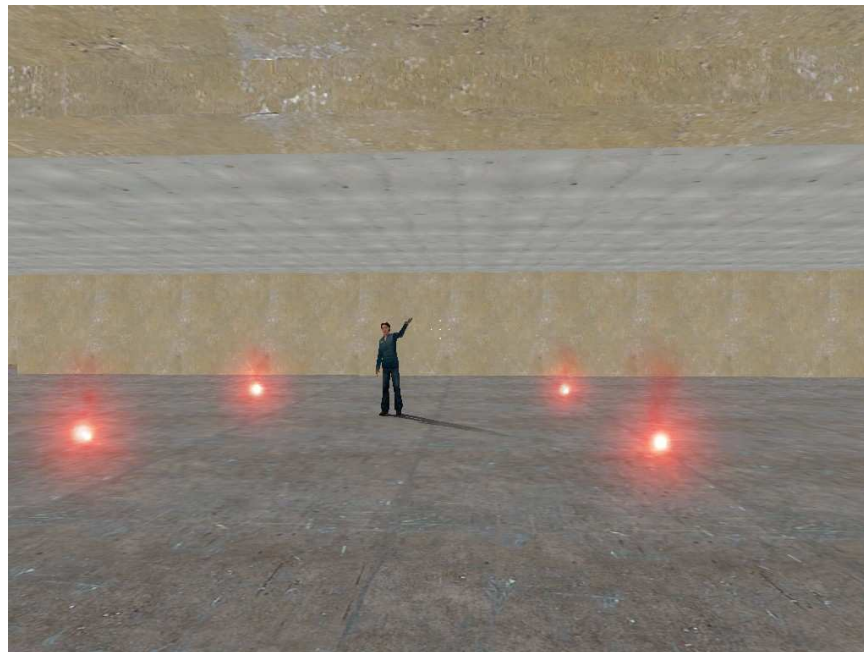


Figure 5.13: First person views of the pre-training VE for Experiment 4b. Upper panel: Entrance to the building, with computer controlled people approaching. Lower panel: The view has moved forward and is greeted with a waving person surrounded by flares inside building.

### **5.5.1 Design**

Participants were shown a pre-recorded tour of a VE before they actively explored a Ushaped route within an outdoor Virtual Environment. In the pre-recorded tour the VE they experienced contained several computer controlled people who all walked into a building. Within the building was a single person surrounded by four red flares. He waved as the participants entered the building. In the training VE (VEA, the same as the incongruent group in Experiment 4a) there were also several computer controlled people who walked a route around the outside of the central building. There were eight possible versions of the route to control for: the combination of tested objects, the effects of route length (four routes had the first leg as the shortest and four routes had the last leg as the shortest) and turn direction (four routes had only 90° left turns and four routes had only 90° right turns).

Although a preliminary rather than a complete experiment, the independent variable can be considered the pre-training experience of human movement (for comparison with earlier experiments with no preliminary human movement. The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency to make the JRD's (in seconds).

### **5.5.2 Method**

#### **5.5.2.1 Participants**

The participants were 24 undergraduate students in partial fulfilment of a course requirement. Their mean age was 22.41 (18 - 51) years old, and of these 7 were men.

#### **5.5.2.2 Apparatus**

The prerecorded pre-training environment illustrating human movement had the same dimensions as the practice environment though without the ceiling. A building the same size as the

target building in the main experiment outdoor environment was located at one end of the environment and had an open face. Several computer-controlled people all moved towards the building, which inside contained one stationary person surrounded by four flares. When the participant's view approached, the stationary computer-controlled person waved. All other materials were identical to those of Experiment 4a.

### **5.5.2.3 Procedure**

Participants undertook a practice exploration and pointing task to familiarise them with the procedure, followed by a pre-recorded tour of the pre-training environment before exploration of the target U-shaped route around the central building, and an alignment test.

During the pre-training, participants experienced a pre-recorded tour of an environment. The view focused on the movement of the computer controlled people and followed them into a distant building. Once in the building the participants saw a stationary computer-controlled person, surrounded by flares, wave at them. The tour then ended. It lasted approximately 90 seconds.

The remainder of the procedure was identical to that of the Incongruent group in Experiment 4a.

### **5.5.3 Results and Discussion**

The error data for Experiment 4b (see Figure 5.14) were entered into a 2 X 2 ANOVA with alignment (aligned, contra-aligned with the first part of the route) and judgement direction (forward, backward) as within-participant factors. No significant main effects or interactions were found.

The latency data (see Figure 5.15) were analysed the same way as the error data and again no significant main effects or interactions were found.

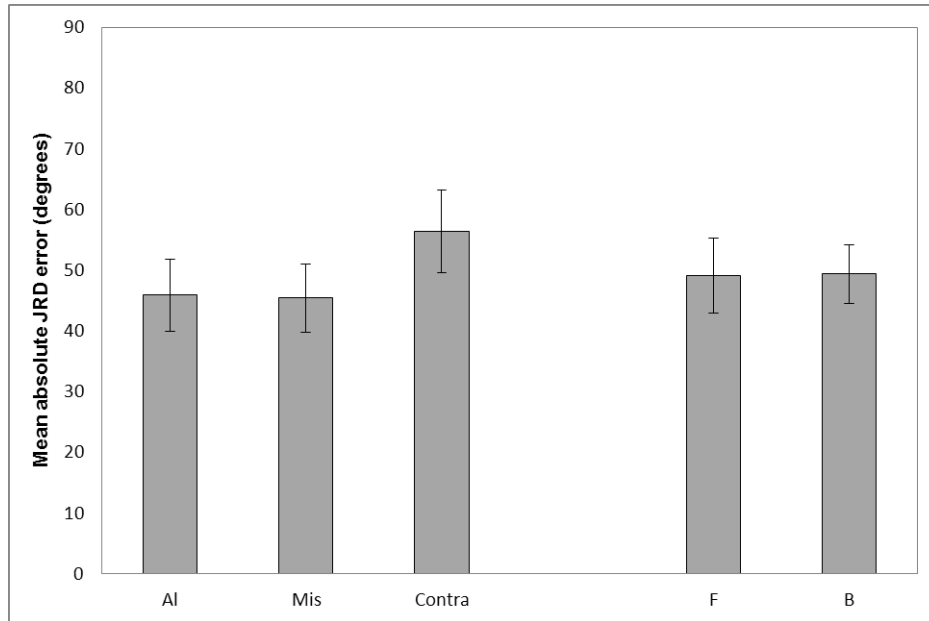


Figure 5.14: Experiment 4b. Mean absolute errors for aligned, misaligned, contra-aligned, forward and backward judgements. Error bars represent one estimated standard error above and below the mean.

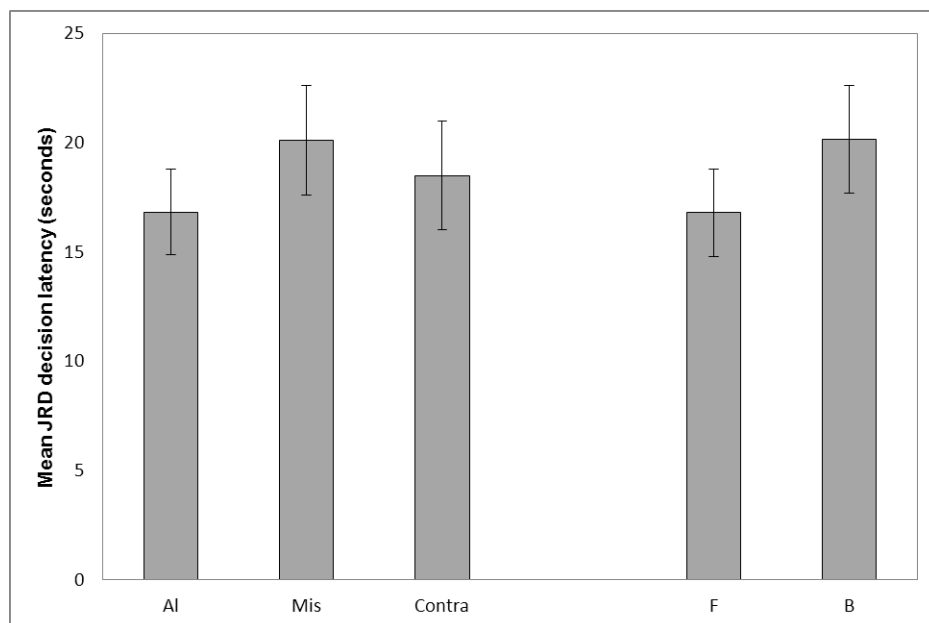


Figure 5.15: Experiment 4b. Mean decision latency for aligned, misaligned, contra-aligned, forward and backward judgements. Error bars represent one estimated standard error above and below the mean.

On first consideration, the lack of a significant alignment effect would seem to suggest that the pre-training allowed the incongruent human movement to reduce or block the influence of the first perspective, presumably by encouraging learning about the direction of human movement. On aligned trials, the angular error of the congruent group from Experiment 4a was approximately 35° while in the current experiment it was approximately 10° greater. To clarify, further analysis was undertaken to compare the group in this experiment (pre-trained incongruent experience) with the congruent group from Experiment 4a in a mixed 2 X 2 X 2 ANOVA. However, no significant interaction between alignment and group ( $p = .58$ ) in the error data was apparent although there was a main effect of alignment ( $F(1, 46) = 7.74$ ,  $MSE = 2170.77$ ,  $p = .008$ ,  $\eta_p^2 = .14$ ). In a similar analysis of the latency data there was no main effect of alignment ( $p = .16$ ) nor an alignment x group interaction ( $p = .53$ ). Therefore, statistically there is little evidence that the group in Experiment 4b responded differently to the congruent group from Experiment 4a.

The safest conclusion from Experiments 4a and 4b is that the FPA effect is strong and reliable following exploration of a novel environment. This alignment effect does not seem to be significantly influenced by the apparent direction of simulated human movement. Of course, further manipulations of the movement of virtual people might reveal a stronger influence. The current movement parameters might be too fast, too slow, or insufficiently natural to be considered truly human, and therefore learnt about in a truly social fashion. Although the visual detail of the simulated characters was high and included a range of genders, ages and ethnicities, it may be that the graphical rendering of movement fell into the 'Uncanny Valley'. The 'Uncanny Valley' as first described by Mori (1970) is where artificial human representations, either computerised avatars or androids, designed to appear extremely realistic actually fail to be considered natural due to some undefined feature. As realism and detail increases so does the positive response to them by participants until suddenly hitting the 'Uncanny Valley', where the response, despite the extreme realism of the representation in question, drops and becomes negative. When they fall into this 'trough' they are rejected strongly by participants as being accurate human representations. If this were the case in the

current experiments the social influence would be understandably small at best. Therefore, despite the interesting possibilities suggested by social influence on spatial learning, and the wider implications for real-world learning, the current VE-based experiments might be at too early a stage to be useful to address the question of competition. A host of variables might need manipulating to reveal experimental alignment effects, so movement does not provide a ready tool for investigating the questions to be addressed in this thesis. More manageable procedures are needed to investigate potential competition effects.

# Chapter 6

## Lack of overshadowing between the first perspective and a source of symbolic alignment

### 6.1 Overshadowing: FP v Symbolic structure

The experiments from Chapter 5 failed to find evidence for competition between different sources of alignment. This however is not surprising considering these experiments were limited in producing any evidence for alignment effects. For further investigation of competition it is necessary to find a strong source of alignment, other than the first perspective, that can be established and learnt about in isolation. Then it will be possible to progress and actually determine whether any competition, blocking or overshadowing, has occurred.

At a basic level an alignment effect can be described as a principal reference vector (Easton & Sholl, 1995; Wilson et al., 1999; Wilson & Wildbur, 2004); a unidirectional reference vector or ‘conceptual north’. The first perspective for example defines a single unidirectional vector that is then applied at a wide variety of locations, not just the first section of an explored route or environment, when making imagined judgements (Experiment 1; Mou et al., 2004; Wildbur & Wilson, 2008). In regards to general navigation and direction arrows are often used to denote vectors and headings (Baus, Cheverst & Kray, 2005; Levine, 1982; Parush

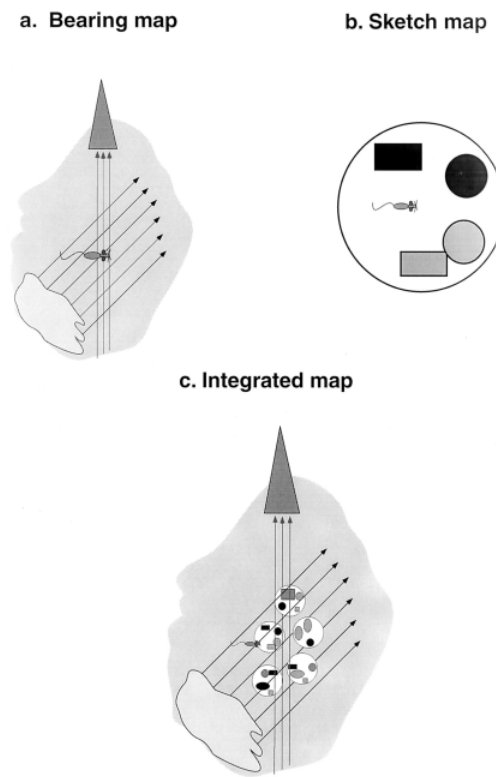


Figure 6.1: Illustration of the integrated maps from Jacobs and Schenk (2003), demonstrating the use of arrows to symbolise vectors.

& Berman, 2004) and Burigat and Chattiro (2007) found an increase in navigation performance when using a 3D arrow to indicate a location compared to a radar like map or lack of navigational aids. The arrow is the simplest symbolic indicator of a vector. Theoretically all attempts to create an alternative source of alignment consist at the most basic level of an attempt to provide such a symbolised vector. For example in Jacob and Schenk's (2003) proposed integrated cognitive map one of the maps involved is directional, and contains vector and orientation information (Figure 6.1). Given the difficulties encountered in Chapter 5 establishing a conceptual north it would be sensible to start at a simpler symbolic level: one that clearly implies a symbolised vector rather than relying on the inference of a vector by a participant from more complex sources of information such as the previously used structure and movement.



