RETRIEVAL, ACTION AND THE REPRESENTATION OF DISTANCE IN COGNITIVE MAPS.

By

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Abstract

This thesis examines the context effects on retrieval, and the influence of action on the representation of distance in cognitive maps. It is proposed that bias in distance estimation is a function of the contexts of retrieval that trigger the representation of action in memory during evaluation tasks. The proposal is consistent with embodied cognition evidence that suggests that actions are implicitly a part of the representation, and will be naturally extracted as part of the retrieval process. The experimental work presented examines two different contextual cues; the frequency of visitation to landmarks, and the importance of activity performed at landmarks. Each cue primes differently the conceptualisation of landmarks prior to making distance estimation. This priming facilitates memory access, which fleshes out relevant spatial information from cognitive maps that are used in distance estimation and route description. This proposal was examined in a series of four experiments that employed structured interviews. Participants had to rate landmarks based on frequency of visitation criteria or importance of activity criteria, or both. They then made verbal distance estimations and route descriptions. The results found implicate the involvement of action representation.

The involvement of action in cognitive process was empirically investigated in three further experiments. A new methodology was developed featuring the use of a blindfold, linguistic descriptions, and control of actual movements. Blindfolded participants learned new environments through verbal descriptions by imagining themselves walking in time with the metronome beats. During turns, they were carefully moved. Following instructions, they performed an action at mid-route. Their memories for the newly learned environments were tested through recalls and measured again with the metronome beats. The results found were consistent with explanations based on network-map theory. They implicate attentional processes as an intrinsic part of the cognitive mechanism, and the strings of the network-map as the actual motor program that executes the movement. These results are discussed in relation to the nature of cognitive maps.

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1. CHAPTER 1: COGNITIVE MAPS

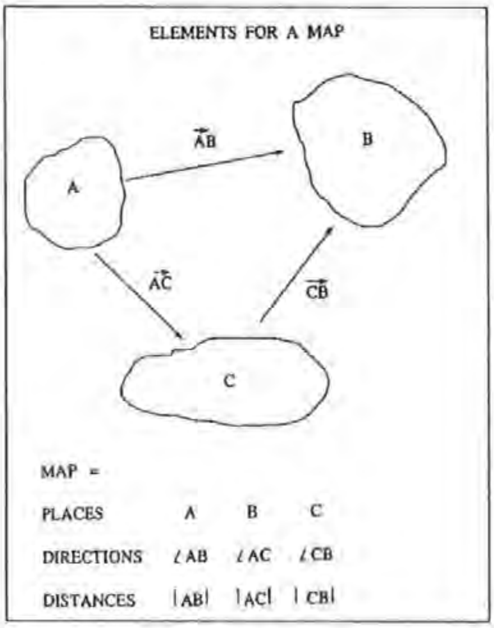
1.1. Introduction

Getting around in space is a behavioural competence, which is essential to human survival in the environment enabling us to perceive and represent spatial aspects of the world. By observing the locations and movements of objects (including people) and the configuration of our environment we learn spatial schemas to perceive, navigate, and remember space. Spatial schemas are internal mechanisms or cognitive structures we develop, which are the indispensable foundation of abstract cognitive tasks (Gattis, 2001). We also have the ability to transmit our spatial knowledge by language. Spatial descriptions normally assume a perspective, either a route perspective or a survey perspective, or a combination of both. The two perspectives have parallels with two major means of learning about environment, the first through navigation, and the second through maps (Taylor & Tversky, 1996).

Tolman (1948) first coined the term cognitive map to account for the behaviour of rats in a maze. He described experiments in which rats were trained to follow a complex path involving numbers of turns and changes of direction to get to a food box. Subsequently in a test situation, the trained path was blocked off and a variety of alternative paths were provided to the rats. It was found that the large majority of the rats jumped the maze's wall and went directly (as the crow flies) to the food source. This shortcut procedure has become a standard indication that animals – and by analogy humans – go beyond the information given when they go directly to a goal after having learned an indirect path.

Since Tolman (1948) first suggested that animals have cognitive maps, hundreds of studies of animal navigation and its physiological basis have been performed. Evidence for the existence of cognitive maps in the hippocampus came from the finding by O'Keefe and Dostrovsky (1971). They found that some neurones in the hippocampus of freely moving rats were intensely active only when the animal's head was in a particular part of the environment, regardless of the view the animal was facing. Such neurones are called place cells. O'Keefe and Nadel (1978) proposed that the hippocampus is central to the construction of cognitive maps that encode a rat's environment in a two-dimensional representation, and the activation of each place cell represents the animal's presence at a particular set of co-ordinates within the representation. The theory of cognitive maps (O'Keefe, & Nadel, 1978, O'Keefe, 1996) claims that cognitive maps contain three kinds of entities. Figure 1.1 shows a schematic example of the elements in cognitive maps.

Figure 1.1: Elements in Cognitive Maps (Illustration taken from O'Keefe, 1996).



The entities in cognitive maps are a set of place representations and the distances and directions between them. Distances and directions can be represented by vectors drawn from one place to another in absolute coordinate systems. In a coordinate system, objects or places are encoded with respect to the three spatial axes so that relations between places are not explicitly represented but are implicit in the structure of the coordinate system and can be derived from it. The locations of objects within allocentric frameworks do not change as the observer moves in the environment, implying that the stored knowledge one has of the environment is composed of fixed spatial representations of the environment and thus answers to Euclidean properties.

However, a large body of evidence has shown that, regardless of how it is acquired – either through direct exploration or by means of spatial artefacts (e.g., maps, virtual reality, and language description) – psychological space is often associated with bias. For example, suppose A and B represent two places or landmarks in an environment, the distance estimated between A $\rightarrow$ B is different from B $\rightarrow$ A (McNamara & Diwadkar, 1997; Moar & Bower, 1983; Moar & Carleton, 1982; Sadalla, Burroughs, & Staplin, 1980), or a route containing more right angle turns is estimated as being longer than a route of equivalent objective length with fewer turns (Byrne, 1979; Sadalla & Magel, 1980). Therefore, Euclidean based cognitive maps either do not exist or exist in conjunction with other forms of spatial representation and may not be called into play every time an individual is required to make a spatial judgement. The bias associated with psychological space is discussed in detail later on in this chapter.

The main aims of the present thesis were to examine in detail how distance estimation and route description are influenced by retrieval processes and actions performed during learning about the environment. The focus on retrieval processes and the representation of action is interesting for two key reasons.

Firstly, while biases in distance estimation have been documented, it is unclear as to the origin of these effects. For instance, there are a number of studies that explain the asymmetrical effects in distance estimation as a function of retrieval processes (Holyoak & Mah, 1982; Huttenlocher, Duncan, & Hedges, 1992; McNamara & Diwadkar, 1997), however it is not quite clear why the retrieval effects are present. One possibility that the present thesis considers as the first theme of investigation is that biases in distance estimation are a function of the retrieval contexts that trigger action-based representations in memory during the estimation tasks. We will examine in detail the issue of retrieval context in Chapter 2 of this thesis.

Secondly, although biases in distance estimation could be partly explained by retrieval context, the representation of action must be emphasised. Theorists have begun to consider the view that cognition is grounded in the individual bodily interaction with the environment (e.g., Barsalou, 1999; Glenberg, 1997). Empirical evidence supporting the embodiment framework can be found in domains such as visual perception, language comprehension, and motor representation. A range of literature that suggests that action is central to spatial representation is reviewed later on in this chapter. For instance, it has been shown that the representation of a visual stimulus generated from pictures or from purely linguistic descriptions can activate motor affordances. In other words, merely viewing an object, an image of an object, or hearing a description of an object results in the activation of the motor patterns necessary to interact with it (Ellis & Tucker, 2000; Tucker & Ellis, 1998; Glenberg & Kaschak, 2002; Richardson, Spivey, & Cheung, 2001). In motor representation research, it has been demonstrated that the processes underlying mental or imagined movements are similar to those underlying actual movements, i.e., motor representation shares the same neural mechanisms as those responsible for actually executing or mentally executing an action (Decety, 1991; Decety, Jeannerod, & Prablanc, 1989; Jeannerod & Decety, 1994).

Based on the evidence underlining the centrality of action the present thesis attempts to establish its influence on the retrieval of distance from memory. This issue is the focus of the second theme of this thesis and is examined in detail in Chapter 4.

Before we consider evidence suggesting the importance of the role of action-based representation in cognition more generally we first examine the evidence to show that there are a number of biases that exist across a range of measures that are associated with cognitive maps. However, before reviewing the relevant literature on bias in distance estimation, it is important to examine how spatial knowledge is acquired. It is to this issue we now turn.

1.2. Acquisition of Spatial Knowledge

Much of the research on the acquisition of spatial knowledge was heavily influenced by the child development sequence theories expressed by Piaget and Inhelder (1967). In adults, it has been suggested that the acquisition of spatial knowledge is developed in a sequence (Siegel & White, 1975; Golledge, Smith, Pelligrino, Doherty, & Marshall, 1985). The sequence of acquisition is as follows.

During the initial exposure to a new space place knowledge is acquired as people learn to recognise landmarks or salient features in the environment. A landmark is initially identified and remembered due to its particular role in the context of people's interaction with the environment. For example, when arriving at a new college campus, students may learn how to identify the library, the students' union, and the important administrative and lecture hall buildings (Evans, Marrero, & Butler, 1981).

Over time, people learn to relate spatially separated landmarks to others in the environment. In so doing, they construct distance and orientation relationships that enable them to find routes connecting landmarks. Route knowledge is characterised as deriving from direct navigation experiences and encoding a sequential record of the space between start points, subsequent landmarks, and destinations. At a minimum a procedural description of the route between A and B must identify locations at which the traveller must change direction and specify the action to be taken at those locations (Thorndyke & Hayes-Roth, 1982). A person who has route knowledge may know the approximate distance between the landmarks along the route he or she travelled. Using the college campus example, let us assume that a student wants to go from the library to the gym hall. The procedural description reported by the student will likely be in the form: "From the library exit I will turn right and go downstairs, cross the car park, go underneath the bridge linking two buildings, cross the road, and walk about 20 meters to the entrance of the gym hall". On its own route knowledge does not tell the traveller where he/she is in relation to the rest of the environment, but one still can navigate efficiently using route knowledge.

The key features of route knowledge representations are: i) they are learned in the context of accomplishing a specific task (getting from the library to the gym hall); ii) they are represented from the egocentric point of view (left and right turns are learned with respect to the body's orientation and direction of travel); iii) they are perspective-dependent, i.e., they are most useful when employed from the same viewing perspective as they are learned, usually terrain-based for pedestrian travel (Allen & Kirasic, 1985; Golledge, 1992).

The next step is to integrate knowledge about different routes by extensive exploration of the environment. The mental representation of an area is seen from a bird's eye point of view as if the person builds a map-like cognitive map of the environment. Thorndyke and Hayes-Roth suggested that "Such knowledge permits the direct retrieval of spatial relations between points without reference to the routes connecting them." (p. 564). Using this representation, pedestrians can sense and communicate the direction of landmarks as if they could see through intervening buildings and obstacles (Golledge, 1992; Thorndyke & Hayes-Roth, 1982). Rather than structuring the spatial relationship between the library and the gym hall in terms of the connecting legs of the route between them, the student may regard the spatial relationship between the buildings as: "The gym hall is located about 200 meters as the crow-flies to the west of the library". The practical value of survey representations is evident when route complexity increases. For example when there is a large traffic jam on the route someone travels daily, a person with survey knowledge may try a different route with success even though he or she has never travelled it before.

1.3. Distortions in Cognitive Maps

Simple tasks like going from home to work, to school, to a store, or directing newcomers to places they have never seen, require information to be stored, accessed, and used in a convenient and easy way. To perform such tasks it is necessary to use one's memory representations of spatial information – that is one's cognitive map.

Investigations into the relationship between physical or actual distance and cognitive distance have shown that the two differ. Furthermore, the differences between actual and cognitive distance are not random; cognitive distance is systematically distorted from the actual distance (Golledge, 1987). The disparity in distance estimations has been explained as a function of hierarchical organisation of memory, the organisation of reference points, the structure of the environment (route complexity, environment complexity), the modes of acquisition at learning (map, navigation), and the contexts of learning (goals or intentions). Each of these phenomena is considered in turn in the next sections.

1.3.1. Hierarchical Organisation

The distortion in people's cognitive representations of the environment may reflect or arise from the encoding of distance in memory. Indeed, there is mounting evidence to indicate that people divide the environment into "chunks" or categories, and that once established, this "chunking" affects spatial judgements.

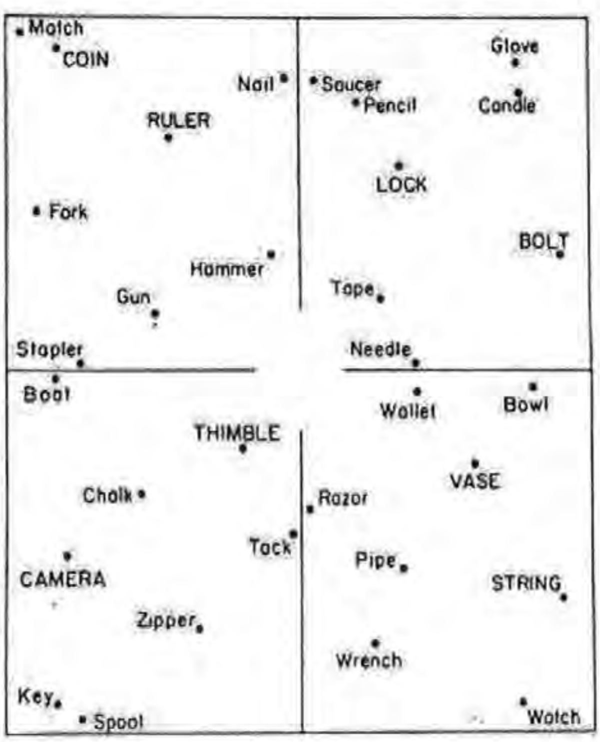
Stevens & Coupe (1978) demonstrated that participants' directional judgements between cities were biased by the relative positions of the states (categories) in which those cities were included (a map showing the true relation between the landmark stimuli is show in Figure 1.2).

Figure 1.2: Map showing the true relation between San Diego, California and Reno, Nevada (Illustration taken from http://www.Igu.ac.uk/psychology/ungar/lecturenotes/pe/pe2.html)

Steven and Coupe asked participants (undergraduate students at UCSD) to indicate from memory the direction from one American City to another by drawing a line in the proper orientation on a circle with North noted at the top. A basic question was: "Which is further east – Reno, Nevada or San Diego, California?" Steven and Coupe found that most people chose Reno as the answer to this question. They explained this by suggesting that since California is perceived generally west of Nevada, participants make the incorrect inference that all cities in California are west of all cities in Nevada. Participants infer the direction of entities in a category (i.e., cities) from the overall direction of the category (i.e., States), thereby distorting the direction of cities in a state in the overall direction of the state. This type of finding implies that our spatial knowledge organisation is hierarchical and regionalised.

Physical barriers have been shown to have a distorting effect on the resulting mental representation of the environment. McNamara (1986) arranged object names, on the floor, in a space divided into four regions of equal size. Regions were separated by black lines on the floor (see Figure 1.3).