## 6.2 Experiment 5a

Experiment 5a used an equivalent to a conventional overshadowing design (see Table 6.1) which allowed two independent sources of alignment to be established in separate groups. The final group consisted of a combination of the two sources of alignment with opposite direction of influence. Participants were given tours of VE's, and these tours differed in the VE experienced and style depending on the group (see Table 6.2). The First Perspective group experienced only a first perspective as they observed a pre-recorded tour around a Ushaped route between four test objects, similar to previous experiments in the thesis. The Symbolic group experienced symbolic information, provided by arrows on the ground, but no first perspective. The 'combined' group experienced a first perspective of a U-shaped route in a VE which faced in the opposite direction to the symbolic information provided by arrows on the ground (see Figure 6.2). Passive tours were used for all groups in this experiment, rather than active exploration, due to the need for a pseudo-random tour in the Symbolic group to remove any potential first perspective. To ensure this experience was the same for all participants in the Symbolic group the tour was recorded; and to equate the tour experience in the Symbolic group with the others passive tours were used for all. The tours for the First Perspective and 'combined' group followed a U-shaped route around the objects, similar to that used in previous experiments.

In similar fashion to the expectations of Experiment 3, if when presented in isolation, both the first perspective of the VE and symbolic information provide separate sources of alignment we would expect to see corresponding alignment effects in the First Perspective group and the Symbolic group. A FPA effect would be evidenced by more accurate judgements when made in alignment with the first perspective than judgements contra-aligned. A Symbolic alignment effect would be evidenced by more accurate judgements when made in alignment with the symbolic information than contra-aligned to the symbolic information. This would appear as an inversion of the typical FPA effect pattern due to the labelling used in the figures for this thesis for ease of comparison: judgements aligned with the symbolic are labelled

Group	Training	Test	Result
Overshadowing	AN -> X	A, B	A>B
A	A-> X	A	A✓
B	B-> X	B	B✓

Table 6.1: General overshadowing design based on Pavlov (1927). Groups A and B have been included so the ability to learn about the individual cues is established.

Group	Traning	Test
Overshadowing (Combined)	First Perspective + Symbol	First Perspective, Symbol
First Perspective (First Perspective)	First Perspective	First Perspective
Symbolic (Symbol)	Symbol	Symbol

Table 6.2: Experiment 5a design

as contra-aligned as the symbolic information is contra-aligned to the first perspective in the Combined group. When considering an overshadowing design the First Perspective and Symbolic are essentially the A, and B, control groups. In the Combined group, the AB overshadowing condition, evidence for competition could potentially take two forms. One would potentially be no alignment effect due to equally poor learning of both the first perspective and the symbolic (in comparison with when they are learnt about in isolation), consistent with the Rescorla-Wagner model predictions. Alternatively overshadowing could be evident in a Pavlovian sense with one source of alignment being learnt about over the other. A FPA effect would indicate overshadowing of the symbolic by the first perspective, and conversely a symbolic alignment effect would indicate overshadowing of the first perspective by the symbolic. However evidence for good learning of both the first perspective and symbolic in the Combined group (in comparison with when they are learnt about in isolation) would instead suggest that no competition has taken place.

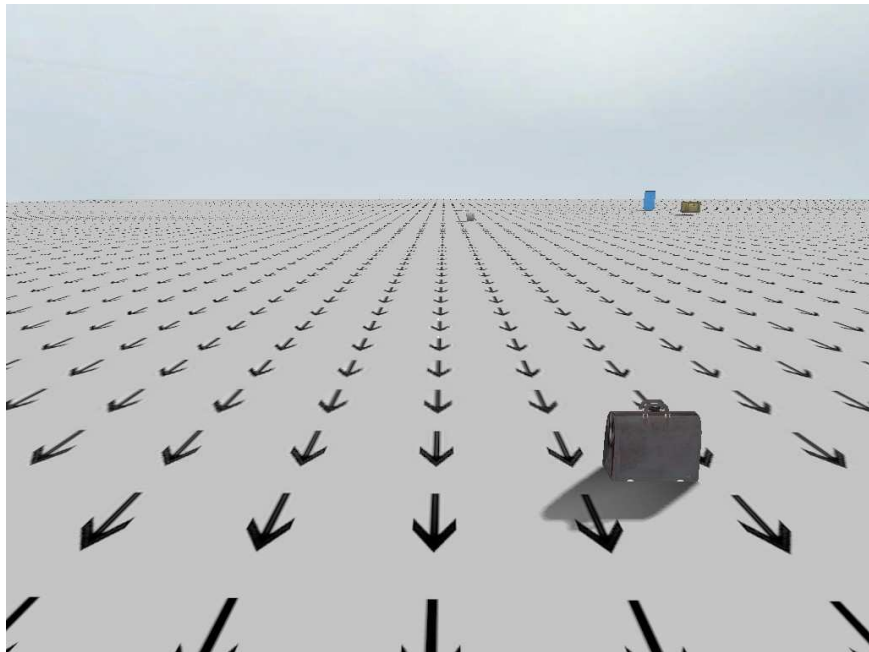
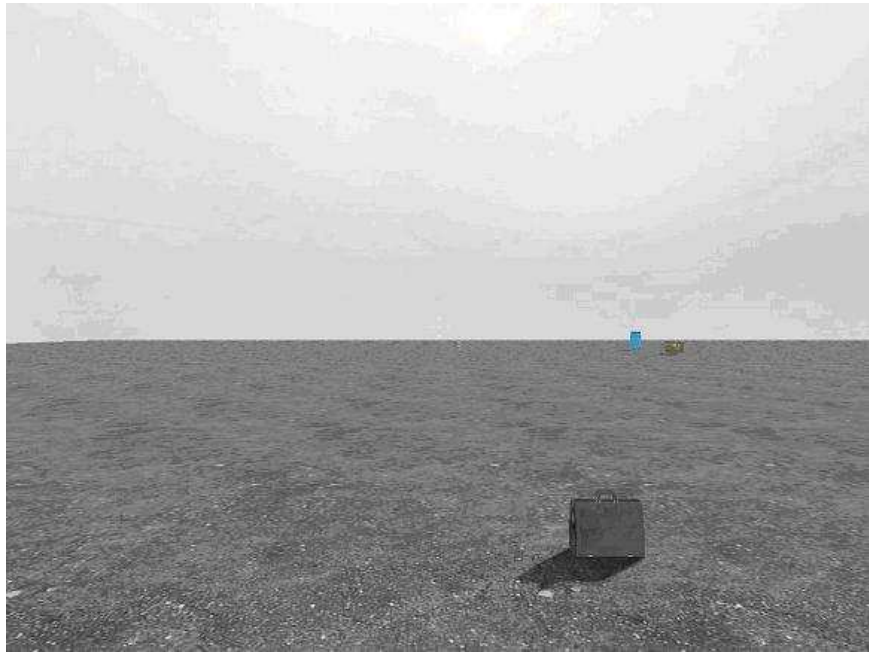


Figure 6.2: First person views of the VE's used in Experiment 5a. Upper Panel: The bland VE used for group FP. Lower Panel: The VE used for the Symbolic group (with no first perspective) and the Combined group (with a first perspective allowed).

## **6.2.1 Design**

Participants were shown a passive pre-recorded tour of one of three different Virtual Environments (VE). In the first group (FP) participants experienced a tour of a bland VE containing only four widely separated objects. The tour followed a U-shaped route between these objects several times as described for similarly spaced objects surrounding a building in Experiment 1. In the second group (Symbolic) participants experienced a tour of the same objects in a VE but with the inclusion of a floor texture consisting of approximately 4 arrows per square metre (see Figure 6.2). The arrows were aligned in parallel, pointing in the same direction. The tour in this case started with rotation and continued on a pseudo-random path that focused on the target objects but did not follow the same U-Shape path as previous. The third group (Overshadowing/Combined) explored the same VE as the Symbolic group but explored the same U-shaped tour around the four objects as the FP group (see Table 6.2 for experimental design); the first perspective on the route faced in the opposite direction to the arrows on the ground.

The independent variable was the type of VE tour experience (FP, Symbol or Combined). The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency to make the JRD's (in seconds).

## **6.2.2 Method**

### **6.2.2.1 Participants**

The participants were 72 undergraduate students who took part to fulfil part of a course requirement. Their mean age was 20.22 (18 - 61) and of these 15 were men (5 in each group). They were pseudo-randomly allocated to one of three groups (n=24) with the constraint that approximately the same number of men served in each.

### **6.2.2.2 Apparatus**

The VE's (FP, Symbolic and Combined) all consisted of a horizontal plane/floor that extended into apparent infinity. The FP VE consisted solely of the floor and the objects; no other details or objects were present. The Symbolic FP VE had an arrow texture applied to the floor instead of the plain concrete texture used by the FP VE. The arrow texture was a black arrow on a grey background, and when placed in the environment equated to 4 whole arrows per square metre. The arrows were approximately .5 metres long, and .3 metres long at the widest point. All the arrows were aligned and pointing in the same cardinal direction. The Combined VE was identical to the Symbolic, but the participants explored a definite first perspective of the VE which was opposite to the direction of the arrows.

The four objects were placed in a U-shape, in the same relative arrangement as in previous experiments (see appendix A). The objects were a briefcase, a red can, a blue barrel and a wooden crate.

### **6.2.2.3 Procedure**

Participants received a practice exploration and pointing task to familiarise them with the procedure, followed by passive exploration of the environment and object array, and an alignment test.

Participants experienced one of three possible tours for either the FP, Symbolic or Combined VE. Each tour last approximately 180 seconds. During the tour the experimenter verbally directed the participant, pointing out and naming each target/test objects as they passed. This was done a total of three times for each object to equate with previous procedures. Then the participant rather than the experimenter pointed out and named the objects as they passed, again each object was named three times. This was to ensure the participants were attending to, and would recognise, the correct target objects. Finally the participants observed the tour as it passed the objects a further three times, but did not have to point out any of the objects.

After the tour was finished, the VE was removed from the computer screen and the pointer program was loaded. As with previous experiments the participants were required to make 12 judgements using the pointer, comprising a random mix of 4 x aligned, 4 x 90-degree misaligned, and 4 x 180-degree contra-aligned trials; the aligned judgements were either aligned with the first perspective (FP and Combined group) or with the Symbols (Symbol group). This meant the contra-aligned judgements for the Combined group were contra to the first perspective but aligned with the symbols. These trials also comprised a mixture of 6 forward and 6 backward judgements, with 6 judgements on the first and 6 on the last parts of the route.

### **6.2.3 Results and Discussion**

The error data for Experiment 5a (see Figure 6.3) were entered into a mixed 3 X 2 X 2 ANOVA with group (FP, Symbolic or Combined) as the between-participant factor and alignment (aligned, contra-aligned with the first part of the route as experienced by groups FP and Combined) and judgement direction (forward, backward) as the within-participant factors.

There was a main effect of alignment ( $F(1, 69) = 4.95$ ,  $MSE = 2791.37$ ,  $p = .029$ ,  $\eta_p^2 = .06$ ) reflecting lower overall error for aligned judgements compared with contra-aligned judgements. Crucially, there was a significant alignment x group interaction ( $F(2, 69) = 4.6$ ,  $MSE = 2791.37$ ,  $p = .013$ ,  $\eta_p^2 = .11$ ) which was a consequence of different apparent alignment effects across the three groups; a FPA effect in group FP, an FPA effect in the Combined group; and the opposite pattern to an FPA effect in group Symbolic, consistent with a symbolic alignment effect. There were no other main effects or interactions.

The latency data (see Figure 6.4) were analysed the same way as the error data and also revealed a main effect of alignment ( $F(1, 69) = 4.26$ ,  $MSE = 24428.55$ ,  $p = .043$ ,  $\eta_p^2 = .05$ ) due to faster overall latency for aligned judgements compared to contra-aligned. A significant alignment x group interaction ( $F(2, 69) = 4.41$ ,  $MSE = 2791.37$ ,  $p = .016$ ,  $\eta_p^2 = .11$ ) was also

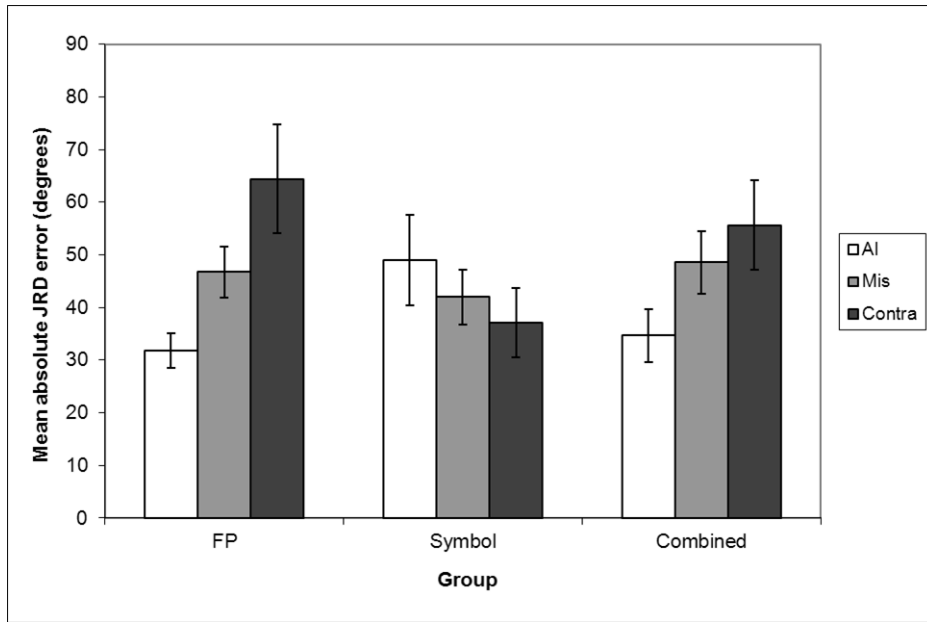


Figure 6.3: Experiment 5a. Mean absolute errors for aligned, misaligned and contra-aligned judgements across the three groups. Aligned is defined with respect to the direction of the first perspective experienced by groups FP and Combined. Error bars represent one estimated standard error above and below the mean.