Figure 1.3: Arrangement of objects into regions (Illustration adapted from McNamara, 1986)

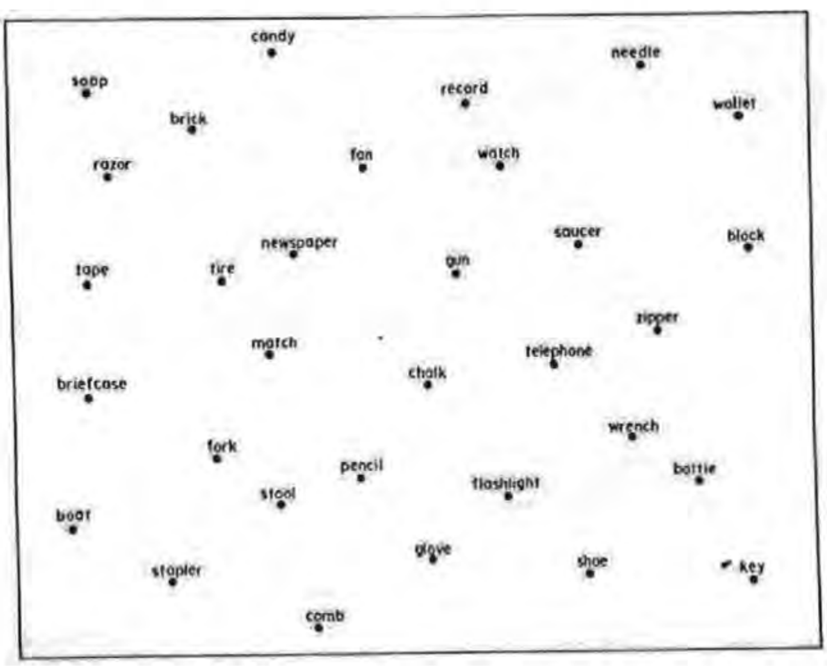


Two groups of subjects learned the locations of objects through direct experience. One group could move in the space without regard to the black lines. The other group had to treat the lines as boundaries by walking around the line dividing the two regions. Pairs of equidistant objects were arranged within regions and between regions. After participants memorised the location of the objects, their memory for the environment was tested using object name recognition, direction estimation, and Euclidean distance estimation. A priming task was used for object name recognition. An object name was presented, as a prime, followed by a target name. The participant had to indicate whether the target was one of the objects whose locations they had memorised.

Participants' reaction times to the target were faster when the target was primed by an object in the same region compared to when the target was primed by an object in a different region. In the direction estimation task, it was found that when two objects were in vertically aligned regions, direction estimates were more vertically aligned than they originally appeared. Similarly, when the two objects were in horizontally aligned regions, direction estimates were more horizontally aligned than they originally appeared. Regional boundaries and object distance also influenced distance estimations. Participants underestimated distances between objects in the same regions and overestimated distances between objects in different regions. This finding suggests that objects in the same physical region are closer in memory than objects in different regions (controlled for the Euclidean distance). The distortion effects of the boundaries on distance and direction estimation also suggest that memory for relations between regions are encoded less accurately than within region relations.

Hierarchical structuring was also observed even though objective boundaries were not present in the space. McNamara, Hardy, and Hirtle (1989) had participants memorise spatial layouts. These spatial arrays did not contain physical or perceptual barriers of any kind. Figure 1.4 shows one of the maps used in the experiment.

Figure 1.4: One of the maps of array of objects used in the experiment (Illustration adapted from McNamara, Hardy, and Hirtle, 1989).

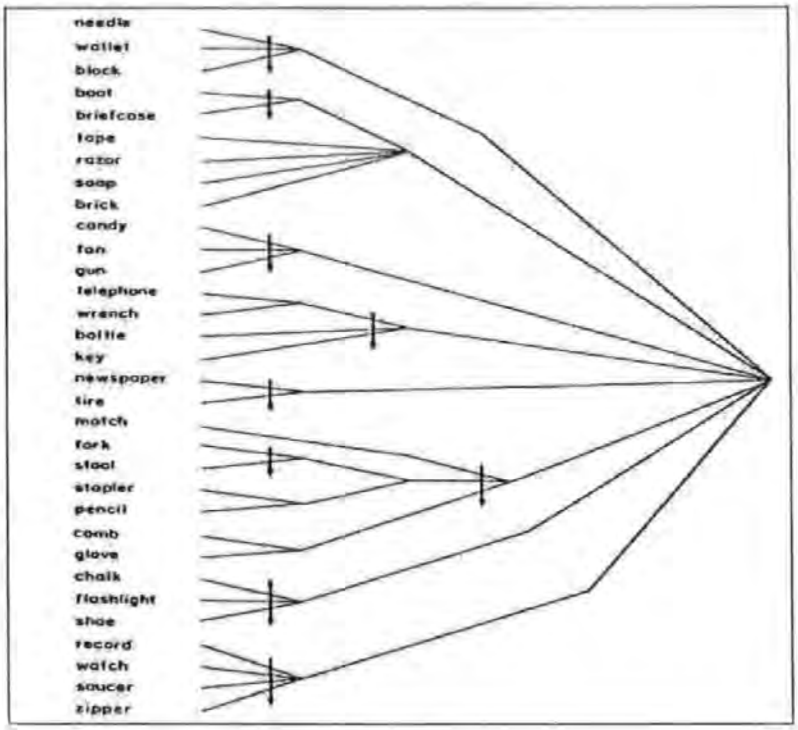


Participants' memories were then tested using recognition tasks, free recall, and Euclidean distance estimation.

In the recognition task, names of objects were displayed one at a time on a computer screen. The participant's task was to decide as quickly as possible whether or not the object had been in the space just learned. It was found that participants recognised an object name faster when it was immediately preceded, or primed by the name of a neighbouring object than when it was primed by the name of a distant object. In the free recall task, McNamara et al. (1989) had participants recall all of the objects several times. This task yielded several protocols for each participant and each spatial layout. These recall protocols were submitted to an ordered-tree algorithm, which attempts to produce trees consistent with the order in which object names were recalled. The ordered tree algorithm was developed to represent regularities in free recall data. After memorising a fixed set of items, subjects are asked to repeatedly recall the material. No restrictions are placed on the order of recall. The input to the algorithm consists of the recall protocols generated by a subject. The output of the algorithm is a hierarchical tree structure, referred to as an "ordered tree". The items are the leaves on the tree, and the internal nodes can be one of three kinds: uni-directional, bi-directional and non-directional. Uni-directional nodes indicate that the branches are always recalled in a single order, bi-directional nodes indicate that the branches are always recalled in a single order or its inverse, and non-directional nodes represent all other cases. Figure 1.5 shows an ordered tree for one of the subjects after memorising items contained in Figure 1.4.

The tree displayed in Figure 1.5 specifies that "boat" and "briefcase" formed a cluster in memory. These objects were a sub-cluster of a larger cluster that also contained "tape, razor, soap, and brick". Different sub-trees presumably corresponded to different subjective regions of the psychological space.

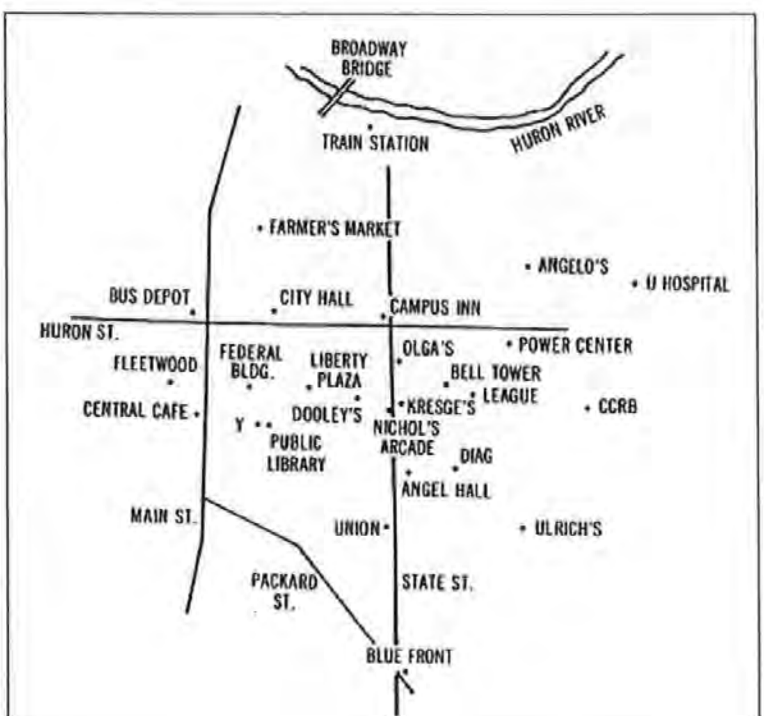
Figure 1.5: An example of an ordered tree for one of the subjects (Illustration adapted from McNamara, Hardy, and Hirtle (1989).



For example, in the tree in Figure 1.5, "needle" and "wallet" are in the same subjective region, whereas "needle" and "boat" are in different subjective regions. Thus, "boat" and "briefcase" as well as "boat" and "tape" were classified as being in the same subjective region. It was found the mean response time for target objects primed by an object in the same subjective region was 659 msec (e.g., needle-wallet), and the mean response time for target objects primed by an object in a different subjective region was 712 msec (e.g., boat-wallet). Pairs of objects were selected so that the actual inter-object distance was the same regardless of whether the objects were in the same subjective region or in different subjective region. It was found the mean distance estimates were 0.91 cm for same region pairs and 3.4 cm for different region pairs (the actual distance was 3.8 cm).

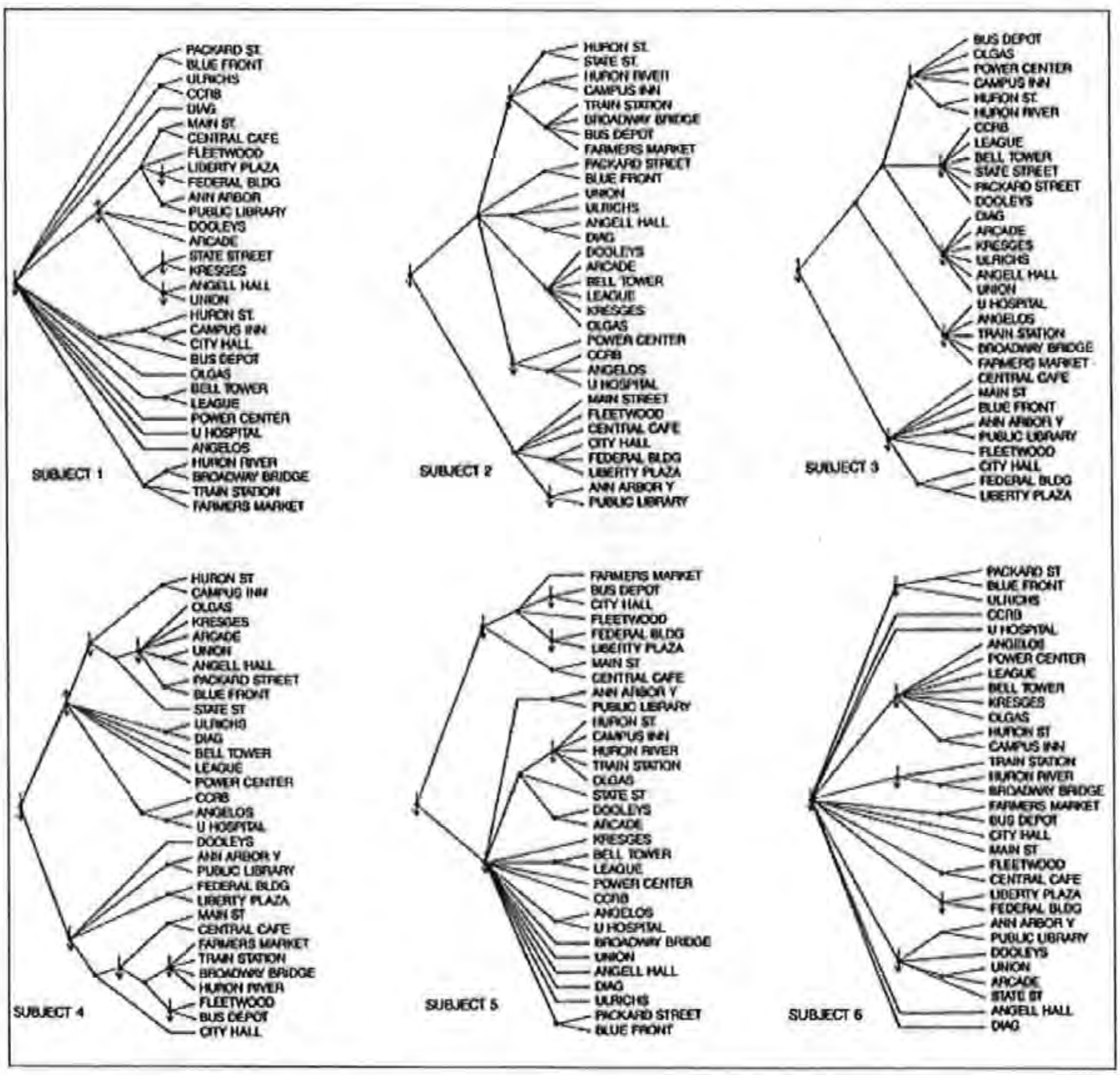
Hirtle and Jonides (1985) extend these results to real world locations, i.e., at the level of landmarks in Ann Arbor City, Michigan. They asked students to memorise landmarks in central Ann Arbor so that they would be able to recall the names and to draw maps locating each landmark (the map of central Ann Arbor indicating the relative locations of landmarks is shown in Figure 1.6). Participants then took part in several tasks, including multiple-trial recall, map drawing and distance estimation. Recall protocols from individual subjects were submitted to the ordered-tree algorithms. There were two distance judgement tasks. In the first task, participants were shown the names of two locations, in sequence, and indicated whether the distance between the two locations was larger or smaller than a standard distance. The second task was a magnitude estimation task. Participants gave a distance estimate, from 1 to 100, for the distance between two locations.

Figure 1.6: Map of Central Ann Arbor (Illustration taken from Hirtle & Jonides, 1985)



Hirtle and Jonides were able to isolate subjective regions of the campus by examining which landmarks were clustered together in hierarchical trees. There was similarity in recall strings across participants, which suggests there is similarity in memory representation of the campus and town (see Figure 1.7).

Figure 1.7: Individual ordered trees derived from the recall data of each subject (Illustration taken from Hirtle & Jonides, 1985).



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

The categorisation of space can be easily extrapolated to the case of route knowledge organisation. Previous studies (Allen, 1981; Allen & Kirasic, 1985; Hirtle & Hudson, 1991) have shown that during the acquisition of route knowledge individuals tend to organise their experience into distinct segments and that these segments influence subsequent judgements of distances.

In Allen's (1981) study, subjects viewed a series of 60 colour slides depicting a 1-km walk that extended through several different types of scenery including a wooded park, a university campus, and several residential areas. Slides portrayed viewpoints separated by 20 m. At turns, the view provides 50% overlap of visual fields in successive slides. Slides were projected at a rate of 5 sec. each. All participants viewed the presentation twice. After they had viewed the slide presentation twice their knowledge was tested using distance judgements. A typical question was "if you were standing along the walk where you could see this scene (reference scene) would you be close to where you could see this scene (a comparison scene) or closer to where you could see this scene (another comparison scene)?" The most important result was that participants were able to make accurate decisions regarding which of two comparison scenes was nearer a reference scene when all three scenes were within a common route segment. However, they grossly distorted their estimates of proximity when the nearer comparison scene was in a route segment adjacent to the one in which the reference scene and more distant comparison scene were located. In such cases, the comparison scene within the same segment was reliably judged to be closer to the reference point, even though it was up to three times the distance from the reference point to the comparison scene in the adjacent route segment.

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

1.3.2. Reference Points

The theory of acquisition of spatial knowledge maintains that we first learn relative locations of landmarks, then we learn routes between them, and finally we fill in survey information. However, it has been found that some landmarks appear to distort the space around them (Holding, 1992; Sadalla, Burroughs, & Staplin, 1980). For example, it was reported that some types of inter-landmark distance judgements are not symmetrical (McNamara & Diwadkar, 1997; Moar & Bower, 1983; Moar & Carleton, 1982; Sadalla, Burroughs, & Staplin, 1980).

Sadalla et al. (1980) initially asked students to give ratings for familiarity, visibility from a distance, dominance of nearby places, and historical and cultural importance, for a set of locations on the Arizona State campus. The sum of the ratings gives each location a gradient of salience. Reference points were identified as locations on and around the Arizona State campus that were visited often, were well known, and were historically and culturally important. For example, within the Arizona State campus the students' union is highly salient as compared to the architecture building. In the experiment Sadalla et al. asked participants to estimate distances between pairs of campus locations, using either a reference point or a relatively unknown location as referent object. They gave participants response sheets, each of which consisted of a semi-circular grid with a location name printed at the origin. The participants were asked to place a second name on the grid at the point that best represented the distance between the two locations. The results showed that on average participants placed the ordinary landmark closer to the salient landmark when the latter was fixed at the origin of the grid than when the ordinary landmark was fixed at the origin. That is, distance estimates were significantly smaller, on average, when the salient landmark (e.g., the students union) was fixed at the origin than when the ordinary landmark (e.g., the architecture building) was fixed at the origin. Sadalla et al. concluded that, "… the cognitive distance between reference points and non reference points is asymmetrical" (p. 475). They argued that asymmetries in estimated distances were caused by how spatial memories were organised, and noted in particular that their study could not determine whether asymmetries were caused by how distances were mentally represented or by how they were estimated.