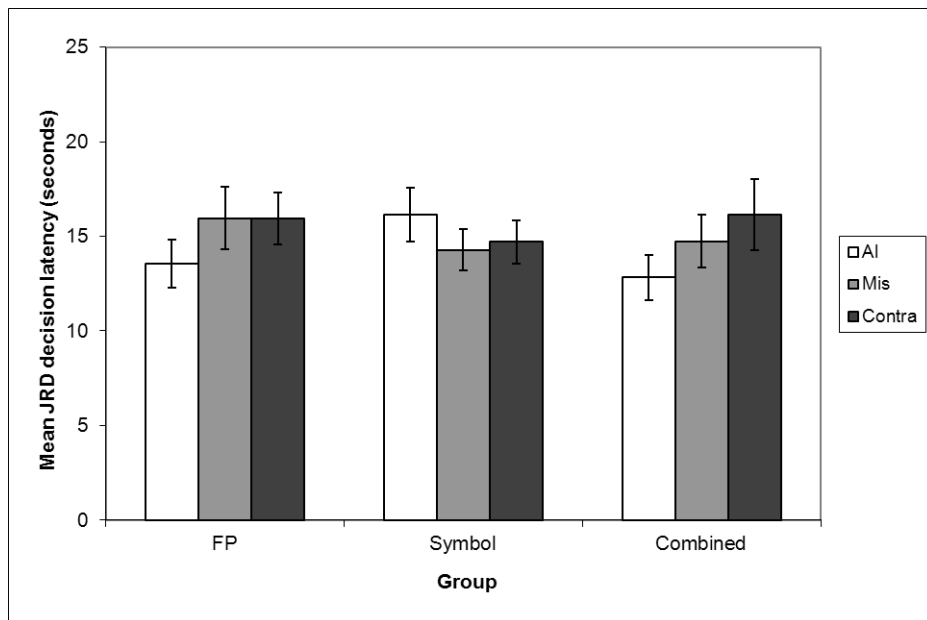


Figure 6.4: Experiment 5a. Mean decision latency for aligned, misaligned and contra-aligned judgements across the three groups. Error bars represent one estimated standard error above and below the mean.

revealed, which was a consequence of differing alignments across the groups; a FPA effect in both group FP and the Combined group, but no alignment effect in the Symbol group.

The group x alignment interaction in the overall analysis suggests that learning about the intended sources of alignment has occurred, and that overshadowing has occurred in the Combined group. The pattern of error data as seen in Figure 6.3 suggests a FPA effect in the FP group, a symbolic alignment effect in the Symbol group and a FPA effect in the Combined group; the first perspective seems to overshadow the symbolic. However, further individual group analysis qualifies this conclusion: the apparent symbolic alignment effect pattern it is not significant ( $p = .32$ ), casting doubt on the independent influence of the symbols. Statistically, and considering the individual data, the pattern in the symbolic group reflects ‘no consistent alignment’. If a symbolic alignment effect has not been established then the FPA effect in the combined group is no surprise and cannot be regarded as evidence of overshadowing. The pattern of data in the Symbolic group is however promising and worth further investigation.

### **6.3 Experiment 5b**

A potential issue is that the arrows used in Experiment 5a could lack sufficient salience as a source of alignment effect for all the participants. This may be because the arrows were not large or bold enough or because the arrangement of arrows was not suitable. Just as Pavlov (1927) noted that a bright light may have more salience or intensity than a quiet tone, it may be that a larger arrow would have more salience than a small arrow. Furthermore, the arrows in Experiment 5a all pointed in the same cardinal direction (north for the sake of simplicity) but in parallel. This may not be the ideal format for suggesting a vector, instead it may be a case of indicating a focal point with the symbols much like the first perspective might include a focal point to orientate towards (Jeffery, 2010; Muir & Taube, 2002). To this end Experiment 5b modified the treatment of two groups from Experiment 5a to provide data from a new





Figure 6.5: First person views of the altered Symbol VE used in Experiment 5b. The small arrows have been removed and 9 large arrows, a carriage and a distant mountain range added.

version of the Symbolic group and the Combined group. All the procedure and details for the Symbolic group and the Combined group remained as described for Experiment 5a. Instead of rows of small arrows all point ‘north’ in parallel, nine larger arrows were used which all pointed to an added focal point (a train carriage and distant mountain range, see Figure 6.5). These groups were re-run in an attempt to establish a significant symbolic alignment effect and re-examine whether there was evidence for competition in the Combined group. In the interests of economy, the FP group from Experiment 5a was not re-run; there is no reason to suspect that a replication would produce a different pattern.

### 6.3.1 Design

Participants were shown a passive pre-recorded tour of one of two possible VE’s. These groups were the same as group symbolic and combined in Experiment 5a with a minor alteration to the materials.

## **6.3.2 Method**

### **6.3.2.1 Participants**

The participants were 48 undergraduate students who took part to fulfil part of a course requirement. Their mean age was 19.72 (18 - 27) and of these 10 were men: 6 men in the symbol group and 4 in the combined group. They were pseudo-randomly allocated to one of two groups (n=24) with the constraint that approximately the same number of men served in each.

### **6.3.2.2 Apparatus**

The same materials were used as in Experiment 5a with some small changes. Instead of the floor being textured with small arrows all aligned in the same direction the floor was a bland concrete texture, with nine large black arrows arranged on top. These nine arrows all point to a distant train carriage and mountain range. The arrows were split into three groups of three. One group of arrows pointed directly toward the objects, and the other two groups of arrows were positioned to the left or right of the first group, rotated toward the objects (see Figure 6.5).

### **6.3.2.3 Procedure**

The procedure was identical to the appropriate groups in Experiment 5a.

## **6.3.3 Results and Discussion**

The data from group FP in Experiment 5a were added to the data collected in Experiment 5b for analysis. The error data (see Figure 6.6 and 6.7) were entered into a mixed 3 X 2 X 2 ANOVA with group (FP, Symbolic or Combined) as the between-participant factor and

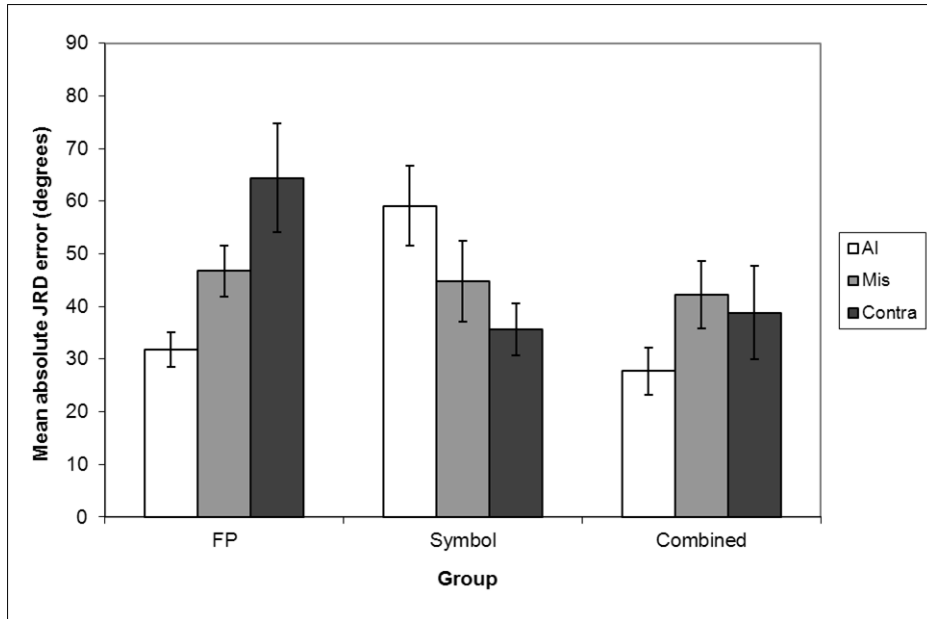


Figure 6.6: Experiment 5b. Mean absolute errors for aligned, misaligned and contra-aligned judgements across the three groups. Error bars represent one estimated standard error above and below the mean.

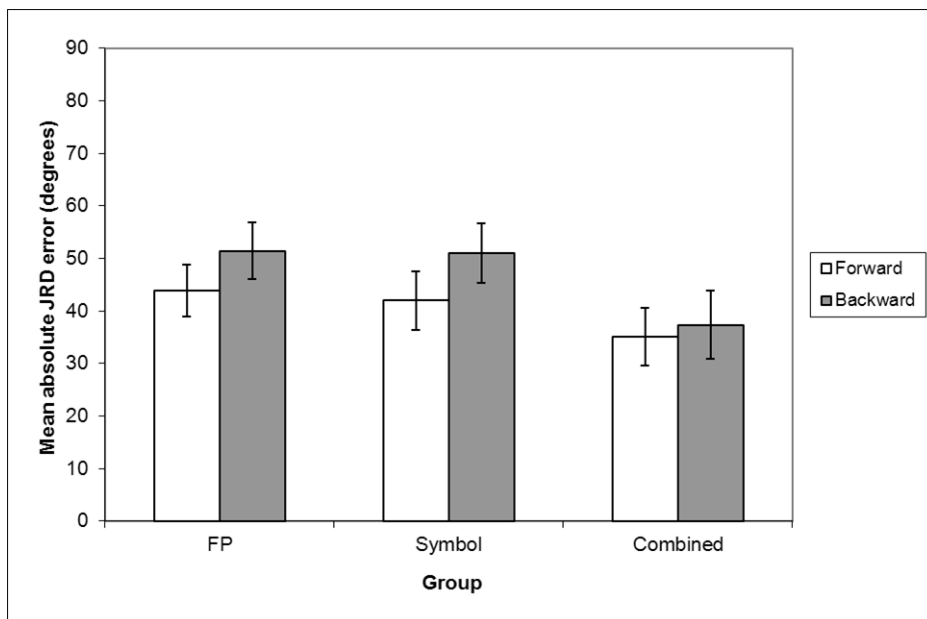


Figure 6.7: Experiment 5b. Mean absolute errors for forward and backward judgements across the three groups. Error bars represent one estimated standard error above and below the mean.

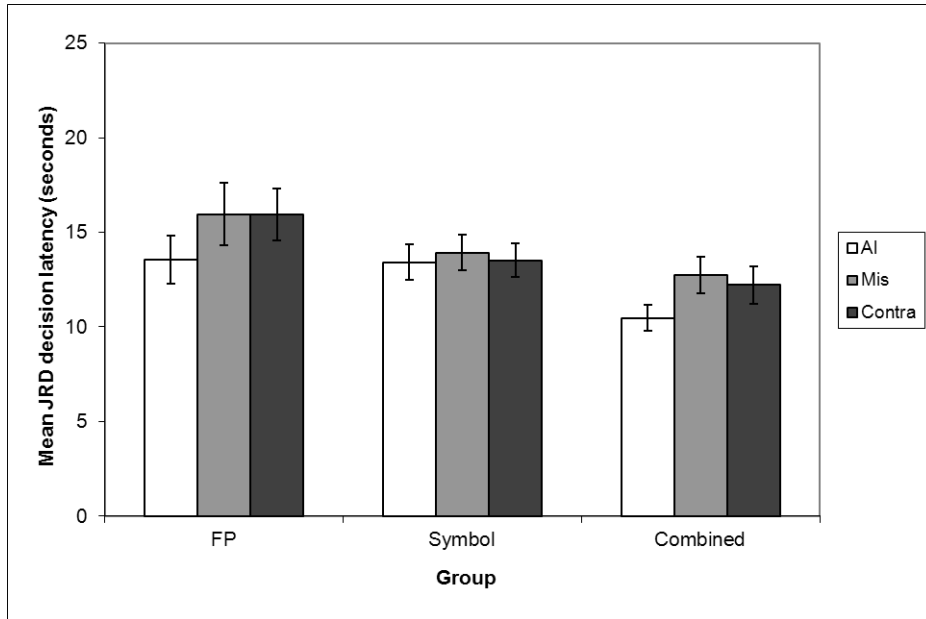


Figure 6.8: Experiment 5b. Mean decision latency for aligned, misaligned and contra-aligned judgements across the three groups. Error bars represent one estimated standard error above and below the mean.

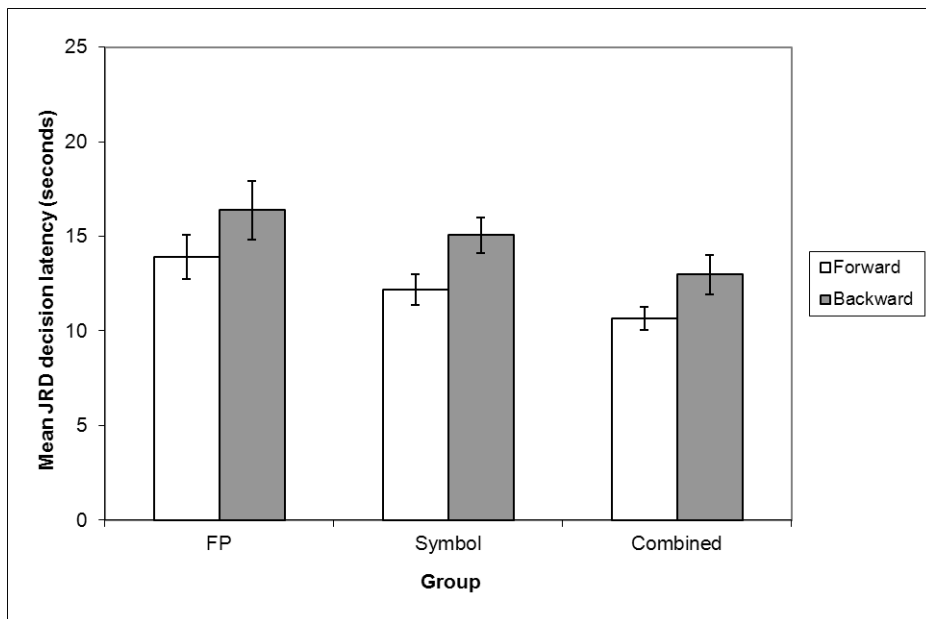


Figure 6.9: Experiment 5b. Mean decision latency for forward and backward judgements across the three groups. Error bars represent one estimated standard error above and below the mean.

alignment (aligned, contra-aligned with the first part of the route) and judgement direction (forward, backward) as the within-participant factors.

There was a significant alignment x group interaction ( $F(2, 69) = 8.13$ ,  $MSE = 1845.45$ ,  $p < .001$ ,  $\eta_p^2 = .19$ ). The interaction between alignment and group is a consequence of an FPA effects in the FP group, a symbolic alignment effect in the Symbolic group, and no alignment effect in the Combined group. There were no other main effects or interactions.

The latency data (see Figure 6.8 and 6.9) were analysed the same way as the error data. There was a main effect of alignment ( $F(1, 69) = 6.93$ ,  $MSE = 21801.76$ ,  $p = .01$ ,  $\eta_p^2 = .09$ ) reflecting faster overall latency for aligned judgements compared to contra-aligned.

This picture was clarified with further analyses of the individual groups using a within-participant 2 X 2 ANOVA, with alignment (aligned, contra-aligned with the first part of the route) and judgement direction (forward, backward) as factors.

In group FP error scores there was a main effect of alignment ( $F(1, 23) = 6.12$ ,  $MSE = 2418.27$ ,  $p = .021$ ,  $\eta_p^2 = .21$ ) which reflects the typical FPA effect pattern; mean aligned judgements, with the first perspective, were smaller ( $M = 31.84$ ;  $SE = 3.26$ ) than the mean contra-aligned ( $M = 64.4$ ;  $SE = 10.26$ ). In the latency data there was an alignment x judgement direction effect ( $F(1, 23) = 4.58$ ,  $MSE = 24427.66$ ,  $p = .043$ ,  $\eta_p^2 = .16$ ) which was a consequence of faster mean latency for forward aligned judgements ( $M = 11.88$ ;  $SE = 1.12$ ), than forward contra-aligned judgements ( $M = 14.99$ ;  $SE = 1.45$ ), and faster backward aligned judgements ( $M = 15.53$ ;  $SE = 1.67$ ) than backward contra-aligned judgements ( $M = 17.18$ ;  $SE = 1.71$ ).

In the Symbolic group error scores there was again a main effect of alignment ( $F(1, 23) = 10.31$ ,  $MSE = 1305.81$ ,  $p = .004$ ,  $\eta_p^2 = .31$ ) which reflects the symbolic alignment effect pattern; mean error for judgements aligned with the symbolic were smaller ( $M = 35.61$ ;  $SE = 4.99$ ) than the mean contra-aligned judgements ( $M = 59.07$ ;  $SE = 7.54$ ). There were no significant effects in the latency data.

In the Combined group there were no significant effects in the error data. However in the latency data there was a main effect of alignment ( $F(1, 23) = 4.54$ ,  $MSE = 16411.67$ ,  $p = .044$ ,  $\eta_p^2 = .16$ ) suggesting an FPA effect pattern; the mean latency for judgements aligned with the first perspective were slightly faster ( $M = 10.46$ ;  $SE = .68$ ) than the mean of those contra-aligned ( $M = 12.22$ ;  $SE = .98$ ).

The significant alignment effect in the Symbolic group consistent with the symbolic treatment means an alternative source of alignment to that of the first perspective has been established. This paves the way for more secure interpretation of the results from the Combined group when considering competition and the overshadowing design. First, the error data clearly suggest an interaction between alignment effects: the FPA treatment produces a significant FPA direction of effect; the symbolic treatment produces a symbolic direction of effect; the combined data do not conform to either of these patterns. In the combined group data, evidence consistent with both alignment effects is apparent: the preferred orientation in the FPA group (i.e. aligned with the first perspective) produces the lowest error mean in that group of  $32^\circ$ ; and this is matched in the Combined group for the same direction with a mean error of  $28^\circ$ . The preferred orientation in the symbolic group (i.e. aligned with direction of the arrows) produces the lowest error mean in that group of  $36^\circ$ ; and this is closely approximated in the Combined group for the same direction with a mean error of  $39^\circ$ . The conclusion from the error data is that, rather than overshadowing (an effect in which one effect would restrict learning about the other), the preferred alignments in groups FP and Symbolic are both available for accurate recall in group Combined.

The latency data appear to complicate the interpretation: individual group analysis suggests evidence of a small FPA effect in group Combined, even though no clear alignment effect was apparent in the latency data of the FPA group itself. Clearly more research is required into the proper interpretation of error and latency data. Do these measures reflect the same or quite separate process? This thesis does not address this important question. At the outset of the current investigations it was decided to place greater emphasis on the error than the latency data, provided the error data were not contradicted by latency data in the form of a

potential trade-off. Note that in group Combined, the absence of an alignment effect in error scores and its presence in latency scores does not represent a trade off: inspection of the right panels of Figures 6.6 and 6.8 shows that error and latency patterns are consistent. The safest overall conclusion is that some indication of the FPA effect is detectable in aspects to the data from group Combined; however, the influence of the symbolic alignment is strong, particularly in errors. This pattern does not justify the conclusion that one alignment effect has overshadowed the other.

Overshadowing is of course only one type of competition effect, and the lack of overshadowing does not necessarily imply that competition in the truly spatial domain does not occur. As shown in other studies (Alexander et al., 2009; Wilson & Alexander, 2008) it is possible to find evidence for one type of competition such as blocking in a design in which true spatial learning is probable. If competition effects can be found using a blocking design then that would strongly suggest at least some similarity in the mechanisms of true spatial and other forms of learning. A lack of blocking as well as overshadowing would suggest that learning mechanisms that have been demonstrated in some procedures do not apply to the area of true spatial learning.

# Chapter 7

## Evidence for blocking between the FP and the Symbolic

### 7.1 Blocking: Symbolic v FP

The apparent lack of competition between alignment effects based on the first perspective and on symbolic cues in an overshadowing design does not rule out spatial competition effects. It is appropriate first to seek evidence for blocking (Kamin, 1969, see Table 7.1) between alignment effects. Blocking designs are easier to interpret than overshadowing designs as the target cues (i.e., those about which learning should be restricted) are treated identically in experimental and control groups. Importantly, the Symbolic group in Experiment 5b clearly demonstrated that symbolic cues can provide a source of alignment learning and can therefore be useful for further experiments into competition. As mentioned in Chapter 1, in a blocking design initially training one cue or source of information restricts learning about subsequently added cues or sources of information that indicate the same outcome. The following experiments do not involve an ‘outcome’ as such, but nevertheless aim to see whether the initial training of one source of alignment learning can block or restrict learning about another source of alignment when both are subsequently presented in compound.



Group	Phase 1 (Pre-training)	Phase 2	Test	Result
Blocking	A	AB	A, B	A>B
Control	X	AB	A,B	A=B

Table 7.1: Blocking Design (Kamin, 1969)

## 7.2 Experiment 6

In this experiment blocking of learning of the first perspective by initial training of symbolic cues was attempted. In the experimental or blocking group (see Figure 7.1) the symbolic cues were trained in a similar fashion to these cues in the Symbolic group in Experiment 5b, by presenting a passive tour of a VE containing target objects with arrow indicators on the ground and salient objects providing a ‘conceptual north’. Subsequently they were trained as described for the combined group from Experiment 5b with both symbolic and first perspective potential sources of alignment learning simultaneously available. The control group experienced a random tour of a bland VE containing only target objects before being subsequently trained as in the combined group from Experiment 5b. The control group equated the time spent in VE’s and training without providing any preliminary training with either the symbolic information or the first perspective. Note that although the objects encountered in phase 1 have been described as ‘target objects’, for both groups the objects viewed in initial training were different to those in the combined VE training phase which formed the basis of the test procedure. This was to limit familiarity with objects, and their arrangement, which might attenuate any alignment effects.

If it is possible to block alignment learning based on the first perspective by initially training symbolic cues, then we would expect to see a pattern of results that reflects a symbolic alignment effect more closely than an FPA effect in the experimental group. However, congruent with the results from the combined/overshadowing group in 5b, a pattern somewhat consistent with a FPA effect in the blocking group would not be surprising as the first perspective is a very salient source of alignment even when concurrently trained with symbolic cues. In the control group, a pattern more consistent with the FPA effect than that found in the ex-

perimental group would be expected; it is this comparison that indicates blocking. Evidence for blocking in the form of learning only about a initially trained source of alignment would suggest that there are similar mechanisms governing learning between temporal and spatial information. Learning of both alignment effects, in a pattern similar to that of the Combined group in Experiment 5b, would suggest that blocking between the two sources of spatial information does not occur, and that the learning principles in the Rescorla-Wagner (1972) and Mackintosh (1975) theories do not apply to true spatial learning. The experimental hypothesis was that initial training one source of alignment would block/attenuate learning of other sources of alignment; in this case the symbolic cues would block the influence of the first perspective.

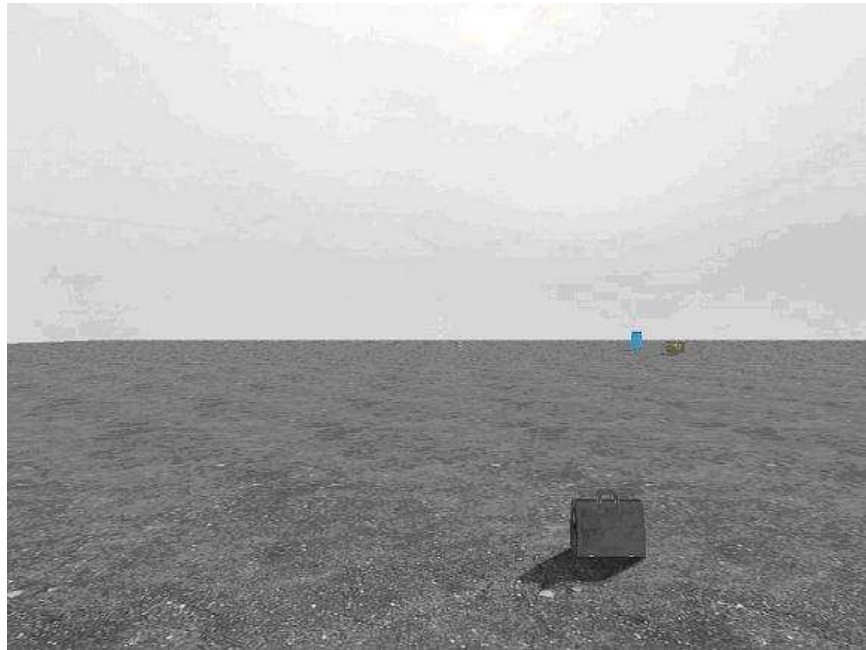


Figure 7.1: First person views of the VE's used in Experiment 6. Upper Panel: Bland VE used for the control group. Lower Panel: VE used for the initial blocking training, with pseudo-random tour and for the second phase of training, with both the first perspective and symbolic information experienced.

### 7.2.1 Design

Participants were randomly assigned into one of two groups. Each group were initially trained by being shown a passive pre-recorded tour of one of two different Virtual Environments (VE) before being shown a second VE (See Table 7.2 for experimental design). In the first group (Blocking) participants experienced a tour of a VE ('Symbolic') containing arrows and objects that indicated a conceptual north (nine arrows, which were all aligned in the same direction, and pointed toward a large train carriage, and mountain range in the distance) along with four target objects. The tour in this VE followed a pseudo-random path and had no identifiable first perspective. This should establish alignment based on the symbolic cues alone. They then experienced a tour of the second VE ('Combined') which had the exact same content and details but this time the tour followed a U-shaped route around a new set of target objects and the route had a definite first perspective which was contra-aligned with the direction indicated by the symbols. The control group experienced a tour of a bland VE similar to that of the Symbol VE but with four different objects and no arrows or train carriage/mountain range. They then experienced a tour of the second VE (Combined) with the nine large arrows, and the tour followed a U-shaped route around these objects several times, and had a definite and defined first perspective contra-aligned to the symbols.

The independent variable was the group (Blocking or Control). The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency to make the JRD's (in seconds).

Group	Phase 1 (Initial training)	Phase 2	Test
Blocking	Symbolic	Combined	First Perspective, Symbolic
Control	Bland (No First Perspective, no Symbolic)	Combined	First Perspective, Symbolic

Table 7.2: Experiment 6. Based on Kamin (1969) blocking design.

## **7.2.2 Method**

### **7.2.2.1 Participants**

The participants were 64 undergraduates who took part to fulfil part of a course requirement. Their mean age was 20.5 years (range: 18 – 35 years) and of these 19 were men (8 in the Blocking group, 11 in the Control). They were pseudo-randomly allocated to one of two groups (n=32) with the constraint that approximately the same number of men served in each.

### **7.2.2.2 Apparatus**

The materials were identical to those used in Experiment 5b. The VE's all consisted of a horizontal plane/floor that extended into apparent infinity. The bland control VE consisted solely of the floor and the objects; no other details or objects were present. In the Combined VE used for the initial blocking training and the second phase of training had a floor which was a bland concrete texture, with nine large black arrows arranged on top. These nine arrows all point to a distant train carriage and mountain range. The VE's used only differed from the materials used in Experiment 5b in regard to objects present in the initial training for the Blocking and Control groups: the symbolic VE experienced in the Blocking group, and the bland control VE, contained a TV set, traffic cone, globe and newspaper. The combined VE which was experienced as part of the second phase contained the objects used in Experiment 5b, a briefcase, a red can, a blue barrel and a wooden crate in the same relative U-shaped arrangement as in previous experiments (see appendix C).

### **7.2.2.3 Procedure**

Similar to previous presented experiments participants received a practice exploration of the practice VE and pointing task to familiarise them with the procedure before progressing onto the blocking experiment training.

Participants were initially trained using pre-recorded tours in one VE and then given further training in a second VE. Each tour lasted approximately 180 seconds. To maintain equivalence with previously used procedures in this thesis all tours followed a similar format, whether U-shaped or pseudo-random. Initially participants had the objects pointed out to them, and named, by the experimenter. This occurred either three times for each object (pseudo-random tour) or each time they were passed during three explorations of the U-shaped route (start to finish, finish to start, start to finish). The participants were then required to point out and name the objects as they passed, again either three times for each object (pseudo-random tour) or during three explorations of the U-shaped route. Finally the tour passed the objects three more times but the participants were not required to name or point them out. After the initial training and second tours were finished, the VE's were removed from the computer screen and the pointer program was loaded. The participants were required to make 12 judgements using the pointer, comprising a random mix of 4 x aligned, 4 x 90-degree misaligned, and 4 x 180-degree contra-aligned trials; the aligned judgements were aligned with the first perspective (as defined by the first perspective in the Blocking group). This meant the contra-aligned judgements were contra to the first perspective but aligned with the symbols (arrows). These trials also comprised a mixture of 6 forward and 6 backward judgements, with 6 judgements on the first and 6 on the last parts of the route.

### **7.2.3 Results and Discussion**

The error data for Experiment 6 (see Figure 7.2 and 7.3) were entered into a mixed 2 X 2 X 2 ANOVA with group (Blocking or Control) as the between-participant factor and alignment (aligned, contra-aligned with the first part of the route) and judgement direction (forward, backward) as the within-participant factors.