The demonstration by Sadalla et al. of the existence of the asymmetry serves as basis for the investigations into the retrieval process considered as a possible explanation for the phenomenon. The issue of the retrieval process is examined in detail in Chapter 2 of this thesis. As we will see later on in Chapter 3 of this thesis, the experiments to be reported aim to find an answer to why retrieval processes particularly play a central role in biases in distance estimation. We attempt to establish the contextual effects that trigger action-based representations during distance estimation processes.

The existence of the asymmetry effect is an obvious violation of metric properties of cognitive maps. In addition, a Euclidean model could not explain the influence of the structure of the environment on distance estimations. It is to this issue we now turn.

1.3.3. Influence of Structure of the Environment

Previous studies have shown that route complexity influences the estimations of distances.

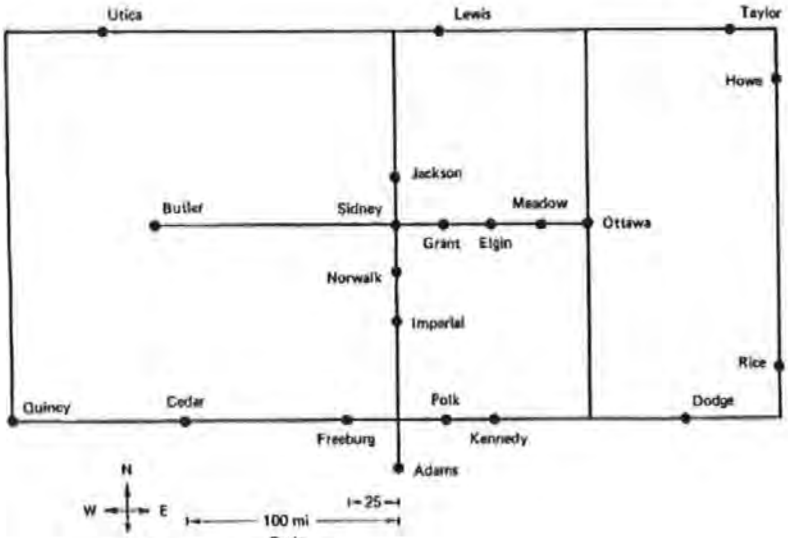
Byrne (1979) asked participants to give estimations of route lengths for routes in urban or rural settings of 300m, 500m, or 750m. Routes were straight or had 2-4 turns. Byrne found significant effects for all three independent variables. Rural routes were judged longer than urban routes. Straight routes were judged shorter than cornered or angled routes. Shorter routes were overestimated in comparison to longer routes. Additionally, when asked to draw road junctions on a piece of paper (true junction angles varied from 60-70 degrees or 110-120 degrees), the result showed that most estimates, for both conditions, were closer to 90 degrees.

For both small-scale (laboratory setting) and large-scale environments (field setting), Sadalla and Staplin (1980a) found that routes containing more intersections are consistently estimated as being longer than routes (of equivalent objective distance) with fewer intersections.

For traversed routes, the perception of route length is influenced by the number of turns that are distributed along the routes. Sadalla and Magel (1980) asked participants to walk two pathways that were laid out with masking tape on the hallway floors of a building. The two pathways each measured 200-foot in length and contained respectively 2 and 7 right angle turns. Immediately after completing the walking task, participants were asked to make distance estimations. Their final task was to draw the paths. Sadalla and Magel found that the path with 7 turns was systematically estimated as being longer than the path with 2 turns; the path with 7 turns was also drawn significantly longer than the path with 2 turns.

Thorndyke (1981) asked participants to learn maps containing city names (the spatial layout of map is shown in Figure 1.8). The routes between the points contained varying numbers of intervening cities (0, 1, 2, or 3). The cities in each pair lay along a route that required no turns. The inter-city distances were 100, 200, 300, 400 miles. Participants studied maps until they learned the positions of the cities in it. After that, they were asked to estimate the distance between pairs of cities.

Figure 1.8: Map of the environment used in the experiment (Illustration taken from Thorndyke, 1981).



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

The findings reviewed in this section suggest that bias in distance estimation occurs independently of the scales of environments studied. Whether in laboratory settings (Sadalla & Magel, 1980), real world settings (Byrne, 1979; Sadalla & Staplin, 1980a), or map settings (Thorndyke, 1981), a general principle in distance estimation seems to emerge with regard to distance lengths; short distances tend to be over-estimated whereas longer distances tend to be under-estimated. There is also a "clutter" effect on distance estimation; environments or routes containing more information or attributes (cities, turns, or intersections), are judged as being longer than environments or routes with less information.

In addition to the clutter effect, distance estimation is also influenced by the contexts of learning. Factors such as goals during learning about the environment, or modes of learning, all contribute to bias in distance estimation. These are the issues we examine in the next section.

1.3.4. Learning Contexts

Thorndyke and Hayes-Roth (1982) reported that knowledge acquired from studying maps is different from knowledge acquired from navigation. They compared participants who had navigational experience in a building but had never seen a map of that building, to those who had seen a map of the building but had never been in it. The participants who had navigational experience were employees who worked in the building. They were separated into three groups depending on their time of exposure to the building (1-2 months, 6-12 months, 13-24 months). The participants who studied the map were psychology students and they were split into three groups; they were asked to study the map of the building until they could recreate the map without error. The first group's exposure to the map was stopped at this point, while the second group received 30 more minutes to study the map and the third group an additional 60 minutes. All participants performed five judgements:

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

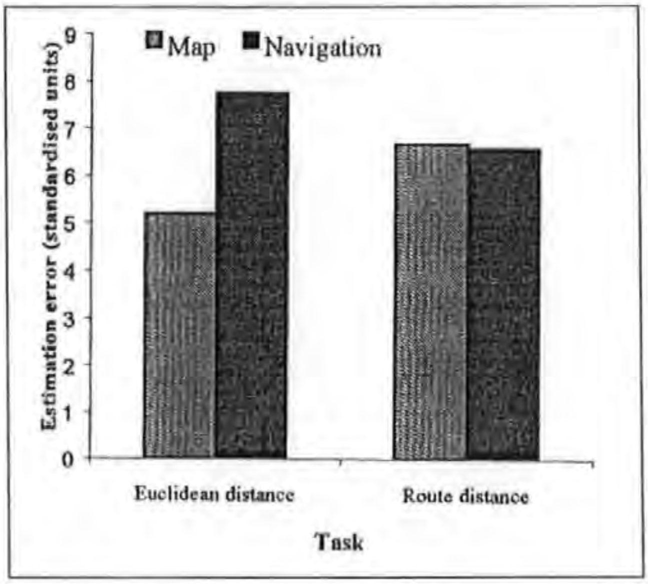
The results showed no difference in performance between the map study groups; all participants made larger errors in route distance estimation than Euclidean distance estimation. In contrast, all participants in the navigation condition made larger errors for Euclidean distance than for route distance estimations. The navigation group that had only 1-2 months experience had greater Euclidean distance judgement errors than those who had longer exposure to the environment. For orientation and simulated orientation tasks, the navigation subjects were more accurate than the map subjects. The navigation group with the most experience overall, performed better than any of the other groups.

These findings indicate that the knowledge acquired by studying a map of an environment is different from the knowledge acquired by navigating through that same environment. According to Thorndyke and Hayes-Roth, map learners acquire a bird's eye view of the environment that encodes survey knowledge. When using this knowledge to perform spatial judgements, individuals have direct access to the knowledge required to estimate Euclidean distances and judge object locations. Through navigation, people acquire procedural knowledge, i.e., the sequential record of the space between start points, subsequent landmarks and destinations. When individuals use only this knowledge to perform spatial judgements, performance is limited by the necessity to derive judgements through computation on the encoded sequences of this knowledge.

More recent studies have examined the influence of goals on spatial memory (Gauvain & Rogoff, 1986; Magliano, Cohen, Allen, & Rodrigue, 1995; Taylor & Naylor, 2002; Taylor, Naylor, & Chechile, 1999).

Taylor and Naylor (2002) examined the influences of perspective-based goals (route or survey) and learning conditions (navigation or map) on the representation of distance. They used the first floor of the Psychology Research Building, Tufts University as the environment. Participants learned the environment by either navigating or studying a map of the building. Participants were randomly assigned to four experimental conditions: (1) navigation-route goal, (2) navigation-survey goal, (3) map-route goal, and (4) map-survey goal. Navigation instructions asked participants to explore the building, while map learning instructions asked participants to study a map of the building. Route goal instructions asked participants to learn the fastest routes between rooms. Survey goal instructions informed participants that they had to learn the layout of the building. After receiving the instructions participants studied the environment (map or navigation) for a minimum of 10 minutes and a maximum of 20 minutes. It was found that overall participants gave more accurate route distance estimates than Euclidean distance estimates. For the learning condition, participants who navigated gave more accurate route distance estimates than map learners; the latter group gave slightly more accurate Euclidean distance estimates than the navigation group (see Figure 1.9). For the spatial goal condition, participants with a route goal gave more accurate route distance estimates, while participants with a survey goal gave equally accurate estimates for both route and Euclidean distances.

Figure 1.9: Comparison of Euclidean and Route distance estimates (Illustration taken from Taylor & Naylor, 2002).



Taylor and Naylor (2002) also examined performance on a route description task. Participants were asked to describe a route within an environment. Route descriptions were then coded for the number of landmarks (rooms, doorways, stairs, hallways), the number of spatial terms (terms providing locative information), and the overall number of words. It was found that participants given a route goal used more spatial terms than participants given a survey goal. Additionally, participants with route goals included more information (landmark information and spatial terms) in their descriptions than participants with survey goals.

In summary, we have seen in this section that the different ways in which space is processed and represented impact upon spatial judgements. Spatial knowledge gained through navigation results in procedural knowledge that is more efficient particularly in route distance estimations, whereas knowledge acquired by studying maps of the environment results in survey knowledge that is more efficient particularly in Euclidean distance estimations. Furthermore, both learning condition and spatial goal influence the representation of spatial perspective through language, i.e., in route descriptions.

Route description constitutes the second variable of interest in this thesis, and will be examined in detail in Chapter 2. We will report in Chapter 3, four experiments that examine biases in distance estimations and the difference in the use of spatial terms in route descriptions as a function of how individual landmarks are primed or cued prior to the judgement and description tasks.

The results from the research reviewed so far suggest that the essence of much of the above work is that space is categorised into regions, and this has an effect on judgements depending on whether the elements involved in these judgements lie within the same or different regions. In addition to the structural complexity of the environment, we have also seen the influence of contexts of learning on distance estimation and route description. Most interestingly, we have seen that some types of inter point relations between landmarks are not symmetric. Several lines of research have suggested that the asymmetrical distance effect is due not to the encoding of distance or how distance has been estimated but to the processes of retrieving spatial information from memory (Holyoak & Mah, 1980; Huttenlocher, Duncan, & Hedges, 1992; McNamara & Diwadkar, 1997). These models are examined in detail in Chapter 2.

For the rest of this chapter we focus on the issue of what cognitive maps are for. As Marr (1982) articulated most clearly in the case of vision, the most important level of explanation required of a process (such as vision) is to ask what that process is for (what Marr termed the computational theory level of explanation). In the case of navigation, we daily experience numerous situations in which we have to find our way travelling in spatially complex environments. In this context, cognitive maps are for enabling us to recognise important places in an environment and enabling us to physically move around and interact with the environment. Therefore one of the main functions of cognitive maps is to facilitate action. So rather than seeing cognitive maps as being abstract representations of the environment, we would like to argue that they are at least partially action-based representations.

However, the mapping between cognitive maps and action has been a neglected topic in the literature on environmental knowledge. Indeed, there is much evidence from the embodied cognition literature arguing for a direct link between mental representation and action. It is the aim of this thesis to examine empirically the direct relationship between spatial representation and action. We will report in Chapter 5 three experiments that directly manipulate the influence of action on distance estimation. In the next section we will review the evidence to show that the relationship between action and representation exists across a range of domains.

1.4. Embodied Cognition

1.4.1. Overview

What does it mean for cognition to be embodied? The word "embodied" refers to the body we have and the world we interact with; i.e., our knowledge comes from the world through our body. The implication of embodied cognition is that the body and the world in which it interacts is directly linked. Many theorists have suggested that perception and action in the real world form the foundations of cognition (Barsalou, 1999; Glenberg, 1997). Furthermore, several programs of research in the past provide support for the embodiment view.

Glenberg (1997) argues that the traditional approach to memory as "for memorising" needs to be replaced by a view of memory as "the encoding of patterns of possible physical interaction within a three-dimensional world" (1997, p. 1). Importantly, the action-based meaning of an object depends on context and past experience. For example, consider how a situation (e.g., a room with a chair) could be meaningful to a person. Glenberg sees the meaning of the situation as consisting of the set of actions available to the person in the situation. The set of actions results from meshing (i.e., smoothly integrating) affordances to accomplish action-based goals. Affordances are potential interactions between bodies and objects (Gibson, 1979; Tucker & Ellis, 1998). Thus a chair affords sitting for adult humans, but not for mice or elephants, who have the wrong sort of bodies to sit in an ordinary chair. If the human has the goal of changing a light bulb, the meaning of the situation arises from meshing the affordances of a light bulb (it can be held in the hand) with the affordances of the chair (it can be stood on to raise the body) to accomplish the goal of changing the light bulb. However, cognition or the conceptualisation of the world in terms of possible actions is "clamped" to or controlled by current environmental stimulation. For instance, my current understanding of the cup, something that I can grasp, lift up, and use as a container, meshes perfectly with my memories of undertaking those actions with that cup. In other words, the meaning of the cup is fleshed out by memories of my previous interactions with it: pouring in coffee and drinking from it.

Several programs of research support the embodiment interpretation. As we reviewed in Section 1.3.1 (McNamara, 1986; McNamara, Hardy, & Hirtle, 1989), work on spatial representation gave evidence that spatial memory is hierarchically structured. Objects in the same physical region of space are closer in memory than objects in different regions, even if the intra-region and inter-region Euclidean distances between object pairs are equal. The hierarchical structuring implies that the representation of space is not Euclidean. As such, the influence of meaning on the hierarchical structuring of mental representations supports the embodiment approach to spatial cognition.

In Bryant, Tversky, and Franklin (1992), participants read about and memorised spatial layouts corresponding to scenes viewed from particular perspectives (e.g., in a hotel scene, "To your left...you see a shimmering indoor fountain..."). Objects were located above, below, in front of, in back of, to the left of, and to the right of the observer in the imagined scene. After the scene was memorised, the time taken to retrieve a particular object was measured. It was found that the fastest responses were to objects located on the head/feet axis, followed by the front/back axis followed by the left/right axis. Bryant et al.

(1992) interpreted these differences as reflecting asymmetries of the body. In other words, retrieval processes appear to be sensitive to how we use our bodies.

As embodied cognition is a pattern of possible actions that incorporate information about spatial layout (Glenberg, 1997), the models that explain the hierarchical coding of distance (McNamara, 1986; McNamara, Hardy, & Hirtle, 1989), and the models that explain the time to retrieve spatial information reflecting the asymmetries of the body (Bryant, Tversky, & Franklin, 1992) are embodied mental models. Most importantly, embodied mental models reflect a structured space, a space structured by possible actions. The bodily interaction in the environment is an important factor in the build up of spatial knowledge. We will now look at how actions are represented.

1.4.2. Representation of Action

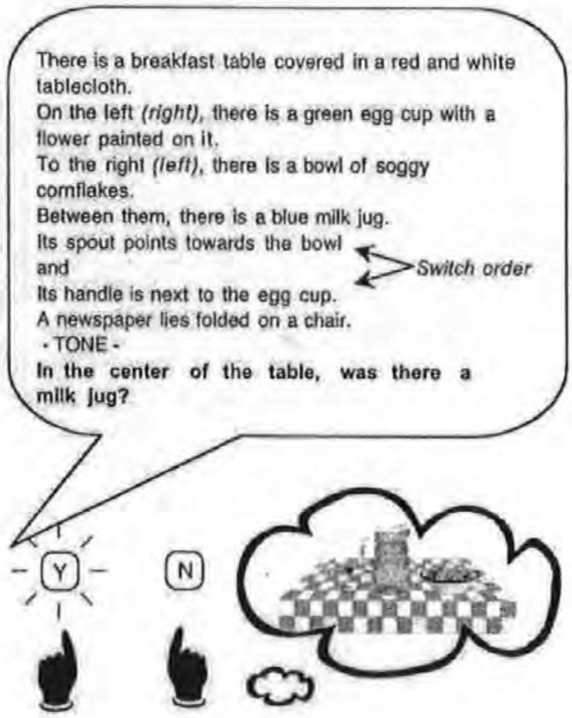
Recent studies have shown that the representation of action or motor representations shares the same neural mechanisms as those that are also responsible for preparing and programming of actual movements (e.g., Decety, 1991; Decety, Jeannerod, & Prablanc, 1989).

Decety et al. (1989) conducted two experiments on a running track in an outdoor stadium. Three white marks (30 cm x 20 cm) were traced on the ground. The targets were located 5 m apart from each other. The starting position on the track was such that the distance from the targets could be either 5, 10, or 15 meters. Starting positions were varied from trial to trial. Relevant to the present study was Decety et al.'s second experiment in which participants carried a rucksack containing a heavy load (25 kg weight) on their shoulders. Decety et al. gave participants specific instructions for using a mental imagery strategy during the experiments. Participants were allowed to look for 5 seconds at one of the targets; then they were blindfolded. After another 5 sec delay, they were requested either to walk at a normal pace to the target and to stop when they thought they had reached its location (actual walking condition), or to imagine themselves walking to and stopping at the target (mental walking condition). Walking times were measured in both the actual and the mental walking conditions. It was found that it took about 30% longer for the participants carrying a 25 kg load to walk mentally towards the targets than actually to perform the task. According to Decety et al., when participants carried the load they programmed centrally a greater force to overcome the resistance. In the actual walking task this increase in force resulted in maintaining the same speed as without load. By contrast, in the mental walking task the increase in encoded force was not used to overcome the resistance due to the load, and was interpreted as an increase in duration of the action. Additionally, the exaggerated sensation of effort reported by the participants in the mental walking task may be interpreted as a subjective correlate of the increased effort specified by the program in order to overcome the weight.

Research within the Stimulus-Response compatibility paradigm has shown that there is a tight coupling between perception and action, i.e., that motor systems can participate in what were once thought to be purely perceptual tasks. For instance, in Experiment 1 of Tucker and Ellis (1998), participants made an orientation judgement (right-side-up/upside-down) about pictures of household objects such as a coffee mug, frying pan, etc. Each object had an affordance- a handle - on the right or the left side. It was found that subjects were faster when they responded using the hand that was on the same side as the affordance. Later work (Ellis & Tucker, 2000) found a similar compatibility effect when subjects signalled a judgement about an object with a motor action (precision pinch/power grip) that was appropriate or inappropriate for that object. This work demonstrated a tight coupling between visual and motor systems: the perception of a graspable object immediately activates a potential motor interaction with that object, even though the affordance is irrelevant to the perceptual judgement. In other words, this is evidence of a direct link between visual perception and motor systems whereby the representation of objects is not merely visual, or an amodal list features, but has a motor component that is just as much part of the object.

Richardson, Spivey, and Cheung (2001) using purely linguistic materials extend Ellis and Tucker (2000)'s finding. Richardson et al. (2001) first constructed rich scene descriptions (24 short scene descriptions and questions). Each scene included a description of an object with an affordance and specified the orientation of that object by reference to surrounding items. First there was a sentence or two conveying the background scene, for example, a breakfast table. Two items, one on either side of the scene, were then described. These items were termed "anchor" objects. Figure 1.10 illustrates the structure of an example of a critical trial.

Figure 1.10: Schematic of a critical item (Illustration taken from Richardson, Spivey, & Cheung (2001).



In Figure 1.10, the anchor objects are a bowl of corn-flakes and an eggcup. Then a third object was mentioned. This was the critical item, an object with an affordance and located between the two anchors. Then two phrases specified the orientation of the critical item. They linked a feature or affordance of the critical object with each of the anchors.

Participants were randomly assigned to a response mapping condition. In the left condition, participants responded "yes" by pressing the "S" key and "no" by the "K" key. In the right condition, this mapping was reversed. Participants heard a short scene description (of the type described above) played over a set of headphones. At the end of each description, participants heard a one second tone and then a question concerning the previous information. They were instructed to give their response as quickly and as accurately as possible. The most important result was the significant interaction between hand and stimulus; RT was faster when response hand and object affordance are compatible. This work showed that visual memory of an object can activate a motor representation, indicating that the motor system can be activated not just by objects that are actually seen but also by those that are imagined.

Glenberg and Kaschak (2002) report data that support an embodied theory of meaning and they present the indexical hypothesis (IH) that relates the meaning of sentences to human action.

They asked participants to judge whether sentences were sensible by making a response that required moving toward or away from their bodies. Participants were presented with a series of sensible and nonsense sentences and they were asked to determine as quickly as possible whether each sentence made sense. Toward sentences such as "open the drawer" implied action toward the body, away sentences such as "close the drawer" implied action away from the body. Nonsense sentences such as "boil the air" did not seem to imply any direction.

According to the IH, meaning is action-based: understanding a toward sentence requires meshing affordances (e.g., of a drawer and the action of opening), resulting in a simulation of actions toward the body, whereas understanding an away sentence results in a simulation of actions moving away from the body. If this simulation requires the same neural systems as the planning and guidance of real action, understanding a toward sentence should interfere with making a movement away from the body, and understanding an away sentence should interfere with making a movement toward the body.

The most important result was the significant interaction between response direction and implied sentence direction. The away sentences were read faster in far condition than in near condition; the toward sentences were read faster in near condition than in far condition. The action sentence compatibility effect was found for imperative sentences (open versus close the drawer), concrete transfer sentences (Courtney handed you the notebook versus you handed Courtney the notebook), and abstract transfer sentences (Liz told you the story versus You told Liz the story).

These results confirm that merely understanding a sentence can facilitate or interfere with a physical response, showing evidence that language understanding taps into an action-based system. Understanding a sentence calls upon the same cognitive mechanisms as those used in planning and taking action. Hence, when the implied direction of the sentence contrasts with the actual response direction, there is interference.

The results from the research reviewed in Section 1.4 indicate that motor activation can occur as part of a cognitive process. The representation of a visual stimulus, generated from pictures or from purely linguistic descriptions accessed from memory, can activate potential motor interactions. Furthermore, understanding a sentence may call upon the same cognitive mechanisms as those used in planning and executing actions. We also have seen that the processes underlying mental movements within visually represented space are similar to those underlying actual movements.

1.5. Summary

Previous studies have suggested that space is categorised into regions, and this has an effect on judgements depending on whether the elements involved in these judgements lie within the same or different regions. In addition to the structural complexity of the environment, the contexts of learning also influence distance estimations and route descriptions. The processes of retrieving spatial information from memory could explain some biases in distance estimation. However it is not quite clear why the retrieval effects are present. One possibility that the present thesis attempts to investigate is that biases in distance estimation and route description are a function of retrieval processes that trigger action-based representations that selectively activate relevant information used during the estimation tasks.

The evidence that indicates that motor activation can occur as part of a cognitive process shows the influence of action in the build up of spatial knowledge. The internalisation of action was demonstrated in several domains of research. For instance, research in visual perception indicates that the representation of a visual stimulus, generated from pictures or from purely linguistic descriptions accessed from memory, can activate potential motor interactions between bodies and objects. In the linguistic domain, understanding a sentence calls upon the same cognitive mechanisms as those used in planning and executing actions. In physical space, the processes underlying mental movements are similar to those underlying actual movements. The role of action is directly manipulated in the present thesis. The direct manipulation of action on distance estimation will give an insight into whether spatial cognition is similarly embodied.

1.6. Précis of the Thesis

It should have become apparent by now that the bodily interaction in the environment is a fundamentally important factor in the build up of spatial knowledge. The pattern of possible bodily actions that incorporated information about spatial layouts indicates that motor representation readily participates in perceptual tasks. It is therefore of most interest to consider an approach to cognitive maps and particularly the investigation into bias in distance estimation using the embodiment framework. It is within the framework of embodied cognition that the present thesis is carried out using distance estimation and route description as dependent variables. The focus of this thesis concerns the influence of contexts of retrieval and the role of action on distance estimation and route description.

The organisation of the thesis is as follows. To set the scene, Chapter 2 examines three models that explain the asymmetry in distance estimation, the implicit scaling model (Holyoak & Mah, 1982), the category adjustment model (Huttenlocher, Duncan, & Hedges, 1992), and the contextual scaling model (McNamara & Diwadkar, 1997).

In Chapter 3, we will focus on the effects of using different contexts to prime or cue landmarks prior to distance estimation and route description. Four experiments that directly manipulate the priming contexts will be reported. The experiments use structured interviews and questionnaires that reflect naturally realistic situations. It will become clear in Chapter 3 that biases in distance estimation and the use of spatial expressions are a function of how individual landmarks are primed or cued prior to the evaluation and description tasks. The cueing of landmarks establishes a cognitive context that selectively activates the relevant information from memory for distance estimation and route description. For instance, an action-based context selectively activates route-based spatial representations, whereas a more abstract context selectively activates survey-based spatial representations.

The representation of action in memory is considered in Chapter 4 when we go to examine how it influences distance estimation. To pin down the influence of action on distance estimation, Chapter 5 reports three experiments that manipulate action directly with visual information strictly controlled. The methodology uses rich scene descriptions depicting spatial relations between landmarks. Routes between landmarks are experienced through mental walks. It will become clear in Chapter 5 that action is integrated into memory shown in the difference between distance estimates before and after performing the action.

Finally, Chapter 6 discusses the findings of this research in the context of current debates on embodiment. We will also address the limitations of the research described in this thesis and make some suggestions for further research.

2. CHAPTER 2: CONTEXT EFFECTS ON RETRIEVAL

2.1. Introduction

The aim of this chapter is to consider in more detail retrieval processes as explanations for errors and asymmetries in distance estimation. We suggest a new possibility that the contexts of retrieval can cue action-based representations that subsequently influence distance estimation. Additionally, we examine the potential influence of the contexts of retrieval on route description. These issues formed the basis of the rationale for the experiments reported in Chapter 3.

First let us examine retrieval processes as explanations for errors and asymmetries in distance estimations.

2.2. Retrieval Processes

There are three main types of models focusing on retrieval processes, which can account for some of the distortions and asymmetries in distance estimation. But firstly let us examine in detail the important points of the Sadalla, Staplin, and Burroughs (1980)'s study that we briefly reviewed in Chapter 1 (Section 1.3.2).

Sadalla et al. (1980) initially asked a group of students to give ratings on three 9-point scales for the number of visits to a place, the knowledge of the place's location, and the historical and cultural importance of the location, for a set of locations on the Arizona State campus. By summing the score of each location over the three dimensions, an overall environmental salience score was constructed for each location. Reference points were identified as locations on and around the Arizona State campus that were visited often, were well known, and were historically and culturally important; for instance, within the Arizona State campus the students' union is highly salient as compared to the architecture building. Therefore, the students' union is considered as a reference point whereas the architecture building is considered as a non reference point. Sadalla et al. then selected a series of reference points and non reference points to be used as experimental pairs of stimuli for spatial judgements. Subsequently, Sadalla et al. asked another group of participants to estimate distances between pairs of campus locations, using either a reference point or a relatively unknown location as referent object. To measure participants' responses, Sadalla et al. gave participants response sheets, each of which consisted of a semicircular grid. The grid was composed of semicircular lines 1.2 cm apart; a location name was printed at the origin of the grid. The participants were asked to place a second name on the grid at the point that best represented the distance between the two locations.

The results showed that subjects on average placed the ordinary landmark closer to the salient landmark when the latter was fixed at the origin of the grid than when the ordinary landmark was fixed at the origin. As an example, the distance from the students' union towards the architecture building is smaller than the distance between the architecture building towards the students' union. Sadalla et al. concluded that, "... the cognitive distance between reference points and non reference points is asymmetrical" (p. 475), and that asymmetries in estimated distances were caused by how spatial memories were organised. They noted however that their study could not determine whether asymmetries were caused by how distances were mentally represented or by how they were estimated.

Now let us turn to the Implicit Scaling Model. A study by Holyoak and Mah (1982) suggested that asymmetrical distance effects are a product of a distorted representation and biased processing.

2.2.1. Implicit Scaling Model

Holyoak and Mah (1982) asked participants to judge the relative closeness of two American cities. The cities used in the experiment are situated on an imaginary straight line linking the West Coast to the East Coast (Figure 2.1). Those cities are San Francisco, Salt Lake City, Denver, Kansas City, Indianapolis, Pittsburgh, and New York City.

There were two tasks. The first task was to judge which of two cities was closer to a given perspective, and the second task was to estimate the distance between two cities. Three groups of participants were used. One group of participants were asked to imagine themselves on the East Coast (Atlantic perspective) when making judgements, a second group of participants to imagine themselves on the West Coast (Pacific perspective) when making the judgements, and a third group of participants were given no specific perspective.

Figure 2.1: Map of United States of America Cities (Illustration adapted from *www.worldatlas.com/webimage/countrys/namerica/usstates/artwork/points/major.htm)*.

The results showed a perspective effect; for example, participants from the Pacific Ocean perspective were faster to judge that San Francisco was closer to the Pacific Ocean than Salt Lake City to the Pacific Ocean than participants from the Atlantic Ocean perspective. Participants also exaggerated the distances between cities that were closer to their perspectives, whereas the distances between cities farther from their perspective were underestimated. For example, the distance between San Francisco – Salt Lake City from the perspective of the Pacific Ocean was judged larger as compared to the distance between Pittsburg – New York City from the perspective of the Pacific Ocean.

Holyoak and Mah suggested an implicit scaling process to explain why there were perspective effects. The crucial assumption of the Implicit Scaling Model (ISM) was that landmarks and ordinary locations evoked representations in working memory that have different implicit scales, i.e., landmarks may activate more locations or more distant locations (or both) in memory than non-landmarks, thereby reduced discriminability between locations. It follows that when participants were asked to make a series of judgements about pairs of remembered locations, in each case they evaluated "how close A is to B", B served as the standard to which A was being compared. During the estimation, a range of locations were called to mind by the two stimuli, especially the standard location B. The information about the stimulus properties was then scaled by the context in which the retrieval takes place. When a landmark established the context, the subjective range of the implicit scale will be larger than when a non-landmark established the context, and the discriminability between locations will be reduced. As a consequence, the distance from landmark to non-landmark was smaller than from non-landmark to landmark.

How could the implicit scaling process be used to explain the asymmetrical distance effect found by Sadalla et al.? It could be used as follows.

As a cognitive reference point is a location with respect to which many other locations have been coded, when presented as the standard it will trigger recall of more locations (near or distant, or both) into working memory. Therefore, the subjective stimulus range will tend to be greater when a reference point is presented as a standard rather than an ordinary location. Since a large implicit scale will yield reduced discriminability, the distance from a non reference point to a reference point will be smaller than the distance from a reference point to a non reference point.

2.2.2. Retrieval-Bias Model

Huttenlocher, Hedges, and Duncan (1991) suggested another model. The retrieval-bias model posits that location is encoded at two levels of detail, a fine-grained level and a categorical level.