The analysis found a main effect of judgement direction ( $F(1, 62) = 7.54$ ,  $MSE = 4414.44$ ,  $p = .008$ ,  $\eta_p^2 = .1$ ) reflecting lower overall error for forward judgements than backward judgements across both groups. There were no other main effects or interactions. The latency data

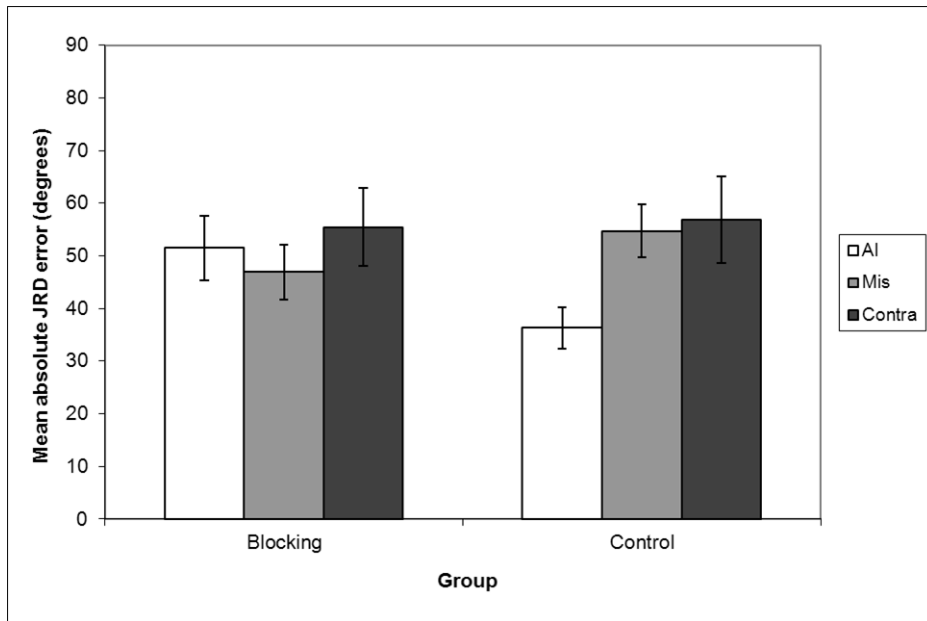


Figure 7.2: Experiment 6. Mean absolute errors for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

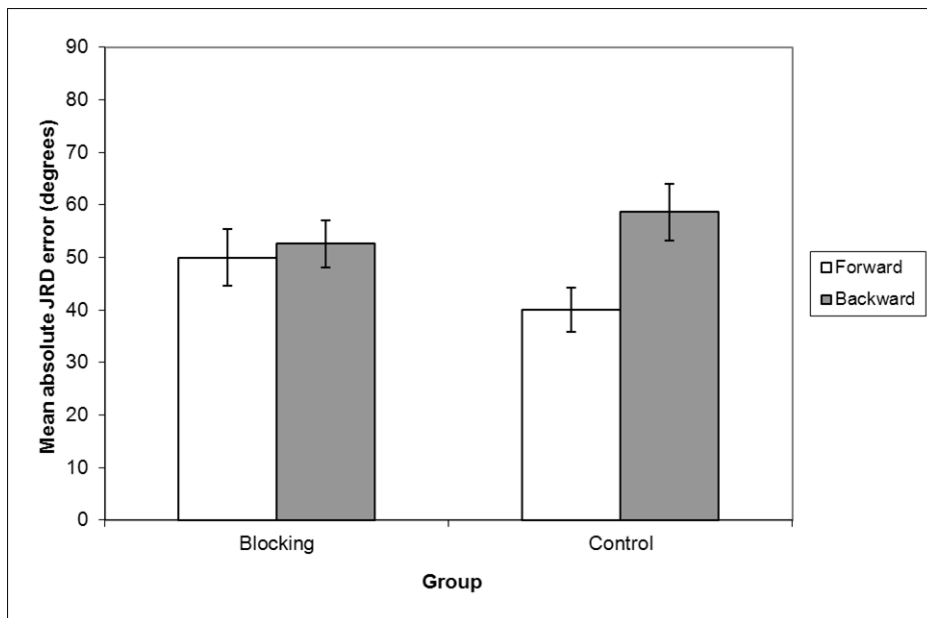


Figure 7.3: Experiment 6. Mean absolute errors for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

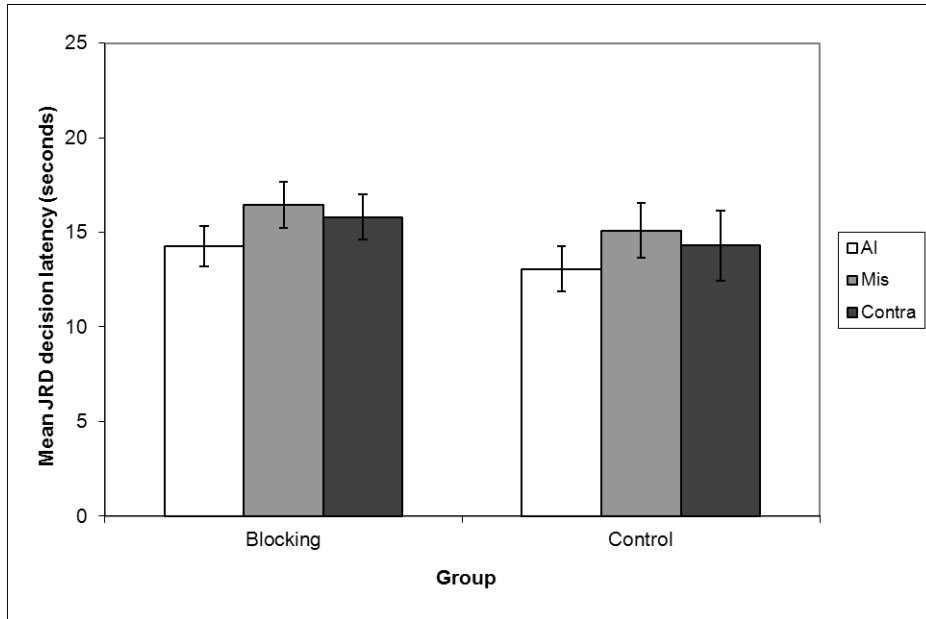


Figure 7.4: Experiment 6. Mean decision latency for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

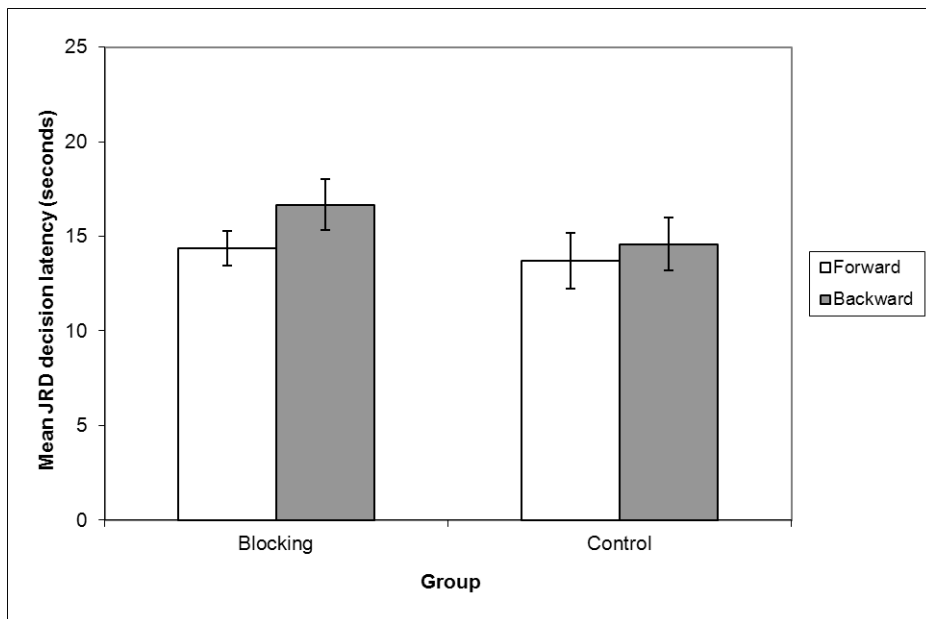


Figure 7.5: Experiment 6. Mean decision latency for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean.



(see Figure 7.4 and 7.5) were analysed in the same way as the error data but there were no significant effects or interactions. The initial analysis suggests no evidence for a difference between groups, which stands to odds with the pattern in the error data in Figure 7.2. Whilst there does not appear to be any alignment pattern in the Blocking group the Control group in contrast displays a typical FPA effect pattern of data.

Further analysis of the individual groups were performed using a within-participant 2 X 2 ANOVA, with alignment (aligned, contra-aligned with the first part of the route) and judgement direction (forward, backward) as factors.

In the Blocking group there were no significant effects or interactions, for either the error or latency data.

In the Control group when analysing the error data there was a main effect of alignment ( $F(1, 31) = 5.45$ ,  $MSE = 2456.35$ ,  $p = .026$ ,  $\eta_p^2 = .15$ ). This was a result of lower mean error for judgements aligned with the first perspective ( $M = 36.33$ ;  $SE = 3.93$ ) than contra-aligned ( $M = 56.8$ ;  $SE = 8.28$ ), a typical FPA effect. There was also a main effect of judgement direction ( $F(1, 31) = 9.69$ ,  $MSE = 563.21$ ,  $p = .004$ ,  $\eta_p^2 = .23$ ) as there was lower error for forward judgements ( $M = 39.94$ ;  $SE = 4.21$ ) than for backward judgements ( $M = 58.57$ ;  $SE = 5.41$ ). There were no significant effects or interactions when analysing latency data.

Interpretation of the data patterns is not immediately clear. In the Blocking group there is no alignment effect, and therefore nothing to confirm that the symbolic cues had been learnt about. Nor is there an interaction between group and alignment that would suggest a difference between the groups due to the initial training. The aligned and contra-aligned judgements in the experimental group reveal high errors for both ( $51^\circ$  and  $55^\circ$  respectively). This is consistent with neither source of alignment having been learnt about. The Control group shows a FPA effect (note the Combined group of 5b also shows a trend towards a FPA effect when both sources of information are available).

Examination of individual aligned and contra-aligned scores suggested the following: in the blocking group, 28% had differences between 'aligned' and 'contra-aligned' (with the first-

perspective) error scores of less than  $10^\circ$ , suggesting no strongly preferred alignment. The mean absolute difference in errors between aligned and contra-aligned judgements for the remainder was  $50^\circ$ , with 12 consistent with the FPA and 11 consistent with the symbolic cues. In the control group, 31% showed differences between aligned and contra-aligned error scores of less than  $10^\circ$ , suggesting no strongly preferred alignment. The mean absolute difference in errors between aligned and contra-aligned judgements for the remainder was  $51^\circ$ , with 13 consistent with the FPA and 9 consistent with the symbolic cues. Therefore, the picture for both groups is quite similar, and the different group patterns in Figure 7.2 are due to the influence of only a few participants. This analysis of individual scores explains the lack of a group x alignment effect interaction in the relevant ANOVA.

Therefore, most participants in both groups (70% overall) showed evidence of an alignment effect, with the influence of both first-perspective and symbolic sources evident. The first perspective influenced a slightly greater proportion of those showing alignment effects in the control group (.59) than the blocking group (.52), broadly consistent with the experimental hypothesis that, in the blocking group, preliminary training with the symbolic cues would restrict the influence of the first perspective. However, the difference is so small that a strong inference regarding blocking cannot be made from it alone.

Experiment 6 failed to support the experimental hypothesis of competition between sources of spatial alignment in a blocking design. A small direction of effect consistent with the hypothesis might conceivably strengthen statistically with more participants, or procedurally with changes that would increase the influence of the symbolic cues.

### **7.3 Experiment 7: FP v Symbolic**

Experiment 7 followed the blocking design (Kamin, 1969) used in Experiment 6 but changed the treatment of the groups such that in the experimental or blocking group the first perspective was initially trained and then the combined VE was experienced. For the control group,

again neither the first perspective nor symbolic cues were experienced during preliminary training as a consequence of a random tour of a bland VE (no FP, no symbols) before they experienced the combined VE.

The predications derived in Experiment 6 obtain in this experiment. If initial training of one source of alignment can block learning of another, then in the Blocking group we would expect to see a predominant FPA effect at testing as a result of phase 1 training, with little subsequent influence of the symbolic cues added in phase 2. Furthermore based on the results from Experiment 6 this is more perhaps more likely if indeed the first perspective is more salient than the symbolic. If however it is not possible to find blocking between sources of alignment then we would expect to see equal learning of the two sources, congruent with that of the Combined group result from Experiment 5b. In the control group, a pattern more consistent with the symbolic effect than that found in the experimental group would be expected; it is this comparison that indicates blocking.

The experimental hypothesis was that the initial training of the first perspective as a source of alignment in the blocking group would restrict alignment learning as a consequence of symbolic cues.

### **7.3.1 Design**

Participants were randomly assigned into one of two equal groups. Each group of participants were trained in phase 1 by being shown a passive pre-recorded tour of one of two different Virtual Environments (VE) before being shown a second VE (See Table 7.3). In the first group (Blocking) participants experienced a tour of a bland VE (FP) with only four objects in. The tour followed a U-shaped route around these objects and had a clearly defined first perspective. They then experienced a tour of the same VE but with the inclusion of nine large arrows on the floor (Combined). The nine arrows were aligned in the same direction, and pointed toward a large train carriage, and mountain range in the distance. The control group experienced a tour of the bland VE from Experiment 6 and again the tour was pseudo-random

Group	Phase 1 (Initial training))	Phase 2	Test
Blocking	First Perspective	Combined	First Perspective, Symbolic
Control	Bland (No First Perspective, no Symbolic)	Combined	First Perspective, Symbolic

Table 7.3: Experiment 7. Based on Kamin (1969) blocking design

and did not follow the U-Shape that defined the FPA effect. They then experienced a tour of the second VE (combined) with the nine large arrows. The tour followed a U-shaped route around these objects and had a clearly defined first perspective. The tour experience (number of explorations, number of times objects indicated/named) was the same as Experiment 6.

The independent variable was the treatment of the group in phase 1 (Blocking or Control). The dependant variables were the mean absolute error in the judgements of relative direction (JRD, in degree's) and the decision latency to make the JRD's (in seconds).

## 7.3.2 Method

### 7.3.2.1 Participants

The participants were 64 undergraduate students who took part to fulfil part of a course requirement. Their mean age was 20.18 years (18 – 59 years) and of these 8 were men (5 in the Blocking group and 3 in the Control). They were pseudo-randomly allocated to one of two groups (n=32) with the constraint that approximately the same number of men served in each.

### 7.3.2.2 Apparatus

The materials were identical to those used in Experiment 6. Once again the objects presented during the preliminary training for both groups were different to those presented in the second phase. The objects used in preliminary training were the same as used for the initial training in Experiment 6.

### 7.3.2.3 Procedure

The general procedure was identical to that of Experiment 6. They only differed in the order of training. Here the Blocking group experienced an initial training tour of the FP VE with a definite first perspective before experiencing the tour of the combined VE.

### 7.3.3 Results and Discussion

The error data for Experiment 7 (see Figure 7.6 and 7.7) were entered into a mixed 2X 2 X 2 ANOVA with group (Blocking or Control) as the between-participant factor and alignment (aligned, contra-aligned with the first part of the route) and judgement direction (forward, backward) as the within-participant factors.

A main effect of alignment was apparent ( $F(1, 62) = 10.91$ ,  $MSE = 2560.37$ ,  $p = .002$ ,  $\eta_p^2 = .15$ ) reflecting lower overall error for aligned judgements than for contra-aligned. There was a main effect of judgement direction ( $F(1, 62) = 4.82$ ,  $MSE = 3751.56$ ,  $p = .032$ ,  $\eta_p^2 = .07$ ) as a consequence of overall forward judgements having lower error than backward judgements. There was also a significant alignment x group interaction ( $F(1, 62) = 6.72$ ,  $MSE = 2560.37$ ,  $p = .012$ ,  $\eta_p^2 = .09$ ). The interaction between alignment and group is a result of a clear FPA effect in the Blocking group and no FPA effect in the Control group.

The latency data (see Figure 7.8 and 7.9) were analysed the same way as the error data. There was a main effect of alignment ( $F(1, 62) = 10.29$ ,  $MSE = 23290.13$ ,  $p = .002$ ,  $\eta_p^2 = .14$ ) due to overall latency across the groups for aligned judgements being faster than those for contra-aligned judgements. There were no other significant effects or interactions.

Further analysis of the individual groups were performed using a within-participant 2 X 2 ANOVA, with alignment (aligned, contra-aligned with the first part of the route) and judgement direction (forward, backward) as factors.

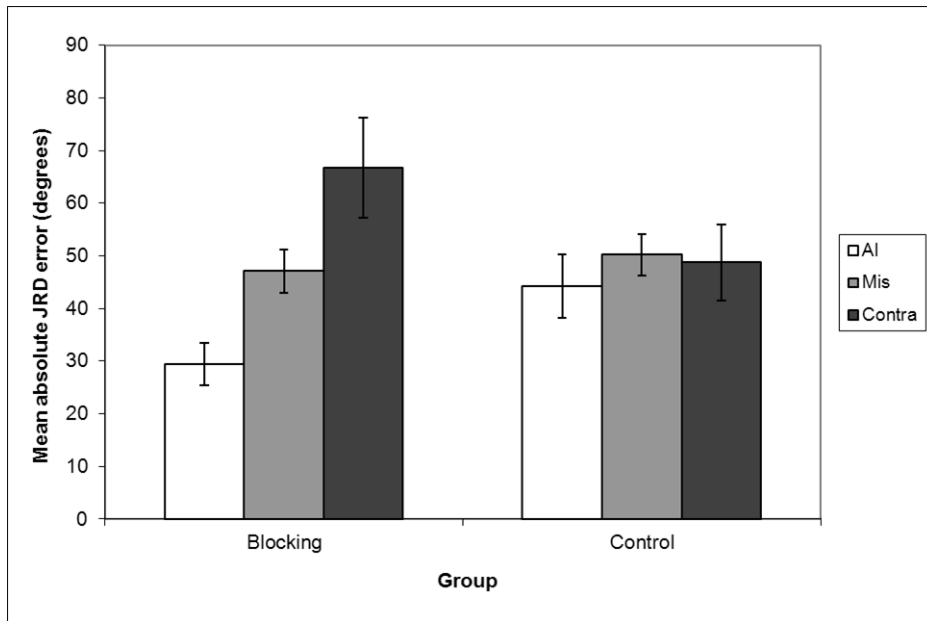


Figure 7.6: Experiment 7. Mean absolute errors for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

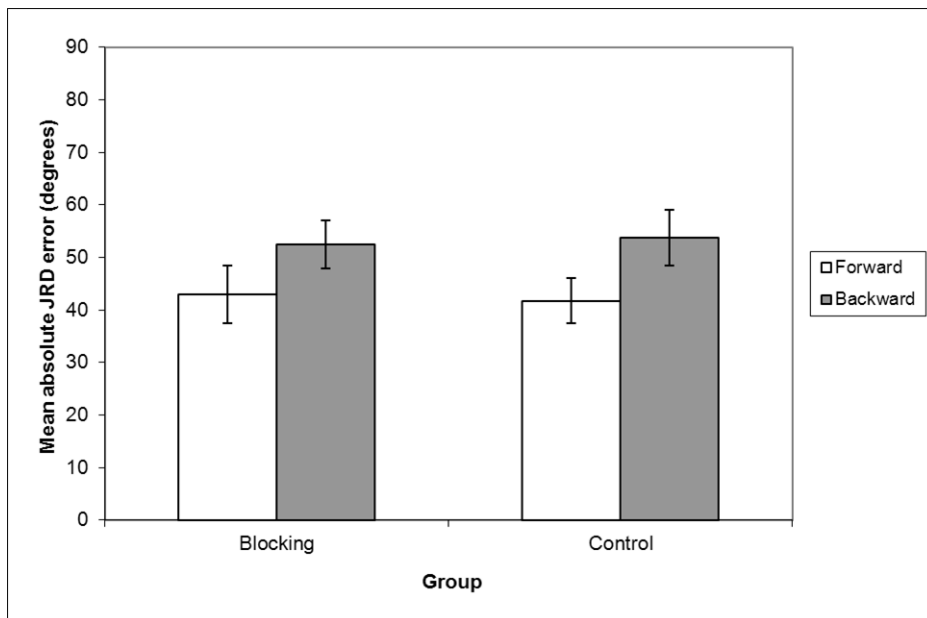


Figure 7.7: Experiment 7. Mean absolute errors for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

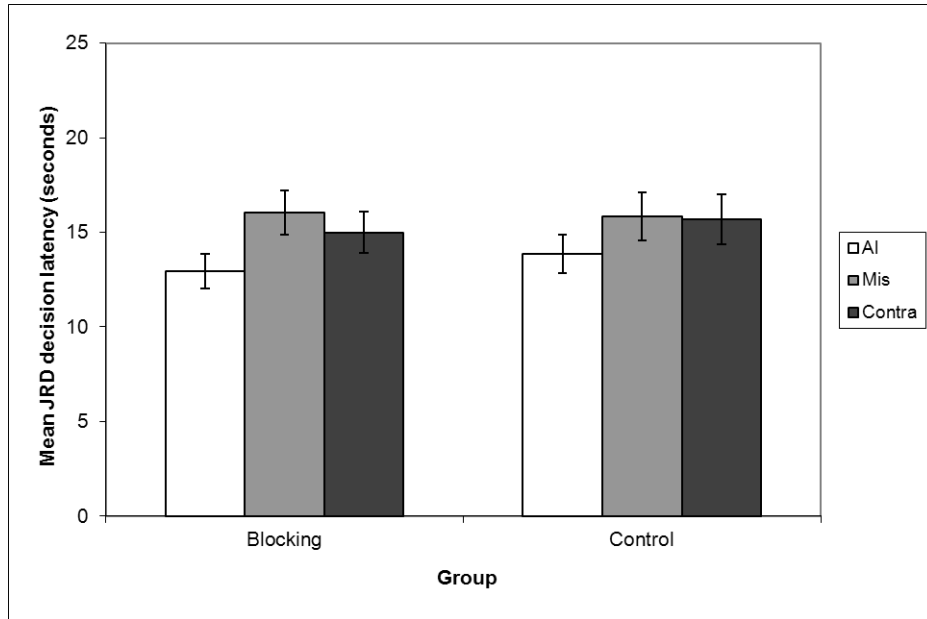


Figure 7.8: Experiment 7. Mean decision latency for aligned, misaligned and contra-aligned judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

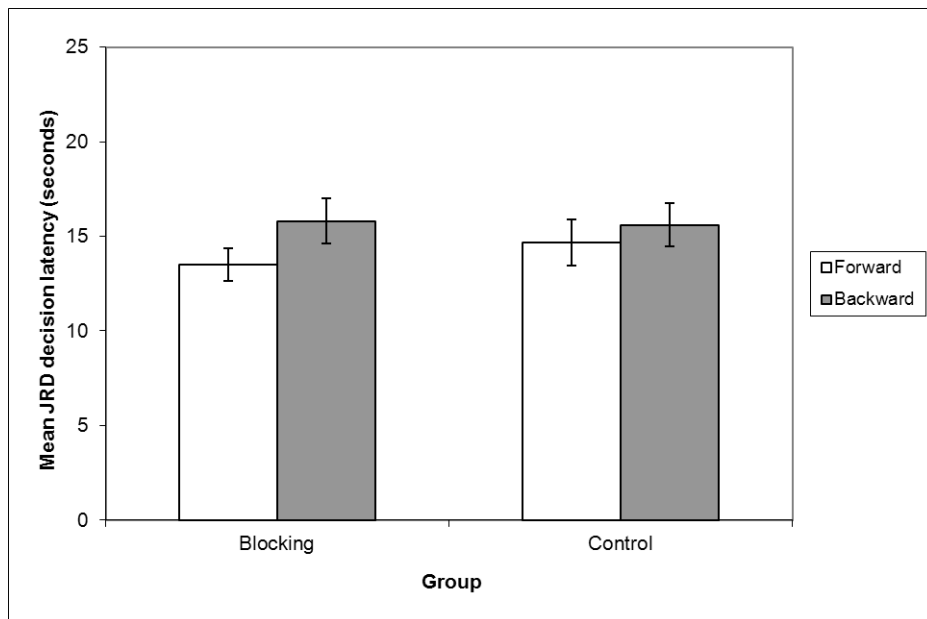


Figure 7.9: Experiment 7. Mean decision latency for forward and backward judgements across the two groups. Error bars represent one estimated standard error above and below the mean.

In the Blocking group error data there was a main effect of alignment, ( $F(1, 31) = 15.51$ ,  $MSE = 2870.39$ ,  $p < .001$ ,  $\eta_p^2 = .33$ ) with mean aligned judgement error being lower ( $M = 29.39$ ;  $SE = 3.97$ ) than the mean contra-aligned ( $M = 66.7$ ;  $SE = 9.44$ ). This main effect of alignment was also found in the latency data, ( $F(1, 31) = 8.34$ ,  $MSE = 16106.32$ ,  $p = .007$ ,  $\eta_p^2 = .21$ ) with mean aligned judgement latency being faster ( $M = 12.94$ ;  $SE = .89$ ) than the mean contra-aligned ( $M = 14.99$ ;  $SE = 1.09$ ). No other main effects or interactions were found in either the error or latency data.

In the control group for the error data there was a main effect of judgement direction ( $F(1, 31) = 4.59$ ,  $MSE = 843.46$ ,  $p = .04$ ,  $\eta_p^2 = .12$ ). There were lower mean error scores for forward judgements ( $M = 41.7$ ;  $SE = 4.33$ ) than backward ( $M = 53.72$ ;  $SE = 5.24$ ). No other main effects or interactions were found in either the error or latency data.

The alignment effect in the Blocking group and the significant group x alignment interaction provides evidence for blocking. Preliminary training of the first perspective led to evidence of learning about the first perspective in the test with no evidence of the influence of the subsequently added symbolic cues. This is consistent with the small direction of effect in Experiment 6. The pattern is consistent with the experimental hypothesis that the preliminary training with the first perspective as a source of alignment in the blocking group would restrict alignment learning as a consequence of symbolic cues. The influence of the symbolic cues is evident in attenuating the effect of the FPA effect in the control group: no such effect is evident in the blocking group.

For consistency with the analysis in Experiment 6, the individual data for aligned and contraaligned error scores were analysed. In the blocking group, 31% had differences between 'aligned' and 'contra-aligned' (with the first-perspective) error scores of less than  $10^\circ$ , suggesting no strongly preferred alignment. The mean absolute difference in errors between aligned and contra-aligned judgements for the remainder was  $68^\circ$ , with 16 consistent with the FPA and only 6 consistent with the symbolic cues. In the control group, 34% showed differences between aligned and contra-aligned error scores of less than  $10^\circ$ , suggesting no



strongly preferred alignment. The mean absolute difference in errors between aligned and contra-aligned judgements for the remainder was  $44^\circ$ , with 12 consistent with the FPA and 9 consistent with the symbolic cues. Therefore, the different group patterns in Figure 7.6 is due to a smaller proportion of participants in the blocking group showing evidence of the influence of the symbolic cues. Most participants in both groups (67% overall) showed evidence of an alignment effect, with the influence of both first-perspective and symbolic sources evident. The first perspective influenced a greater proportion of those showing alignment effects in the blocking group (.73) than the control group (.57), consistent with the experimental hypothesis that, in the blocking group, preliminary training with the first perspective would restrict the influence of the symbolic cues. The influence is statistically reliable.

In Experiment 7, preliminary training with one source of alignment restricted learning about another subsequently added alignment source. The greater salience of the first perspective lead to a pattern consistent with blocking of learning about symbolic cues. Experiment 7 provides a secure demonstration of blocking in a design that reflects aspects of true spatial learning. This is the first unequivocal demonstration of such an effect, although others of a more conventional design are consistent (e.g., Wilson & Alexander, 2008). The implication is that spatial learning is not immune to competition effects and therefore does not have a unique learning status. If all new spatial information was automatically processed, preliminary experience of a set of cues that can form the basis of an alignment effect should not restrict the processing of subsequently introduced cues. In the control group, the combined influence of exposure to the first perspective and the symbolic cues led to good spatial learning with no strong group preference for either perspective, but average errors that were similar to the blocking group. This pattern reflects learning about both perspectives. In the blocking group, preliminary experience of the first perspective restricted subsequent learning about the symbolic cues: only 6 of 32 participants were more efficient at making judgements aligned with the direction congruent with the symbols. Note the blocking design is particularly powerful for making the inference of competition: in Experiment 7, the experience with the symbolic cues was identical in both groups.