According to Huttenlocher et al. (1991) people performing spatial estimation combine inexactly represented fine-grain locations with categories. This process produces a characteristic pattern of bias across a category towards the category centre. Indeed when asked to reproduce the location of a dot in a circle from memory, participants produced angular and radial bias toward the center of mass of the quadrants. Participants seemed to impose quadrants on the circle by dividing it along the horizontal and vertical axes. Huttenlocher et al.'s model posits that the dot location is encoded hierarchically – at fine-grain and category levels. The fine-grain level consists of an inexact but unbiased representation of the dot's location in terms of polar coordinates. The inexactness comes from imprecise encoding or loss of precision in memory. The category level consists of the quadrant of the circle where the dot was located, and the information at this level is exact. According to the model, the inexact fine-grain representation is combined with category level information in forming estimates of location.

How could the retrieval-bias model be used to explain the asymmetrical distance effect found in Sadalla et al.?

A reference point is a location with respect to which many non-reference points or ordinary locations have been coded. In a situation in which the distance is estimated between a reference point and a non reference point, on each trial, one item is fixed at its true location and the location of the other object must be retrieved from memory. When the non-reference point's location must be retrieved from memory, the memory report will be biased toward the fixed reference point. However, when the reference point's location must be retrieved from memory, the memory report will be unbiased. The reported distances will be underestimated when the reference point is fixed relative to when the non-reference point is fixed. This is the pattern obtained by Sadalla et al.

According to Huttenlocher et al. the asymmetrical distance effect is a conceptual process arising after the encoding of distances.

2.2.3. Contextual Scaling Model

McNamara and Diwadkar (1997) reported a series of experiments in which they probed the nature of the asymmetry distance effect, and evaluated the ability of existing models (e.g., implicit scaling, and retrieval-bias model) to account for them, and proposed an alternative model of why spatial estimation may be asymmetric.

McNamara and Diwadkar noted that in the retrieval-bias model (Huttenlocher, Hedges, & Duncan, 1991), when both landmark and non-landmark had to be retrieved from memory, asymmetries would not be expected. Indeed, the retrieval of the landmark will be unbiased, whereas the retrieval of the non-landmark will be biased toward the landmark, and the reported distance between them will be underestimated. However, in the retrieval-bias model there is no mechanism to account for the order of retrieval, and hence, when both landmark and non landmark had to be retrieved from memory estimates should be symmetric. The retrieval-bias model may be able to explain asymmetries in such cases if the concept of "fixed" is extended to include unbiased retrieval.

McNamara and Diwadkar (1997)'s model posited that the direction of the asymmetry, whether the estimate from A to B is larger or smaller than the estimate from B to A, is determined by which element of the comparison serves as the referent and establishes the context of the estimate. This means that by manipulating the order in which the location is retrieved first one can change the asymmetry direction. If the first location A, was made the referent, then the direction of the asymmetry would reverse. Additionally, the implicit scale would be larger when the first object was a landmark than when it was a non-landmark. Consequently, estimates of distance would be smaller from landmarks to non-landmarks than from non-landmarks to landmarks.

McNamara and Diwadkar presented participants with the name of a building on a computer. They were told to get a clear idea of its location on campus and to press the "enter" key after they had done so. The name of the second building was then presented. Subjects then estimated the distance in yards between the two buildings. They were instructed to be as accurate as possible. Subjects were given a standard distance to help them scale their distance estimates. It was found that when subjects were asked explicitly to retrieve a landmark first, they underestimated distances to close non-landmarks relative to the reverse ordering of locations.

In another experiment, McNamara and Diwadkar tested whether the context evoked by a landmark was different from the context evoked by a non-landmark (Holyoak & Mah, 1982). Pairs of landmarks and non-landmarks were used. One member of each pair of landmarks was printed at the top of each page of a booklet. Subjects were asked to draw on each page a map of the campus, which included the building identified on the page and other campus buildings which were within 200 yards of it by putting dots on the page, and to place the names of the buildings next to the dots. It was found that the mean number of buildings placed on the maps per cue per subject was larger for landmarks (3.29 buildings) than for non-landmarks (2.87 landmarks). Furthermore, the average distance between each cue and the buildings retrieved in response to that cue (these distances were measured on a scale map of the campus) was larger for landmark cues (273.3 ft) than for non-landmark cues (251.1 ft). This experiment demonstrated that on average subjects recalled more buildings and more distant buildings in response to landmark cues than in response to non-landmark cues.

The most important result was that landmarks are better retrieval cues than non-landmarks. When landmarks establish the context for estimation, they evoke a larger subjective stimulus range in working memory. Since the implicit scale is larger when landmarks establish the context it will yield reduced discriminability (Holyoak & Mah, 1982), consequently distances between landmarks and non landmarks are underestimated. The corollary of this is that, when non-landmarks establish the context the subjective range is smaller, consequently distances are exaggerated. The contextual scaling model could thus explain the asymmetry distance effect observed by Sadalla, Burroughs, and Staplin (1980).

According to McNamara and Diwadkar (1997), the contextual scaling model is a collection of psychological principles.

1) The most general principle is that thinking about an object or an event creates a context in working memory for subsequent mental processing, and these contexts may be different for different stimuli.
2) A related principle is that processing a stimulus in one context may be very different from processing the same stimulus in another context.

3) A third principle is that, stimulus properties are not retrieved from long term memory and reported in a pure form, but rather, are interpreted and scaled by the context in which the retrieval takes place.

2.2.4. Summary

We have seen in this section that estimates of distance using spatial memory systematically violate the axiom of symmetry. The implicit model (Holyoak & Mah, 1982), the retrieval-bias model (Huttenlocher, Hedges & Duncan, 1991), and the contextual scaling model (McNamara & Diwadkar, 1997) attribute the asymmetrical distance effect to the cognitive processes during the time of retrieving distance information from cognitive maps, not to the representation of distance in cognitive maps. Additionally, landmarks evoke larger implicit scales in working memory than do non landmarks.

Given these effects, we consider a possibility that the contexts established on the same landmarks during the retrieval of spatial information from memory might trigger action-based representations in memory that flesh out relevant information used for distance estimation and route description. We hypothesise that thinking about the importance of an activity performed at a landmark/non landmark may cue distance estimates in terms of route based knowledge. Thinking about the frequency of visitation for the same landmark/non landmark may cue more abstract survey knowledge. Therefore, we might expect distance estimates to be more accurate in the context of importance of activity performed at landmark/non landmark than in the context of frequency of visitation at landmark/non landmark, even when the landmark/non landmarks are the same in both cases.

In the experiments we report in the next chapter, we test whether it is the case that the contexts established on the same landmarks during retrieval of distances from memory trigger action-based representations that influence distance estimation. Additionally, we also look at the effects of contexts of retrieval on route description. For the remainder of this chapter, we focus on how route descriptions can be classified. Before we go onto examining route classification, we first review relevant literature on spatial language in an attempt to identify various factors that cause us to utter one spatial description rather than another.

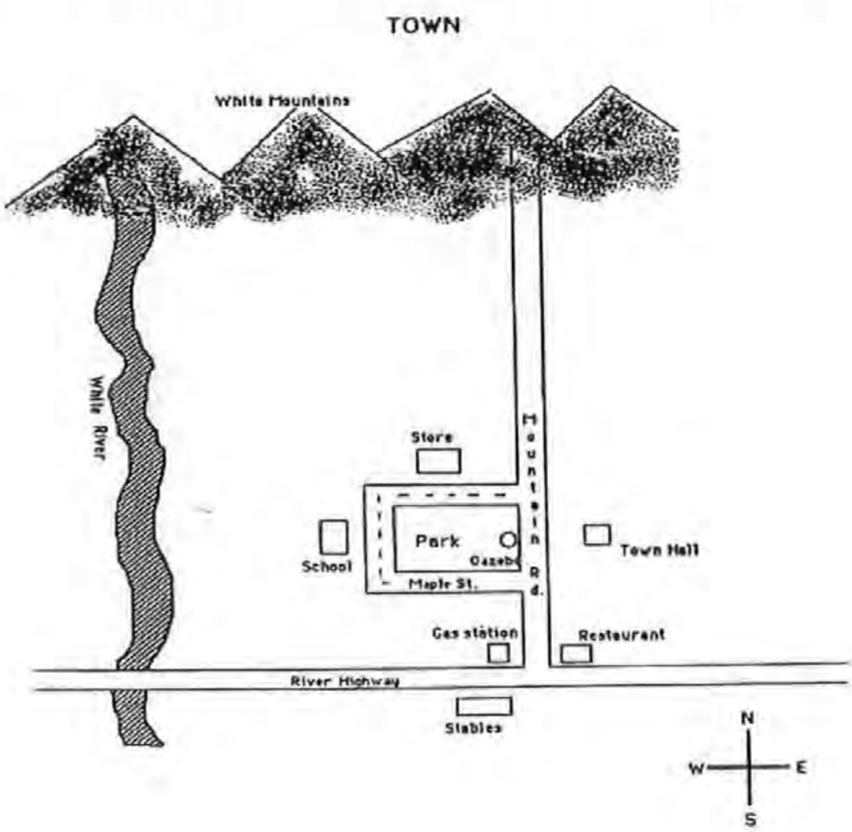
2.3. Spatial Description

Verbal description and depiction processes themselves are thought to offer some insight into our representational structure of the environment.

Taylor and Tversky (1992a) conducted a number of experiments aimed at identifying strategies used when drawing or describing memorised maps. Participants were asked to memorise environments (e.g., a small Town, an Amusement Park, or a Convention Center) through studying maps or descriptions. Participants were told that they would either sketch the map or describe the environment. In fact, they did both, in counterbalanced order. Following is an example of a survey description of Town, extracted from Taylor & Tversky (1996); the map of the Town is shown in Figure 2.2a.

"North of town are the White Mtns. And east of town is the White River, which flows south from the White Mtns. The main road by town runs in the east-west directions and crosses the White River. The stables are on the south side of this road, named River Hwy. And across the road to the north is the town. Running up through the town from the River Hwy. To the White Mtns. Is Mtn. Rd. the gas station is on the west side of Mtn Rd. and the north side of River Hwy, at the intersection, and the restaurant is just across Mtn. Rd. from the gas station. The town hall is on the east side of Mtn. Rd. a little farther along, and the Maple St. circle is on the west side of Mtn. Rd. across from the town hall in the middle of the circle created by Maple St. and Mtn. Rd. is a park with a gazebo. On the west side of the circle facing onto Maple St. is the school and on the north is the store."

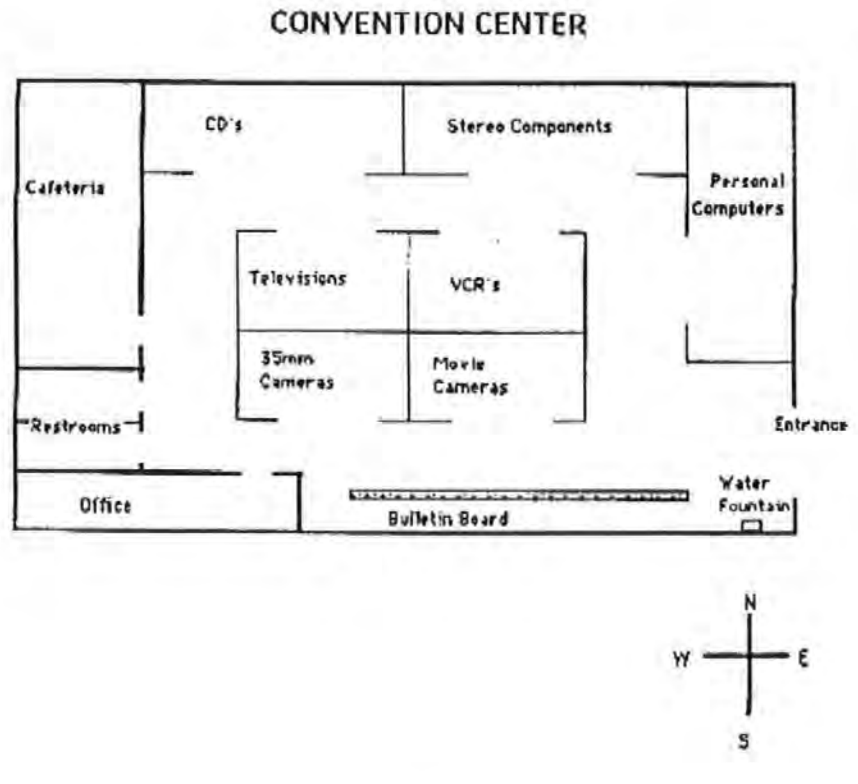
Figure 2.2a: Map of Town (Illustration taken from Taylor & Tversky, 1996).



A route description (Convention Center) is shown below (extracted from Taylor & Tversky, 1992); the map of the Convention Center is displayed in Figure 2.2b.

"The entrance is on the east side of the building. As you enter, there is a water fountain on your left, and beyond it a bulletin board. As you walk down the corridor in front of you, you pass movie cameras on your right, then 35mm cameras. On your left is the office. As you reach the end of the corridor, the restrooms are directly ahead of you, side by side. Turn right and continue walking; the cafeteria will be on your left. Turn right again at the end of the corridor; the CD players will be just ahead on your left, and the televisions on your right. Farther up, the VCRs are on the right and stereo components on your left. Turn right at the end of the hallway; you will pass personal computers on your left and then find yourself back at the entrance."

Figure 2.2b: Map of the Convention Center (Illustration taken from Taylor & Tversky, 1992a).



Taylor and Tversky found that the maps that the participants in the "description condition" constructed, solely from descriptions, were quite similar to the maps the participants in the "map condition" studied. Participants also reliably tended to subdivide the environments and to draw or describe one set of features prior to another. For example for Town, the hierarchy was based on scale: the larger, global features compared with the smaller, local ones; i.e., mountains and rivers, then major streets and highways, and finally, buildings. Most participants, began drawing with the large border features, continued with the major roads, and then placed the smallest features, the buildings.

The most interesting result was that readers form the same spatial mental models capturing the spatial relations between landmarks from both survey and route descriptions, as well as from maps.

Other studies have found that modes of acquisition of spatial knowledge influence the choice of types of verbal description produced by participants. Taylor and Tversky (1996) found that the majority of the descriptions of a college campus and neighbourhood environment, all learned by navigation took a route perspective. Taylor and Tversky indicated that in a route perspective, the locations of landmarks in the environment are described in relation to the changing position of the speaker or the listener in terms of his or her left/right/front/back (LRFB); i.e., a route perspective takes the listener/reader on a mental tour through the environment. In contrast, in a survey perspective the locations of landmarks are described with respect to one another in terms of the cardinal system North, South, East, and West (NSEW); a survey description takes a perspective from above. Table 2.1 displays the properties of types of description perspectives adapted from Taylor and Tversky (1996).

Table 2.1: Properties of Types of Description Perspectives (adapted from Taylor & Tversky, 1996).

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

Taylor and Tversky (1996) also found that although the selection of perspective to be used in description may depend in part on how an environment has been experienced, it also depends on the characteristics of the environment; environments with single paths and landmarks of about equivalent size encourage a route rather than a survey perspective.

The verbal communication of how to get from a starting place to a destination place requires the speaker to access his or her environmental knowledge from memory, and to produce a coherent set of verbal instructions based on that knowledge. Although there are a number of lines of research into spatial language (e.g., Landau & Jackendoff, 1993; Taylor & Tversky, 1992a, Taylor & Tversky, 1992b, Taylor & Tversky, 1996), there have been only few studies that look into the classification of route descriptions (Denis, 1997; Denis, Pazzaglia, Cornoldi, & Bartolo, 1999). Route description aims to assist the physical displacement in an environment by using verbal instructions that specify how one can get from one place to another. However, it was often thought that the act of describing a route mainly consists of purely procedural commands like:

"Proceed forward for 20 meters. Stop. Rotate 90 degree to the right. And so on".

Route descriptions however never come down to a succession of prescriptions of progress and reorientation. In every day situation, route descriptions would look something like:

"From the Library, I go down a flight of steps, walk across the patio, go down another flight of steps, I walk through the car park then turn right, walking through the car park still, the Brunel Lab is on my right hand side, and the Babbage building is in front of you."

The mention of landmarks to be encountered along the route is of central importance. Natural route descriptions in general contain instructional statements prescribing actions to be performed by the user of these instructions. This process is based on the subdivision of the route into segments that connect reorientation points. Indeed, the objective of the speaker is to make the user progress along the route segments of appropriate length and execute reorientation at critical points. The sites where reorientation is to occur are generally specified by referring to landmarks rather than in terms of the exact distances to cover until reorientation.

Natural route descriptions reflect two components - landmarks and prescribed actions; the categorisation of route descriptions would therefore reflect different combinations of both components in order to specify the topological relations of the describer to the landmarks to be encountered along the route (Denis, 1997).

In addition, in describing space people must take a perspective on it (Taylor & Tversky, 1996). Route perspective and survey perspective use language differently. "In a route perspective, landmarks are described relative to an observer moving through the environment in terms of the observer's front, back, left, and right, using an intrinsic frame of reference. In a survey perspective, landmarks are described relative to one another as if from above, in terms of the canonical directions, using an extrinsic frame of reference" (p. 389). However, Denis, Pazzaglia, Cornoldi, and Bartolo (1999), found that in natural urban environments the existence of intervening physical obstacles makes compass orientation of limited use. In contrast, heading towards landmarks and following pre-existing paths are essential and make up a substantial part of route descriptions.

As far as our study is concerned, verbal route description constitutes our second dependent variable. We want to examine the influence of contexts of retrieval on distance estimation as well as on subsequent verbal description that specifies the route that links the two landmarks. We follow Denis (1997)'s categorisation scheme and use the Taylor and Tversky (1996)'s operational definitions of route and survey perspectives to develop our own route classification. The description of the categorisation scheme will be shown in the next chapter.

2.4. Summary

We have seen that the asymmetry effect could be explained through retrieval processes. The implicit scaling model and the contextual scaling model insist on the importance of the contexts established by the landmarks used as referents for distance estimation. We have discussed the possibility of an action-based representation on the same landmarks, and we have looked at route descriptions and how the categorisation of route descriptions could be made.

In the next chapter we test whether the contexts of retrieval effects on the same landmarks influence distance estimation and route description.

3. CHAPTER 3: CONTEXT EFFECTS ON RETRIEVAL; FOUR EXPERIMENTS

3.1. Experiment 1

3.1.1. Introduction

We have seen in Chapters 1 and 2 that landmarks distort space around them in such a way that the cognitive distances between landmarks and ordinary locations are asymmetrical (Sadalla, Burroughs, & Staplin, 1980). Following Glenberg (1997), if memory is viewed as the encoding of possible bodily interactions with the environment then the conceptualisation of a landmark will depend on the current context combined with memory of undertaking those actions at that landmark. Therefore, the memory of previous interactions with a landmark would flesh out the relevant information for that landmark.

The present study was based on the following hypothesis. It may be the case that thinking of the importance of activity performed at a landmark might cue or trigger action based representations or route type knowledge in terms of the interaction one has with that landmark. On the other hand, thinking about how many times one pays a visit to the same building might cue more survey type representations. If this was the case, then the distance estimation from memory would be a function of the contexts evoked at the time of retrieval, i.e., the distance evaluated in the context of frequency of visitation would be different from the distance evaluated in the context of importance of activity. Additionally, subsequent route description linking those landmarks also would be a function of the contexts in which distance estimation has been made. In other words, there would be a difference in the use of spatial perspective (route or survey) between the context of frequency of visitation, and the context of importance of activity. To test this hypothesis, we set up four experiments that will be reported later on in this chapter.

3.1.1.1. Method Outline

In past research, a number of methods of collecting estimates of distance have been used (Montello, 1991). They included a placement method in which subjects marked out a distance on a form of some kind to indicate the relative distance between two objects (e.g., Sadalla, Burroughs, & Staplin, 1980) or numerical estimates of magnitude of distance (e.g., McNamara, 1986).

To keep as naturalistic and realistic a setting as possible, all of the experiments reported in the present study used numerical estimates, which are the most common method used in everyday settings. For example, when tourists arriving in Plymouth ask Plymouth residents how far it is from the Railway Station to the Light House, they would provide a numerical estimate in time or in space - they would not mark out the distance on a sheet of paper and show it to the tourists.

The series of experiments to be reported used interview procedures. The method was structured to reflect naturally realistic situations. The University of Plymouth campus, an intra-urban scale environment, was used as the stimulus setting.

Initially, participants were asked to evaluate a series of landmarks in the college campus by giving ratings for frequency of visitation and/or importance of activity performed at those landmarks (hereafter *frequency* or *importance*) using two 10-point Likert scales (10 = highest score; 1 = lowest score).

The direction of estimation (hereafter *direction*) was manipulated from high to low. Given the significant asymmetry in distance estimation effects, it was important to include this as a variable in the present study. The inclusion of direction as variable had two purposes, first as a control variable, second to examine whether the asymmetry distance effect could be observed using verbal distance estimates as a measure. The direction of estimation was fixed using the participants' ratings of landmarks. For example, the Students' Union and the Security Lodge were given ratings of 10 and 1 respectively. The distance estimations could be given in both directions, i.e., from Students' Union to Security Lodge (high to low direction) or Security Lodge to Students' Union (low to high direction).

Simple and direct questions were used during the interviews. For distance estimation, we asked participants to give verbal estimates of the distances between specific pairs of landmarks. The distance estimates given by the participants represented the distances traversed on foot from one landmark to another. For instance, the following questions could be asked straight to the participants,

"In walking distance how far do you think it is in metres from the Students Union to the Security Lodge?".

For route description, participants were instructed to imagine themselves at the starting location from which they would describe how to reach the destination on foot. We used open questions to investigate route descriptions, for instance

"Imagine that you are at the Students' Union. How would you get from the Students' Union to the Security Lodge? Would you please describe your route in as much detail as you can?".

The distance estimation was measured as the ratio between the estimates of distances and the (actual) traversed distances as described in route descriptions. The choice of perspective used in route descriptions were recorded by a categorisation of participants' route description protocols which will be described in detail later on in this chapter.

To begin with, in Experiment 1 participants were initially asked to evaluate landmarks by giving ratings for one dimension, i.e., frequency of visitation or importance of activity, before they were asked to give the estimations of route distances and then route descriptions between landmarks. Two groups of participants were used, one for frequency of visitation and one group for importance of activity. Before we describe the experiment in full, we first describe the method of selecting landmarks.

3.1.1.2. Setting and Landmarks Selection

The study was carried out in the Plymouth University campus, an intra-urban scale setting. The campus has modern and period architectural style buildings. It is organised on an irregular grid pattern (non-perpendicular paths). Its units are distributed toward the Plymouth City Centre. One central artery road separated the campus main buildings from other units (see Figure 3.1.1). The units are listed in Table 3.1.1, and those that are used as landmark stimuli in the present study are marked as follows with regard to their general uses: research/teaching units (T), resident halls (R), and other facilities (F).

Figure 3.1.1: Map of the University of Plymouth.

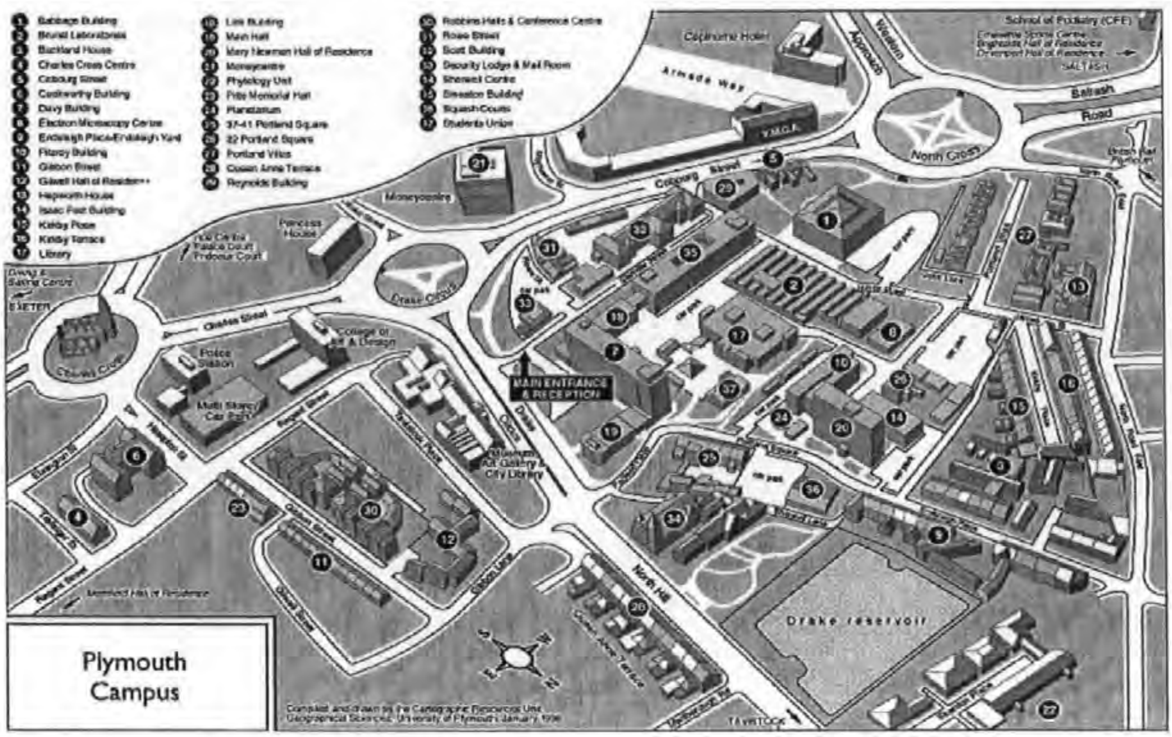


Table 3.1.1: List of Landmarks extracted from the University of Plymouth Map.

Babbage building (T)	Main Hall (T)	Robbins Hall
Robbins Conference Centre (T)	Brunel Lab (F)	Mary Newmann (R)
Charles Cross Centre	Chaplaincy (F)	Phytology Unit
Row Street	Scott Building (T)	Cobourg Street
Pitts Hall (F)	Security Lodge (F)	Cookworthy (T)
Planetarium (F)	Sherwell Centre (T)	Davy Building (T)
Portland Square	Library (F)	Link Building (T)
Smeaton Building	Moneycentre (T)	Squash Courts (F)
Endsleigh Place	Portland Villas	Students Union (F)
Fitzroy Building (T)	Princess House	Gibbon Street
Queen Anne Terrace	Gilwell Hall (R)	Reynold Building (T)
Hepworth House	Isaac Foot Building. (T)	Kirby Place

Twenty-two university units were then generated to provide a heterogeneous space. This list of landmarks was used in order to assess participants' knowledge of Plymouth University Campus.

To make sure that the locations were well known to each participant, we asked them to indicate whether they knew the landmarks or not. This initial screening of landmarks' location was done through ratings using a 10-point Likert scale. Participants were explained that the score 1 represents "I don't know" and the score 10 represents "I am certain" . Participants were further explained that the score 10 would mean that they knew the location of that landmark and that they were able to direct other people to that place from anywhere within the campus if asked to do so.

Landmarks that were given a rating of 1 were eliminated and participants were asked to give ratings for frequency of visitation or importance of activity performed at that place to the remaining landmarks using a 10-point Likert scale. Note that for frequency of visitation ratings, participants were explained that the score 1 represents "Never go" and the score 10 represents "Very frequently". For importance of activity ratings, participants were explained that the score 1 represents "Not at all important", and the score 10 represents "Very important" (samples are shown in Appendices 7.1.1.1 & 7.1.1.2).

Once the ratings for frequency of visitation or for importance of activity were done, the selection of landmarks for distance estimation was taking place. First, the experimenter scanned the participants' ratings, looking for scores of 10 or 1. However, when these extreme scores were not used, the next lowest scores or the preceding highest scores were considered. Then the experimenter chose four landmarks, two landmarks with the highest scores and another two landmarks with the lowest scores. The selected landmarks were then assembled randomly into two distinct high-low pairings in order to make two different directions for distance estimation and route description. For example, from the ratings for frequency of visitation *Robbins Lecture Theatre* and *Students Union* were given the highest scores, whereas *Security Lodge* and *Chaplaincy* had the lowest scores. These four landmarks were assembled into two pairs for distance estimation and route description. These two pairs were arbitrary labelled Route A and Route B. Continuing the example:

- *Students Union - Security Lodge* denoted Route A;
- *Chaplaincy – Robbins Lecture Theatre* denoted Route B.

These two pairs of landmarks were presented to the subjects in counterbalanced order for distance estimation and route description.

The selection of landmarks for distance estimation was made for each participant based on the participant's ratings for frequency of visitation or for importance of activity therefore different participants estimated different landmarks.

Simple and direct questions were used during the interviews. For distance estimation, we asked participants to give verbal estimates. The distance estimates given by the participants represented the distances traversed on foot from one landmark to another. For route description, we used open questions. Participants were instructed to imagine themselves at starting locations from which they would describe how to reach the destinations on foot. In the next section we show how we define the question stimuli used to examine participants' distance knowledge and route knowledge.

3.1.1.3. Interview Questions

After participants had given ratings for frequency or importance to landmarks, they were asked for distance estimation, which they had to give twice during the interview. The first estimation (henceforth the *initial estimation*) was asked immediately after they finished the ratings for frequency or importance; the same question was asked again one more time at the end of the interview (henceforth the *final estimation*). The following phrasings were used verbatim during the interview (X and Z represented two different landmarks):

a) initial estimation:

"You just indicated that you know X and Z well. In walking distance, how far do you think it is in metres from X to Z?"

b) final estimation:

"Now, in walking distance how far do you think it is in metres from X to Z?"

For route description, we used an open question, for instance:

"Imagine that you are at X. How would you get from X to Z? Would you please describe your route in as much detail as you can?"

Before we go onto describing the method, we need to show how the dependent variables were treated before they were used in the analyses. The treatment of route description was done through a detailed categorisation scheme. The aim of the categorisation of route descriptions was to isolate the propositions or statements that identify route perspective, survey perspective, as well as other styles. The categorisation scheme is described later on in the Results Section.

3.1.1.4. Data Treatments

We first transcribed the interviews in order to record the participants' distance estimation and route description. But first we show how distance estimations were treated as we need to measure the "physical" or actual distances to be used as referents to the corresponding distance estimates.

In the present study, the actual distances were recorded by following the participants' route descriptions on a scaled map of the campus (scale: 1/1250) with a map distance measure. These measures were then translated into metres. For the analyses, the distance estimations were ratio measures. The ratio was obtained by dividing the estimated distance by the actual distance (both measured in metres). Therefore, in terms of the accuracy in distance estimation:

- ratio = 1 would indicate perfect accuracy
- ratio < 1 would indicate under-estimation
- ratio > 1 would indicate over-estimation.

3.1.2. Method

In this experiment, two groups of participants were used. One group estimated the distances between places characterised by its frequency of visitation and described the routes linking those landmarks (the *frequency group*), the other group estimated the distances between places characterised by its importance of activity and described the routes linking those places (the *importance group*).

All participants gave distance estimates and route descriptions for two distinct pairs of landmarks called *Route A* and *Route B*. The order of presentation of Route A and Route B were counterbalanced within each group of participants.

The experiment was repeated in a second session in order to ensure that the asymmetry distance effect could be observed in verbal distance estimates. The second session followed the first session after at least two weeks break to allow sufficient forgetting. Over the two sessions, each participant produced 8 distance estimates and 4 route descriptions in total.

3.1.2.1. Experimental Design

To examine the context effects on retrieval, the experimental design used was a 2 condition (frequency vs. importance) x 2 route (A vs. B) x 2 direction (high-low vs. low-high) x 2 estimation (initial vs. final) mixed design with repeated measures on the last three factors. The between-subjects factor was condition (frequency vs. importance), and the other factors were within-subjects factors.

3.1.2.2. Participants

Thirty-eight undergraduate students took part in the experiment in exchange for course credit. Two subjects did not turn up at the second session, and consequently their responses were eliminated.

Data from 36 participants were entered into analysis. Age ranged between 18 and 20 year olds (mean age = 18.64, SD = 0.68). Participants had attended the university between one and twelve months (mean time of attendance = 3.15 months, SD = 3.06). They were individually tested and were randomly assigned to frequency or importance conditions.