What is perhaps surprising in these data is that while most (67%) participants showed evidence of more efficient judgements aligned with a particular perspective (either the first, or that indicated by the symbols), 33% did not. Of course, the criterion for not showing an alignment effect (a difference in errors between aligned and contra-aligned judgements of less than 10%) is somewhat arbitrary. However, 10° error in spatial judgements is a very small margin. While it is possible that some of the 33% made judgements that were aligned with another unmeasured perspective (neither first perspective nor symbolic cues), it is difficult to envisage what the basis of that alignment effect might be in the relatively bland VEs used in the current experiments. Although further investigation is needed to draw firm conclusions, the 33% who did not show any alignment effect suggests that some people can develop orientation-free representations of a newly explored space. This issue was not the focus of the current experimental programme and is therefore not developed further.

# Chapter 8

## General Discussion

### 8.1 Overview of research aims and relevant results

The principle aim of this thesis was to investigate a prediction from the general hypothesis that mechanisms of temporal and spatial learning share similarities. Evidence of competition between sources of spatial alignment effects would strongly suggest a spatial learning mechanism that produces similar effects to the mechanism or mechanisms that operate in temporal (associative) and possibly other forms of learning. Given that most goal-directed spatial search tasks can admit to a non-spatial solution, it was important to identify a task and associated measurements that reflect truly spatial learning. Alignment effects satisfy this constraint because there is no way to define or measure orientation-dependence that is not tied to spatial direction. In preparation for the relevant experiments, the conditions that produce the first perspective alignment (FPA) effect were addressed and established. The main findings and implications will be briefly summarised before a fuller discussion.

Experiment 1 found that despite variations in the level of detail and the surrounding perspectives in VEs, the FPA effect was a strong and consistent feature of spatial recall of a newly explored route in four groups. The finding is at odds with the ‘salience hypothesis’ of Wilson et al. (2007) which predicts that increasing surrounding spatial cues should attenuate the

influence of the first perspective by establishing anchor points that reduce the salience, and therefore the influence, of the first perspective. The findings in Chapters 3 and 4 established support for a modified version of the salience hypothesis as an explanation for attenuation of the FPA effect. The modified version stresses the influence of exploratory experience of the surrounding features and details prior to the exploration of the to-be-tested route. The experience of exposure to surrounding detail and information, compared against a control condition of exposure to irrelevant information in Experiments 2a and 2b, led to an attenuation of the FPA effect. This is consistent with the creation and use of alternative anchor points to the first perspective, prior to exploration. The original salience hypothesis simply stated that extra detail and features be present; Experiments 2a, and 2b demonstrated that this extra detail required exploratory experience, leading to the amended salience hypothesis. Parenthetically, further work by Tlauka, Carter, Mahlberg and Wilson (2011) has confirmed that this attenuation of the FPA effect only occurs in the short term when there is immediate testing, with the effect returning after a sufficient delay between training and testing. This suggests that whilst the spatial information about the surroundings (experienced during the passive tour) were learnt, the route itself was still encoded separately. Note that the procedures used in Experiment 2a and the experimental group of Experiment 2b mimics typical experience in real-world exploration tasks, and leads to comparable results. Participants typically locomote through space to reach the start of a route; they do not ‘instantly transport’ to the initial location and first perspective as they do in VE exploration (or text descriptions or maps). This procedural difference probably accounts for the difference between learning from secondary media and real-world learning. Having established the conditions under which the FPA occurs it was possible to move on to focus on the second and main research aim: investigating whether competition effects could be found between sources of alignment.

Initial attempts to produce sources of alignment effects in addition to that of the FPA were unsuccessful. Experiment 3 built on the conflicting work of Shelton and McNamara (2001) and Mou et al. (2007), using an object-array design. Not only was there a lack of evidence for competition effects, but there was no support for any preferred orientation or source of

alignment effect with the design that was employed. Experiment 4a and 4b attempted to use simulated human movement as a competing source of alignment to the first-perspective, but no competition effects were found.

Therefore, Experiment 5a reverted to the established route-exploration design, but employed a very bland VE in which an alternative source of alignment to the first perspective was established by using symbols to indicate a preferred direction; more efficient judgements in line with the direction indicated by the symbols is referred to here as ‘symbolic alignment’. While the pattern of data conformed to separate influences of the first perspective and symbolic cues, and was consistent with overshadowing of the symbolic cues by the first perspective, this pattern was not statistically reliable. Experiment 5b introduced a manipulation to increase the salience of the symbolic cues. Evidence of the independent influence of symbolic cues and the first perspective was established. However, no evidence of overshadowing was found, contrary to Pavlov’s (1927) salience hypothesis, and Rescorla and Wagner’s (1972) limited associative strength model. Rather, both sources of alignment appeared to be available. Unlike the groups trained with either the first perspective alone, or the symbolic cues alone, the majority of participants in the Combined group, where both sets of cues were trained, were similarly efficient on judgements aligned with both perspectives. Of 24 participants exposed to both sets of alignment cues, 5 (21%) were more efficient on judgements aligned with the first perspective, and 5 (21%) showed the reverse pattern, aligned with the symbolic cues; the majority 14 (58%) showed similar efficiency (i.e., less than 10° difference) aligned with the first perspective and the symbols.

Establishing a symbolic alignment effect experimentally paved the way for further studies using a blocking design. Experiment 6 investigated whether preliminary training with the symbolic cues would restrict subsequent recall based on the first perspective. A small and statistically unconvincing difference that was consistent with a blocking direction of effect was found, but the results do not amount to evidence for blocking. Experiment 7 used the same design as Experiment 6, but this time preliminary training was with the first perspective initially, to look for evidence of restricted learning to subsequently added symbolic cues.

When first perspective and symbolic cues were simultaneously presented without preliminary training in the control group, two-thirds of the participants showed an alignment effect, with .43 in alignment with the symbolic cues. Preliminary training with the first perspective in the blocking group resulted in two-thirds of the participants showed an alignment effect, with considerably fewer (.27) in alignment with the symbolic cues. The results are interpreted as showing that preliminary training with the first perspective restricted or blocked learning about symbolic cues.

## **8.2 The FPA effect and the salience hypothesis**

Past experiments on the first perspective alignment effect suggested a disparity in the results obtained from different media. In experiments using primary learning from experience of the real-world, the FPA effect was either absent (Richardson et al., 1999; Rossano et al., 1999; Wilson et al., 2007, Experiment 3) or only present under restricted conditions such as when exploring corridors (Wilson et al., 2007, Experiment 1). Also, as mentioned in Chapter 5, some inconsistencies in the FPA effect have been reported between very similar experiments (Mou et al., 2007; Shelton & McNamara, 2001). A potential explanation was offered by Wilson et al. (2007) which predicted that high levels of surrounding detail should attenuate the FPA effect. Low levels of detail do not provide sufficient spatial information for the establishment of anchor points as alternatives to that aligned with the first perspective. Experiment 1 in this thesis investigated this prediction by manipulating the level of detail available within the VE's (enriched or impoverished) and the types of VE's explored (indoor or outdoor). This experiment presented four conditions that differed in the detail, with impoverished indoor VE's having the least amount of available information and the rich outdoor the greatest. As such a continuum of differing FPA effect presence or strength was predicted in accordance with this hypothesis. At odds with the salience hypothesis, the FPA effect proved extremely robust under all variations.

The results from Chapter 4 provided evidence to support a modified salience hypothesis,

which builds on the anchor point hypothesis supplemented by direct experience of spatial information. Experiment 2a found an attenuation of the FPA effect when participants were pre-exposed to a tour that gave them exploratory-style experience of relevant surrounding spatial information prior to experiencing the first perspective on the route to be tested. Interestingly, the tour that provided the exploratory experience was passive and not under participant's direct control; therefore, it appears to be multiple perspectives of the surrounding area that reduces the importance of the first perspective, rather than control over exploration. This result could be interpreted as in agreement with the salience/anchor point hypothesis if the importance of exploratory experience, rather than simply viewing from a distance, is taken into consideration. The combined results of Experiment 2b and 2c confirmed that the attenuation of the FPA effect was from experience of relevant spatial information and not simply greater familiarity with any VE.

The revised hypothesis was that additional detail experienced only from within the route, and at a distance, is insufficient to establish alternative anchor points such as those suggested by Coucelis et al. (1987) or alternative preferred orientations: hence, no difference in the strength of the FPA in the groups employed in Experiment 1. This at first appears counterintuitive, especially for human spatial learning; if the information is available, then why does it not lead to the predicted effects? Other previously mentioned studies (Chapuis et al., 1987; Stanton et al., 2003; Wilson et al., Submitted) have, however, shown that successful novel shortcutting ability in both humans and non-humans requires experience that connects two subspaces. Even though connecting paths, distant landmarks and relevant local structure were all available, actual exploration was still required to facilitate a shortcut. The results of the experiments in Chapters 3 and 4, as well as supporting the modified salience hypothesis, further strengthen the idea that actual experience of exploration is required for good spatial learning.

The results from Chapters 3 and 4 do not provide evidence on whether the first perspective, or alternative spatial cues, are encoded associatively. The attenuation of the FPA effect could be explained in both associative or traditional spatial learning terms. Although not originally

designed to investigate competition, it is possible to consider the attenuation of the FPA effect to be tentative evidence for competition between sources of spatial alignment. Pre-exposure may have led to learning about anchor points, spatial configurations, or an alternative orientation, which subsequently blocked learning about the first perspective on the explored route. The design of the experiment is similar to that of a blocking design if the pre-exposure tour to the explored VE is considered preliminary training for the blocking group, and if the pre-exposure tour to an irrelevant VE is considered a control (see Table 8.1). However, due to the nature of the tour it is not possible to precisely determine the source or focus of the initial learning.

An alternative interpretation to the hypothesis of anchor point development or other spatial cues blocking the FPA effect is that the tour experience led to effectively orientation-free encoding of the entire VE through experience of several orientations: as the tour progressed, an increasing number of perspectives or orientations could have been established before the first perspective on the experimental route. Therefore, a qualitatively different form of encoding might have been established, and it is not clear how this relates to blocking effects. Many participants in Experiments 5b, 6a and 6b apparently showed no preference for either of the promoted alignments. The problem with an account based on no preferred alignment is that it is not clear whether ‘orientation-free’ learning can be differentiated from ‘multiple-orientation’ learning; therefore, the hypothesis of orientation-free learning does not make any different predictions from multiple orientation learning.

Yet another alternative is to consider a cognitive or more traditional spatial learning explanation. The additional tour exploration of the surrounding area could have strengthened the creation of a cognitive map providing more alternatives that are at least equally salient to the first perspective. The Jacobs and Schenk (2003) integrated cognitive map is one explanatory possibility, especially when considering the salience hypothesis. Exposure to more surrounding spatial information and detail could have led to more vector information being included along with the first perspective, leading to an orientation free representation of the VE, as well as allowing other salient information such as landmarks to be integrated, facilitating



later judgements. As with 'orientation-free' learning, it is not clear that the concept of a cognitive map makes any predictions involving alignment effects that do not follow from the theory that many environmental perspectives have been encoded.

While the designs employed in Chapters 3 and 4 make it difficult to ascertain whether a single or multiple orientations were adopted, and as such definite conclusions can not be drawn about competition effects in spatial alignment learning, the results do reinforce the value of VEs as experimental tools, and the importance of investigating competition in alignment effects within the domain of spatial cognition. That real-world alignment effect outcomes are mirrored using VE simulations is an important finding, adding to those findings that suggest strong similarities in VE and real-world spatial learning.

It is argued that spatial alignment effects are important to investigate competition effects as they are a measure of true spatial learning, free from the criticisms levelled at the interpretation of spatial experiments by Mackintosh (2002). Spatial alignment effects cannot be explained in associative terms. Participants are asked about spatial information and the distal/angular relationship pertaining between objects. This task requires the use of spatial information and cannot be explained as approaching a landmark associated with a goal, nor can it be accounted for in terms of instrumental learning. The relationship between the target object and others is learnt but it is not learnt in relation to an action, goal or event. Importantly then, any competition like effects found in this realm can be said to have greater relevance to the issue of whether spatial learning is governed by a similar underlying learning mechanism to that of associative learning than more traditional designs and measures.

Group	Phase 1 (Initial training)	Phase 2	Test (JRD)
Blocking/VEA	Tour of VEA surroundings (A)	First perspective on route in VEA surroundings(AB)	Little evidence of first perspective
Control/VEB	Tour of irrelevant VEB surroundings (X)	First perspective on route in VEA surroundings (AB)	Stronger evidence of first perspective

Table 8.1: Experiment 2b expressed as a blocking design

### 8.3 Attempts at finding competition like effects: blocking but not overshadowing

The experiments in Chapters 3 and 4 point to the conclusion that the FPA effect is extremely robust from exploration of a new route provided learners have no prior knowledge of the surrounding area. Attenuation of the effect only occurs if there is additional spatial learning prior to exposure to the first perspective. With the initial research aims satisfied, the focus of the thesis moved to that of competition between sources of alignment. Competition effects are well documented in contemporary associative learning theories, and are central to their interpretation. More traditional accounts of spatial learning do not invoke cue competition, and some versions, such as cognitive mapping theory (O’Keefe & Nadel, 1978) specifically assume that true spatial learning will be immune to cue competition.

Chapter 6 found no evidence for overshadowing; however, an alternative source of alignment was established that could be used in conjunction with the FPA effect. Using a bland and low detailed VE, similar to that of the impoverished outdoor VE in Experiment 1, it was possible to present an alternative form of alignment to the FPA effect by using symbolic cues. Although there was a lack of significant alignment effect in the overshadowing group, due to apparently good learning about both the first perspective and the symbolic cues, the pattern of data still conformed to a FPA effect. This suggests that the first perspective was a more salient source of alignment information than the symbolic cues. The results of Experiment 6 were consistent with this interpretation in that symbolic information managed to disrupt

learning about the FPA effect, but not significantly block it as traditionally described.