3.1.2.3. Procedure

Each participant was tested individually in the Social Laboratory of the Psychology Department. The session lasted about 15 minutes. The participant and the experimenter sat on chairs at a desk, facing each other. A tape recorder and a microphone were placed on the desk. The structured interview was based on the following pre-defined sequence shown in Table 3.1.2.

Table 3.1.2: Diagram of the Sequential Procedure in Experiment 1.

• Initial Screening for known landmarks

↓

Ratings for Frequency (or Importance)

↓

Filler questionnaires

↓

Route A Initial Distance Estimation

↓

Route A Route Description

↓

Route B Initial Distance Estimation

↓

Route B Route Description

↓

Ratings for Importance (or Frequency)

↓

Route A Final Distance Estimation

↓

Route B Final Distance Estimation

↓

General information (genre, age, attendance) •

Initially, participants were asked to screen 22 landmarks in order to indicate which ones they knew and which ones they didn't using ratings. Next, the participants were asked to give ratings for the first criteria (frequency of visitation or importance of activity performed at that landmark) only to landmarks they knew well. While the experimenter made the selection of landmarks for distance estimation, participants were given filler questionnaires to complete. Then, the participants' distance knowledge and route knowledge were tested through interview, which was tape-recorded (the recorder was switched on).

During distance estimation, we explained to the participants that we wanted them to estimate walking distances expressed in metres, not time estimation. During spatial descriptions, some participants were silent for a period of time. The experimenter's only help was then to ask them the question "*Where are you now?*" After the participants had finished their route descriptions, the recorder was switched off as they were asked to give ratings for the second dimension (importance or frequency) to landmarks they knew well one more time. After that, the participants' distance knowledge was tested one more time, and this was tape-recorded. Finally, the participants were asked to give general information regarding their age, sex, and how long they had been attending the university.

During the second session (after two weeks break), the same procedure applied which was conducted with the same participants. However, although Route A and Route B remained unchanged, both routes were presented back to the participants for distance estimation and route description in the reverse directions.

3.1.3. Results

Before we go onto the analyses of distance estimation, we need to show how route description protocols were categorised. The aim of the analysis of the content of the route descriptions was to collect evidence, if any, for the difference in the use of perspective expressions (route or survey expressions) between the frequency group and the importance group. In the next section we describe in detail our categorisation technique.

3.1.3.1 Categorisation Technique

We started our categorisation by first defining the environmental features that are used in route descriptions. For instance buildings, streets, parking, traffic lights, signposts, etc were considered as landmarks.

Then we followed Denis's (1997) technique for route description segmentations. We operationally define each statement or proposition to convey only one instruction. Each proposition can specify either:

- An action prescription, for example, *go forward, go straight ahead,* etc, or
- An action prescription and a landmark, for example, *walk past the bank machine on your left, go along the corridor*, etc, or
- A description of a landmark encountered at this point of the journey, for example, *you can see the sign-post, the Students Union is in front of you, Link Building is south of the Students Union*, etc, or
- A description of the identity or the physical features of the landmark, for example, *the pub is the Duchess, The big glass doors,* etc.

We followed Taylor and Tversky's (1996) work on spatial descriptions for the operational definitions of perspective expressions. In the present study, we defined:

- Route perspectives as statements that describe the locations of landmarks from the egocentric point of view of the speaker or the listener (e.g., "*The Students Union is on my left*", "*The Library is in front of you*").
- Survey perspectives were:
    - 1) statements describing the locations of landmarks with reference to a system of co-ordinates (e.g., "*the Mary Newman Building is north of Link Building*");

- 2) statements describing landmarks in relation to one another as a chunk (e.g., "*The road between Link Building and the Security Lodge*"; "*Behind the Students Union is the Planetarium*").

Each proposition was then given a code that identified it to different classes or categories. We defined 5 classes with the objective of providing the general characteristics of route descriptions in terms of the use of landmarks and the use of perspective expressions. The entire categorisation scheme is shown in Table 3.1.3. Although we used a detailed categorisation scheme, the aim of the categorisation was to isolate the propositions that reflect the use of the perspective expressions.

This scheme was subjected to internal validity. To that purpose we used the Cohen's Kappa as a measure of agreement. It must be noted that Cohen's Kappa has a range from 0 – 1.00, with larger values indicating better reliability. Generally, a Cohen's Kappa > 0.70 is considered satisfactory.

To proceed to the measure of Cohen's Kappa, we first asked two colleagues independently to categorise 12 complete route descriptions chosen randomly from the pool of descriptions. They were asked to use the classification scheme as their guide for the categorisation. In the present study, we found Cohen's Kappa = 0.78, therefore the coding scheme could be used reliably.

Table 3.1.3: Classification Scheme for Route Descriptions.

Classes	Sub-classes	Codes	Examples of Utterances
1: Start position		C1	Come out of X; Leave X
2: Action prescriptions without mention of landmarks			
	1: Proceed straight ahead	C21	Go forward; Go straight ahead
	2: Proceed pseudo distance	C22	Go a bit further
	3: Change of direction	C23	Turn left/right
	4: Maintain progress	C24	Keep going
	5: Change the current path	C25	Cross over
3: Action prescriptions with mention of landmarks			
	1: Aim at a specific landmark	C31	Go towards X;
	2: Use of a specific landmark	C32	Follow X; Take X; Go through X
	3: Maintain progress on a specific landmark	C33	Keep going on the corridor
	4: Change the current path	C34	Cross over the road
	5: Proceed past a landmark	C35	Go past X
	6: Reorientation at a specific landmark	C36	Turn left/right at X
4: Introduction of new landmarks			
	1: Use of "There is"	C41	There is a pub
	2: Description of visual scene	C42	You find X; You see X;
	3: Egocentric point of view	C43	X is on my left/right/in front/behind
	4: Landmark's point of view; Allocentric co-ordinates	C44	X is between two buildings; X is opposite a building; X is south of a building
5: Description of landmarks			
	1: Landmark identity	C51	A pub called The Duchess
	2: Landmark Physical Features	C52	A tall building; The red doors
	3: Landmark's Function	C53	The main entrance
6: Destination / Goal		C6	It's there

Note: X = environmental features (buildings, streets, signposts, etc.)

Of most interest in the present study were the propositions or items in Class 4 that identify the use of perspective i.e., item 4:3 (route) and item 4:4 (survey). These Class 4 two items were used to establish the proportions of perspective expressions used in route descriptions in the frequency group and in the importance group. The items belonging to Class 1, 2, 3, 5, and 6 were called "other categories".

To establish whether the type of rating dimensions (frequency of visitation or importance of activity performed at landmark) influence the extent to which participants used survey or route expressions, for each participant we calculated the ratio. First, for each participant we sum up all the items used in route descriptions for that participant. We also calculated the percentages of route items (% route) and survey items (% survey) for that participant by dividing the total number of route items, or the total number of survey items, by the total number of items in that participant's route descriptions. These figures, (% route) and (% survey) could then be used for the calculation of the ratio using the following formula:

$$\text{Ratio} = (\%\ \text{route}) / [(\%\ \text{route}) + (\%\ \text{survey})]$$

The resulting ratio would have the values varying from 0 to 1:

- Ratio = 0 would indicate the exclusive use of survey perspective;
- Ratio = 1 would indicate the exclusive use of route perspective;
- Ratios < 0.5 would indicate the predominant use of survey perspective;
- Ratios > 0.5 would indicate the predominant use of route perspective;
- Ratios = 0.5 would mean the mixed use of route and survey perspectives.

The analyses of route descriptions will be shown later on in Section 3.1.7.5. Before we go into the analyses proper, we need to look at the nature of the landmarks that were selected for participants in the Experiment, and how they rated these landmarks.

3.1.3.2. Correlation between Ratings

First, we wanted to examine the selection of landmarks between groups. As all participants were given the same questionnaire, the 4 landmarks that were selected for the tests were almost identical between groups, shown in Table 3.1.4.

Table 3.1.4: List of Pairs of Landmarks Selected for Distance Estimation and Route Description, in Experiment 1.

	Route A		Route B	
Subjects	Frequency	Importance	Frequency	Importance
1	Students Union-Scott	Link-Security Lodge	Brunel Labs-Sherwell	Cookworthy-Students Union
2	Library-Squash Courts	Main Hall-Reception	Chaplaincy-Robbins	Scott-Mary Newmann
3	Sherwell-Security Lodge	Library-Brunel Labs	Squash Courts-Robbins	Planetarium-Robbins
4	Students Union-Scott	Link-Reception	Pitts-Sherwell	Security Lodge-Students Union
5	Students Union-Brunel Labs	Davy-Planetarium	Isaac Foot-Link	Brunel Labs-Library
6	Library-Scott	Students Union-Security Lodge	Security Lodge-Sherwell	Davy-Robbins
7	Students Union-Pitts	Library-Isaac Foot	Security Lodge-Students Union	Security Lodge-Students Union
8	Students Union-Scott	Students Union-Isaac Foot	Pitts-Davy	Squash Courts-Robbins
9	Students Union-Scott	Davy-Planetarium	Squash Courts-Link	Pitts-Link
10	Sherwell-Pitts	Mary Newmann-Scott	Scott-Students Union	Security Lodge-Students Union
11	Students Union-Brunel Labs	Robbins-Squash Courts	Isaac Foot-Robbins	Scott-Sherwell
12	Davy-Chaplaincy	Link-Pitts	Fitzroy-Link	Chaplaincy-Robbins
13	Robbins-Scott	Robbins-Planetarium	Isaac Foot-Link	Brunel Labs-Link
14	Robbins-Chaplaincy	Robbins-Davy	Security Lodge-Library	Security Lodge-Pitts
15	Robbins-Davy	Sherwell-Pitts	Scott-Students Union	Babbage-Library
16	Students Union-Security Lodge	Link-Reception	Davy-Robbins	Davy-Robbins
17	Robbins-Sherwell	Babbage-Security Lodge	Main Hall-Babbage	Chaplaincy-Link
18	Link-Babbage	Scott-Davy	Isaac Foot-Robbins	Mary Newmann-Link

This was expected, given that participants were all students sharing many common goals and routines, and they had all been on campus for a relatively short period of time. It is not surprising that the buildings rated high and low in frequency of visitation or importance of activity were the similar between groups, and hence were selected for distance estimation and description.

Now let us look at the correlations between the ratings for landmarks.

Over the two sessions, there 288 ratings in total (36 participants x 4 landmarks x 2 sessions), the correlation between ratings of frequency of visitation and importance of activity performed, $r_{(288)} = 0.718$, $p < .0001$.

There were 144 ratings over the two sessions in each group (18 participants x 4 landmarks x 2 sessions). We found a significant correlation between ratings of frequency of visitation and importance of activity performed. In the frequency group, the Pearson Correlation Coefficient $r_{(144)} = 0.70$, $p < 0.0001$; in the importance group, $r_{(144)} = 0.73$, $p < 0.0001$.

The implication for the present study is that the same landmarks were evaluated similarly in terms of both frequency of visitation and importance of activity performed for both groups of participants.

3.1.3.3. Distance Estimation Descriptive Statistics

Let us examine the relationship between distance estimates and their corresponding actual distances as measured from the route descriptions.

Over the two sessions, there 288 distance estimates in total (36 participants x 4 distance estimates x 2 sessions), the correlation between estimate and actual was $\underline{r}_{(288)} = 0.38$, $\underline{p} < .0001$.

In each group, there were 144 distance estimates in total over the two sessions (18 participants x 4 distance estimates x 2 sessions). We found a significant correlation between estimated and actual distances. In the frequency group, the Pearson's Correlation Coefficient $\underline{r}\ (144) = 0.39$, $\underline{p} < .001$, and in the importance group, $\underline{r}\ (144) = 0.43$, $\underline{p} < .001$. This result indicated that in both groups the distance estimations given by the participants were significantly correlated with the actual traversed distances as expressed in their route descriptions.

How did the frequency group and the importance group give distance estimation from memory? As shown in Table 3.1.5 below, both groups on average under-estimated distances as compared to the actual distances. Additionally the frequency group gave smaller distance estimates than the importance group.

Table 3.1.5: Descriptive Statistics for Distance Estimations and Actual Distances (expressed in metres) Pooled Across Sessions for Each Group in Experiment 1.

	Descrip. Stat.	**Frequency**	**Importance**
Estimated Distances	Minimum	10.00	10.00
	Maximum	600.00	1000.00
	Mean	164.43	239.89
	Std.Dev.	144.30	209.89
	Skewness	1.08	1.38
Actual Distances	Minimum	100.00	75.00
	Maximum	525.00	475.00
	Mean	278.00	256.65
	Std.Dev.	92.54	100.55
	Skewness	0.32	0.17

Table 3.1.5 also shows large variability in distance estimation and actual distance; there is also some positive skewness in the distribution of the data indicating a departure from normality. However, it is important to note that ANOVA is very robust when it comes to violation of the normality assumption, and the deviations were not deemed sufficient to merit data transformation (see Howell, 1999).

Now we turn to examining whether there are any significant differences between groups as a function of direction, route, or the version of estimation. We performed the analysis of variance on distance ratio, and fixed the level of significance of the analysis at $p < 0.05$ throughout the study.

3.1.3.4. Distance Estimation Analyses

The analysis used was a 2 condition (frequency vs. importance) x 2 route (A vs. B) x 2 direction (high-low vs. low-high) x 2 estimation (initial vs. final) 4-way analysis of variance with repeated measures on the last three factors. The between-subjects factor was condition (frequency vs. importance), and the other factors were within-subjects factors. This 4-way ANOVA was performed on distance ratio. The ANOVA results are shown in Table 3.1.6.

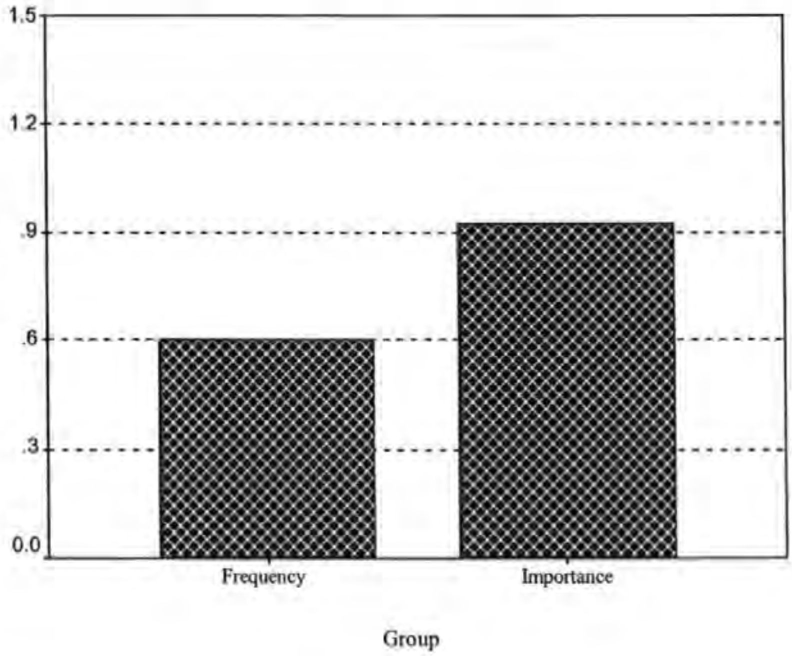
Table 3.1.6: Results of Four-Way ANOVA for Distance Ratio in Experiment 1.

Source	df and F value	MS	Significance
Condition (C)	$F_{(1, 34)} = 5.076$	7.569	*
Route (R)	$F_{(1, 34)} = 0.854$	0.483	ns
Direction (D)	$F_{(1, 34)} = 1.627$	0.413	ns
Estimation (E)	$F_{(1, 34)} = 1.836$	0.183	ns
R x D	$F_{(1, 34)} = 0.420$	0.159	ns
R x E	$F_{(1, 34)} = 2.453$	0.247	ns
D x E	$F_{(1, 34)} = 0.000$	0.000	ns
R x C	$F_{(1, 34)} = 0.099$	0.056	ns
D x C	$F_{(1, 34)} = 2.255$	0.573	ns
E x C	$F_{(1, 34)} = 0.101$	0.010	ns
R x D x C	$F_{(1, 34)} = 0.009$	0.003	ns
R x E x C	$F_{(1, 34)} = 0.039$	0.004	ns
D x E x C	$F_{(1, 34)} = 0.226$	0.025	ns
R x D x E	$F_{(1, 34)} = 0.171$	0.015	ns
R x D x E x C	$F_{(1, 34)} = 0.441$	0.038	ns

Note. ns: $p > .05$; *: $p < .05$.