Overall, clear evidence for a blocking effect was found in Experiment 7, with learning about the first perspective restricting alignment learning based on the symbolic cues. The different outcome based on whether pre-training involved symbolic cues or the first perspective again appears to rest with the first perspective being more salient than the symbolic cues. Salience is a well established influence on learning and is well documented in associative learning (e.g. Mackintosh, 1975). Restricted learning about one source of alignment as a consequence of prior learning of another source conforms to a blocking effect. Irrespective of any implied explanation (associative or otherwise) this effect will be referred to in this thesis as blocking. This finding is perhaps the most important contribution presented in this thesis. The blocking in the spatial domain described in this thesis is consistent with blocking effects found in temporal studies, and the latter can be explained according to formal associative models. However, because the present designs involve ‘incidental learning’ (i.e. learning in the absence of a goal) rather than goal-directed learning, a model that depends on competition for ‘associative strength’ between landmarks and a goal does not seem appropriate *a priori*.

Considering associative learning mechanisms, the pattern of data is most readily interpretable in terms of changes in attention (e.g. Mackintosh, 1975). Mackintosh predicts that blocking can occur after the first ‘trial’ as the predictive value of a conditioned stimulus (CS) will be compared with others (or the background cues) and the better predictor will be attended too. The initial training of one CS will result in that stimulus having a greater associative strength with the unconditioned stimulus, and therefore be a better predictor of that event than a CS added later. However overshadowing is not necessarily predicted by Mackintosh as, “If a subject simply receives reinforced trials with an AB compound, both A and B should be established as signals for reinforcement, and without invoking the inverse hypothesis it is hard to see why the presence of one should cause any decline in attention to the other.” [pg.284]. As can be seen from the results of Chapter 7 this suggestion conforms much more closely to the data than the predictions from the Rescorla-Wagner (1972) that both blocking and overshadowing should be found. However, the comparison cannot be pursued; as discussed

below, the alignment learning procedure does not conform closely enough to the requirements of associative learning.

## **8.4 Relevance of results to associative and cognitive explanations of spatial learning**

Competition-like effects were established using procedures and measures of truly spatial learning. This suggests there is at least something in common between the mechanisms involved in spatial and temporal learning. However, because the procedures employed in this thesis did not involve goal-directed learning, it is difficult to see how an explanation in terms of ‘associations’ between cues and a goal could be invoked as an explanation for competition effects. Further, according to most traditional accounts of spatial learning, an essentially ‘incidental’ form of learning such as spatial alignment learning would not be anticipated to show competition effects at all. This presents a potential dilemma in that neither current associative nor spatial theories provide an explanation for the present findings.

One group of theorists propose that all knowledge is associative (e.g. Pearce, 2009). Their assumptions include: (i) that a hallmark of modern theories of associative learning is that cues compete with each other for associative strength with an outcome; (ii) there is nothing special about spatial learning, it simply comprises associating landmarks with goals; (iii) therefore, we should find evidence of cue-competition in spatial learning: specifically landmarks should compete with each other for associative strength to a goal; (iv) if we find evidence of cuecompetition in spatial learning, that is evidence that spatial learning is associative in character. However, there is a logical flaw in this thinking: because associative learning is characterised by competition effects does not mean that competition effects necessarily implies associative learning.

A second group of theorists (Cheng & Newcombe, 2005; Jeffery, 2010; O’Keefe & Nadel, 1978; Tolman, 1948): (i) accept a role for associative learning, but maintain that spatial learning is completely different; (ii) assume that in spatial learning, exploration of a new space

must entail automatic updating of spatial information otherwise there would be no point to exploration (iii) assume that if spatial knowledge is automatically updated, cue-competition will not be found, such effects would hinder integrated maps (Jacob & Schenk, 2003; McNaughton et al., 2006); (iv) therefore, failure to find evidence of cue competition confirms that spatial learning is not associative. This view fails to properly recognise that some spatial information can be redundant, and a mechanism for restricting spatial learning makes evolutionary sense, otherwise all new details would be processed, leading to inefficiency and ‘clogging’ of the system. It is perfectly feasible that new spatial information will be automatically attended to unless prior experience makes that new information redundant. Failure to find evidence of cue competition does not necessarily confirm that spatial learning is not associative; for example, this could be a problem with the experimental design (cue competition is not universally found in associative learning experiments).

An overriding problem with investigating these issues, and reformulating theories, is the failure to clearly recognise that, very often, all that is required to reach a goal is associative learning (Mackintosh, 2002). Associative solutions to spatial problems are often simpler than those based on true spatial learning, and organisms seek the simplest solutions to problems. If both approaches are flawed, how can we modify them to accommodate the results of Experiment 7?

First, Experiment 7 suggests that competition effects operate in the truly spatial domain, and such effects have been established in studies of associative learning. Therefore we have to assume that there is a similarly operating ‘mechanism’ (or mechanisms) that govern the processing of all information. For simplicity let us assume that this mechanism is some form of change in ‘attention’: little attention might be devoted to new spatial cues when prior spatial cues have been used to establish an adequate representation of the environment (unless those cues are accompanied by a surprising event of importance). The account is developed no further because this thesis does not address the precise nature of the learning mechanism.

Second, the analysis presented in this thesis suggests that there are different types of knowl-

edge structure (Shanks, 2007): for example, associations are contentless links, whereas vectors contain distance and directional information (we could add propositions and doubtless other knowledge structures). Just as changes in attention have been proposed to account for competition in associative cue learning (e.g. Mackintosh, 1975), when engaged in vector learning, attention could be the mechanism that determines which vectors are processed at the expense of others. For example, a vector from landmark B to a goal could be actively ignored if the vector from Landmark A to the goal is adequate to locate the goal and captures all of the participant's attention. Similarly, if cue-set A establishes a conceptual north which facilitates spatial recall, the addition of cue-set B suggesting an alternative 'north' may be ignored.

Therefore the reformulation is simple: similarly operating mechanisms, possibly based on changes in attention, will determine that some cues are processed at the expense of others to a greater or lesser degree. The mechanism(s) operates on the acquisition of both associative and vectorial knowledge structures, even though the resulting structures differ. Adequate information from one temporal or spatial source can make a second source uninformative, with a consequent decline in processing, regardless of the knowledge structure.

## **8.5 Summary**

This thesis initially set out to address the inconsistencies in the occurrence of the firstperspective alignment effect across different media, as all the experiments in the thesis involved spatial learning from virtual environments, a secondary medium. Experiments 1 to 2c established the crucial condition that produces the FPA effect: experience of the first perspective must not have been preceded by exploratory experience of the surrounding area. The motivation behind the investigations was to provide a well-understood effect to use to investigate competition between truly spatial sources of learning. These preliminary findings turn out to be consistent with spatial competition effects in demonstrating that prior exposure to relevant spatial information can have an attenuating effect on a subsequently experienced source

of alignment learning. However, none of these studies employed a sufficiently convincing control condition.

The salience hypothesis of Wilson et al. (2007) was modified to take into account the importance of exploration of the surroundings of a VE for the attenuation of the FPA effect to occur. With the inconsistencies in the literature clarified, the FPA was then used to explore the issue of competition effects in spatial learning. Initial investigations in Chapter 5 were inconclusive due to the problems with establishing an alternative source of alignment to place in competition with the first perspective. Investigations into the use of object arrays in Experiment 3 failed to provide even a single source of alignment, and whilst human movement such as that in Experiments 4a and 4b might provide an interesting potential source of alignment for future research, insufficient evidence was found to merit further use of it in the thesis.

The experiments in Chapter 6 established that a ‘symbolic alignment effect’ could potentially be used to compete with the first perspective as a source of alignment. Subsequent experiments addressed the question of whether competition in the form of overshadowing or blocking occurs in true spatial learning. Experiment 5a and, in particular, Experiment 5b, found no evidence of overshadowing of spatial learning. Whether a lack of overshadowing is unique to spatial learning, or whether overshadowing is simply difficult to establish unless it is based on differences in salience, awaits further experimentation. Taking into account that different models of associative learning have differing predictions on the presence of overshadowing (Mackintosh, 1975; Rescorla & Wagner, 1972) Experiments 6 and 7 sought evidence of blocking of true spatial learning. Although the evidence for blocking in Experiment 6 was very weak, in Experiment 7 evidence consistent with a blocking effect was found using a truly spatial task and truly spatial dependent variables. In Experiment 7 this thesis provides the first sound demonstration that one spatial learning source can spontaneously compete with another source. The findings of Chapter 7 are initially difficult to reconcile with either of the current conflicting theoretical camps. The mechanism (or mechanisms) responsible for spatial competition apparently shares similarities with the mechanism responsible for temporal or associative competition between cues and outcomes. However, spatial and

temporal knowledge structures differ (cf. Shanks, 2007). Neither the theory that all knowledge is associative, nor that spatial learning is immune to cue competition, can be maintained. The resolution, based on the evidence in this thesis, is that a common learning mechanism, perhaps attention-based, operates on both temporal and spatial learning, despite these being quite different knowledge formats. Future research should address the specific mechanisms involved in both temporal and spatial competition.



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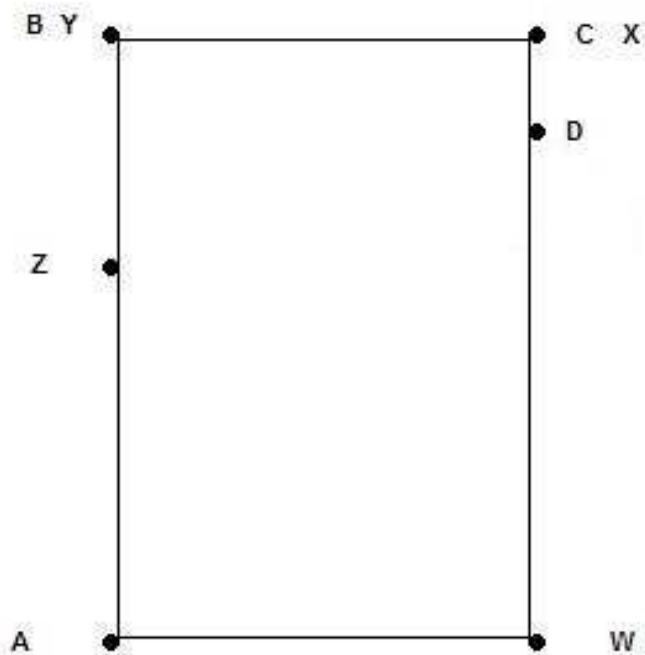
# Appendix A

## Routes and objects

Route	Objects	Length of first leg	Initial turns
ABCD	Newspaper, Concrete Block, Blue Barrel, Trolley	Long	Right
DCBA	Trolley, Blue Barrel, Concrete Block, Newspaper	Short	Left
WXYZ	Brush, Blue Barrel, Concrete Block, Bucket	Long	Left
ZYXW	Bucket, Concrete Block, Blue Barrel, Brush	Short	Right
CWAZ	Blue Barrel, Brush, Newspaper, Bucket	Long	Right
ZAWC	Bucket, Newspaper, Brush, Blue Barrel	Short	Left
DWAB	Trolley, Brush, Newspaper, Concrete Block	Short	Right
BAWD	Concrete Block, Newspaper, Brush, Trolley	Long	Left

Table A.1: Route name, objects length and initial type of turns





- Key
- A - Newspaper
  - B/Y - Concrete Block
  - C/X - Blue Barrel
  - D - Trolley
  - W - Brush
  - Z - Bucket

Figure A.1: Route and object diagram

# Appendix B

## Pilot

Previous experiments using a U-route, in varied mediums differed from the experiments in this text in the amount of times the U-route was experienced (Wildbur & Wilson, 2008; Wilson et al., 2007). The route was experienced twice (from start to end, end to start) for each section in the previous experiments. For all relevant experiments in this thesis the routes were experienced three times (from start to end, end to start and start to end) for each of the three sections (experimenter naming objects, participants naming objects, final exploration). A pilot experiment based on the tour and environment used in Experiment 2a was conducted. Rather than the three explorations of the route for each section as experienced in Experiment 1 it was reduced to two. This change revealed no significant difference in error and latency data in comparison with the data from Experiment 2a.

Study	Initial Experience	FPA route exploration	Test
Experiment 2a (n=24)	Tour of VEA	Explored VEA (3 explorations per section)	JRD's for VEA
Pilot (n=12)	Tour of VEA	Explored VEA (2 explorations per section)	JRD's for VEA

Table B.1: Comparison of design for Experiment 2a and the pilot study

# Appendix C

## **Instructions for Experiment 2c**

### **No New Instruction group**

#### **Before the presentation of the two pre-recorded tours**

“I am going to show you two pre-recorded tours of a 3D environment. All you need to do during this stage of the experiment is watch the tours. They should both last between two to three minutes, each. Once both tours are finished I will load the environment that you will explore.”

#### **As the VE loads**

“This is the environment that you will explore. I will direct you along a route around the outside of a building three times. Each time I will point out the objects that you will need to remember for the test. After the first three explorations you will get to explore three more times, though this time you will point out and name the objects as you pass them. This is so I know we are both calling the objects by the same name, and so that I know you are focussed on the correct objects. Finally you will get to explore a further three times along the route except for these explorations you will not need to point out any of the objects to me.”

**Once all the explorations are finished**

“Would you like to explore the route some more or are you ready for the test?”

## **New Instruction group**

### **Before the presentation of the two pre-recorded tours**

“I am going to show you two pre-recorded tours of a 3D environment. All you need to do during this stage of the experiment is watch the tours. They should both last between two to three minutes, each. Once both tours are finished I will load a new and different environment for you explore.”

### **As the VE loads**

“This is the new environment that you will explore. The new environment might look familiar because it contains similar buildings and objects to those that you have just seen in the pre-recorded tour, but this virtual environment is actually very different in layout. I will direct you along a route around the outside of a building three times. Each time I will point out the objects that you will need to remember for the test. After the first three explorations you will get to explore three more times, though this time you will point out and name the objects as you pass them. This is so I know we are both calling the objects by the same name, and so that I know you are focussed on the correct objects. Finally you will get to explore a further three times along the route except for these explorations you will not need to point out any of the objects to me.”

### **Once all the explorations are finished**

“Would you like to explore the route some more or are you ready for the test?”

# Appendix D

## Object array arrangement



Figure D.1: Experiment 4 object array arrangement. From left to right: Kettle, Boot, Wrench, Pan, Cup, Keyboard and Jar.