The result of the analysis yields no main effects of route, direction, or version of estimation (initial or final estimation). There was a significant main effect of condition on distance ratio, $F_{(1, 34)} = 5.076$, $p < .05$. Figure 3.1.2 displays the mean distance ratios for both groups of participants.

Figure 3.1.2: Main Effect of Condition on Distance Ratios in Experiment 1.



Overall, we found that the distances were under-estimated. However, on average the importance group gave longer distance estimations (mean = 0.92) than the frequency group (mean = 0.60), and in terms of accuracy the importance group was more accurate than the frequency group. None of the interactions were significant.

In sum, the result of the analyses on distance estimation indicated that participants in the frequency group gave shorter distance estimates than those in the importance group. In terms of accuracy, the importance group was more accurate than the frequency group.

Let us examine now whether there are significant differences between the frequency group and the importance group in the use of perspective in route descriptions.

3.1.3.5. Route Description Analyses

As each participant produced four route descriptions over the two sessions, there were 144 route descriptions in total (36 participants x 2 routes x 2 sessions). The categorisation of the protocols of all route descriptions across participants generated 1638 propositions overall.

Recall that to quantify whether a participant used a predominant perspective in his or her descriptions, for each participant we calculated the ratio by dividing the percentage of route perspective expressions (% route) by the sum of the percentage of route (%route) and the percentage of survey perspective expressions (%survey) across his or her 4 route descriptions.

$$\text{Ratio} = (\%\ \text{route}) / [(\%\ \text{route}) + (\%\ \text{survey})]$$

- Ratio = 0 would indicate the exclusive use of survey expressions;
- Ratio = 1 would indicate the exclusive use of route descriptions;
- Ratios < 0.5 would indicate the predominant use of survey expressions;
- Ratios > 0.5 would indicate the predominant use of route expressions;
- Ratios = 0.5 would mean the mixed use of route and survey expressions.

Table 3.1.7 shows us that not all route descriptions used perspective; of the 144 total descriptions, 43 % in the frequency group and 36 % of in the importance group did not use perspective (called as other category in the present study).

Of the remaining descriptions, Table 3.1.7 reveals that the frequency group used more survey perspective than route perspective expressions, while the importance group produced more route perspective than survey perspective expressions.

Table 3.1.7: Mean percentage of participants who used survey only, route only, mixed (survey and route), and other categories expressions in Route Descriptions in Experiment 1.

	Groups	
	Frequency	**Importance**
Used of Perspectives		
Survey	31 %	14 %
Route	22 %	39 %
Mixed	4 %	11 %
Other Category	43 %	36 %

A t-test revealed that the ratio was significantly greater in the importance group (mean ratio = 0.68) than in the frequency group (mean ratio = 0.43), $t_{(85)} = 2.79$, $p < 0.01$.

In sum, the analyses on route descriptions indicated both groups of participants used a range of spatial perspective expressions. However, the frequency group used more survey perspectives in their descriptions, whereas the importance group used more route perspectives in their descriptions.

3.1.4. Discussion

Before we proceed to the discussion of the data, let us summarise the significant findings we have.

We found that the ratings for frequency of visitation of landmarks and importance of the activity at landmarks selected for distance estimation and route description were strongly correlated. Buildings visited frequently were also associated with important activities (not surprisingly).

We also found a strong correlation between the actual distance and the estimated distance. However, the frequency group gave shorter distance estimates than the importance group, and in terms of accuracy the latter group was more accurate than the former one.

In the categorisation of route descriptions, we found the frequency group to use more survey perspective expressions than route perspective expressions in their descriptions; on the other hand, the importance group used more route perspective expressions than survey perspective expressions in their route descriptions.

How could our data be interpreted?

Firstly, our data indicated that overall the distances estimated from memory were sensitive to the traversed distances. This result is in line with evidence from other studies (e.g., Decety, Jeannerod, & Prablanc, 1989; Reiser et al, 1995; Thorndyke & Hayes-Roth, 1982).

The effect of direction was not observed in this experiment; the distance estimations given for both directions for Route A and Route B (direction high to low and low to high, and the reverse directions at the second session) did not yield any significant asymmetry effect. The absence of the asymmetry effect may be due to the method of measurement. While the present experiment used verbal estimates of route distances as traversed by participants, previous studies used Euclidean distances measured by line scale estimates (Holyoak & Mah, 1982; Sadalla, Burroughs, & Staplin, 1980) or by numerical estimates (McNamara & Diwadkar, 1997). Another possible explanation for the absence of an asymmetry effect in the present experiment may be that the asymmetry exists only in certain circumstances (Holding, 1992), or that it does not exist in route distance estimates.

It was clear that landmarks that had been selected for distance estimation and route description were the same landmarks for the frequency group and for the importance group. Furthermore, when we focused on the ratings of landmarks (frequency of visitation and importance of activity ratings) within subjects, we found that both rating dimensions were highly correlated.

This finding indicated that, although participants were able to use both survey and route representations of the environment flexibly, the rating dimension affected the extent to which each of these representations was used. It may be the case that the conceptualisation of the same landmarks through the ratings for frequency of visitation versus importance of activity primes or evokes a particular type of cognitive context. This contextual priming may subsequently influence distance estimation and types of perspective given in route description. For instance, in relation to distance estimation, it could be said that the priming based on the frequency of visitation leads to access of survey knowledge of that environment and the use of survey knowledge may produce short (underestimated) route distances. On the other hand, the priming based on the importance of activity leads to access of route-based knowledge of that environment and the use of route-based knowledge leads to more accurate distance estimation.

This view is in agreement with previous studies (Taylor and Naylor, 2002; Thorndyke & Hayes-Roth, 1982). For instance, Taylor and Naylor (2002) found that participants given route goals (they were instructed to learn the fastest routes between landmarks) made more accurate route distance estimates, while those who were given survey goals (they were instructed to learn the layout of the environment) gave more accurate Euclidean distance estimates. While Taylor and Naylor interpret their finding as the result of goals at learning, the present data attributes the difference to the cueing context established prior to the retrieval of distance from memory.

According to Thorndyke and Hayes-Roth (1982), a person equipped with survey knowledge is efficient at giving accurate Euclidean distance estimates as he/she has direct access to spatial information; on the other hand, someone who uses route knowledge is efficient at giving accurate route distance estimates as he/she must compute complex sequences of route legs to derive the estimate of distance. Our data indicated that the priming with the importance of activity creates a cognitive context that triggers route based knowledge thereby producing relatively accurate route distance estimation and the predominant use of route perspective in spatial description; whereas the priming with the frequency of visitation induces a cognitive context that triggers survey knowledge thereby producing short route distance estimation and the predominant use of survey perspective in spatial description.

Following Thorndyke and Hayes-Roth's suggestion we make the following hypothesis. If it were the case that the frequency group favoured survey-based representation then they may give more accurate Euclidean distance estimates than the importance group; subsequently, the frequency group would use more survey perspective expressions than route perspective expressions in their spatial description.

On the other hand, if the importance group favoured route-based representation then they may give more accurate route distance estimates than the frequency group; subsequently, the importance group would produce more route perspective expressions than survey perspective expressions in their spatial description.

To test this hypothesis, we set up Experiment 2 to assess the validity of these assumptions. In Experiment 2 participants were asked to estimate route distances <u>or</u> Euclidean distances (i.e., the shortest distances between two landmarks), and then to describe routes linking those landmarks, using the same methodology (with a few changes) as that used in Experiment 1.

3.2. Experiment 2

3.2.1. Introduction

Experiment 1 had participants estimate route distances from memory and then generate spontaneous route descriptions. The overall results established that the conceptualisation of the same landmarks through the ratings for frequency of visitation versus importance of activity performed evokes a particular type of cognitive context, which subsequently influences distance estimation and types of verbal description given. In relation to distance estimation, we suggested that the priming induced by the ratings for frequency of visitation triggers survey based knowledge, which leads to under-estimation of route distances and the use of more survey perspective expressions than route perspective expressions in descriptions. On the other hand, the priming induced by the ratings for importance of activity triggers route based knowledge, which leads to more accurate distance estimates and the use of more route perspective expressions than survey perspective expressions in descriptions.

Experiment 2 was set up to assess the validity of these assumptions. Types of distance (Euclidean versus route) were combined with condition (frequency versus importance) to produce four groups. Prior to making distance estimations and giving route descriptions, participants were asked to rate landmarks based on frequency of visitation or importance of activity performed. The experiment also controlled for possible asymmetries in distance estimation as in Experiment 1. Only one session was used in Experiment 2.

3.2.2. Method

The method used was similar to that used in Experiment 1, but with some changes. Four groups of participants were used.

All participants initially screened a series of landmarks presented to them in order to establish which landmarks they knew with certainty and which ones they did not know. This initial screening of landmarks' location was done through ratings using a 10-point Likert scale, and participants were explained that the score 1 represents "I don't know" and the score 10 represents "I am certain". Participants were further explained that the score 10 would mean that they knew the location of that landmark and that they were able to direct other people to that place from anywhere within the campus if asked to do so. Landmarks that were given a rating of 1 were eliminated.

Then participants were asked to give ratings for frequency of visitation <u>or</u> importance of activity performed at that place to the remaining landmarks using a 10-point Likert scale. Note that for frequency of visitation ratings, participants were explained that the score 1 represents "Never go" and the score 10 represents "Very frequently". For importance of activity ratings, participants were explained that the score 1 represents "Not at all important", and the score 10 represents "Very important".

Then followed the initial distance estimation and route description tasks[1]. After that, participants gave ratings for the second dimension to known landmarks, that is, the frequency group gave ratings for importance of activity; the importance group gave ratings

[1] Note that the actual Euclidean distances were measured from a scaled map of the campus (scale: 1/1250) by joining the centres of the two buildings with a straight line. The measure of the actual route distances were the same as in Experiment 1, i.e., they were measured by following the participants' route descriptions on the scaled map.

for frequency of visitation. Then, participants evaluated the distance from memory one more time (final estimation).

The distance estimation data as well as the route description data were treated in the same manner as in Experiment 1.

3.2.2.1. Experimental Design

The design used was a 2 condition (frequency vs. importance) x 2 type of distance estimation (route vs. Euclidean) x 2 direction (high to low vs. low to high) x 2 estimation (initial vs. final) mixed design with repeated measures on the last two factors. The between-subjects factors were condition and type of distance estimation, and the other factors were within-subjects factors. Each participant gave 4 distance estimates and 2 route descriptions.

3.2.2.2. Participants

Seventy-six undergraduate students took part in the experiment in exchange for course credit or for money. Four responses were eliminated due to poor quality of recordings (2 participants), inability of producing distance estimations (1 participant), and distance estimations given in one direction only (1 participant).

Responses from 72 participants were used in the analyses. Participants were between 18 and 45 years old (mean age = 21.65, SD = 4.79). They had attended the university between 3 and 43 months (mean time of attendance = 11.09 months, SD = 8.63). They were randomly assigned to one of the four experimental conditions and were individually tested. Table 3.2.1 displays the distribution of participants into 4 groups: frequency/route (FR), frequency/Euclidean (FE), importance/route (IR), or importance/Euclidean (IE).

Table 3.2.1: Distribution of Participants in Experiment 2.

		Distance estimation Types		
		Euclidean	Route	N
	Frequency	18	18	36
Condition	Importance	18	18	36
	N	36	36	72

3.2.2.3. Procedure

In this experiment, we used two groups of participants for the frequency condition and two other groups for the importance condition. Half the participants in the frequency condition gave route distance estimates (FR group) whereas the other half gave Euclidean distance estimates (FE group). Similarly, half the participants in the importance condition estimated route distances (IR group) whereas the other half estimated the Euclidean distances (IE group). All participants gave distance estimates and route descriptions for two distinct pairs of landmarks; one pair of landmarks represents direction high → low (denoted Route A), and the other pair represents direction low → high (denoted Route B).

The structured interview was exactly the same as in Experiment 1, but only one session was needed. Below is the diagram of the sequence of events in the interview (Table 3.2.2).

Table 3.2.2: Diagram of the Sequence of the Interview, in Experiment 2.

• Initial Screening for known landmarks

↓

Ratings for Frequency (or Importance)

↓

Filler questionnaires

↓

Route A Initial Distance Estimation

↓

Route A Route Description

↓

Route B Initial Distance Estimation

↓

Route B Route Description

↓

Ratings for Importance (or Frequency)

↓

Route A Final Distance Estimation

↓

Route B Final Distance Estimation

↓

General information (genre, age, attendance) •

For participants who were to give Euclidean distance estimations, the following question was put to them:

a) initial estimation:

"You just indicated that you know X and Z well. What is the shortest distance in metres between X to Z? By shortest distance I mean the distance between the centres of the two buildings, that is the distance as the crow-flies, also called as the crow-flies distance".

b) final estimation:

"Now, what is the shortest distance in metres between X to Z?"

3.2.3. Results

3.2.3.1. Distance Estimation Descriptive Statistics

Now we want to look at the relationship between distance estimates and their corresponding actual distances as measured from the route descriptions. As each participant produced four distance estimates, there were 288 distance estimates in total (72 participants x 2 routes x 2 estimates). There was a significant correlation between distance estimate and actual distance, the Pearson's Correlation Coefficient $\underline{r}_{(288)} = 0.49$, with the level of significance $\underline{p} < .001$.

Table 3.2.3 displays the Pearson Correlation Coefficients for condition (frequency vs. importance) and for type of distance estimation (Euclidean vs. route).

Table 3.2.3: Correlation between Estimate and Actual Distances in Experiment 2.

Groups	Pearson Correlation Coefficient	p (2-tailed)
Euclidean	$r_{(144)} = 0.198$	*
Route	$r_{(144)} = 0.621$	**
Frequency	$r_{(144)} = 0.574$	**
Importance	$r_{(144)} = 0.408$	**

Note: *: $p < .05$; **: $p < .01$.

Now let us look at how the four groups of participants gave distance estimations in relation to the corresponding actual distances (Tables 3.2.4 and 3.2.5).

Table 3.2.4: Descriptive Statistics for Distance Estimations for Frequency Condition (expressed in metres), in Experiment 2.

	Frequency			
	Distance Estimated		Actual Distance	
	Euclidean	Route	Euclidean	Route
Minimum	40.00	30.00	100.00	100.00
Maximum	800.00	1000.00	325.00	575.00
Mean	238.47	361.11	190.97	303.47
Std. Deviation	164.51	229.14	52.79	94.41
Skewness	1.78	0.66	0.36	0.28

Table 3.2.5: Descriptive Statistics for Distance Estimations for Importance Condition (expressed in metres), in Experiment 2.

	Importance			
	Distance Estimated		Actual Distance	
	Euclidean	Route	Euclidean	Route
Minimum	50.00	50.00	50.00	175.00
Maximum	900.00	800.00	350.00	625.00
Mean	263.61	296.25	199.30	308.33
Std. Deviation	204.63	162.48	64.99	108.81
Skewness	1.367	0.83	0.30	0.90

As shown in Tables 3.2.4 and 3.2.5, in both frequency and importance conditions on average route distances are longer than Euclidean distances.

There was also large variability in distance estimation and in actual distance; there was also some positive skewness in the distribution of the data indicating departure from normality. However, we decided not to transform the data for the same reason we provided in Experiment 1.

Now we turn to examining whether there are any significant differences between groups and between types of distance estimations as a function of direction, or version of estimation (initial/final estimation). We performed analysis of variance on distance ratio, and fixed the level of significance of the analysis at $p < 0.05$ throughout the study.

3.2.3.2. Distance Estimation Analyses

The analysis used was a 2 condition (frequency vs. importance) x 2 type of distance estimation (route vs. Euclidean) x 2 direction (high-low vs. low-high) x 2 estimation (initial vs. final) 4-way analysis of variance with repeated measures on the last two factors. The between-subjects factors were condition (frequency vs. importance), and type of distance estimation (route vs. Euclidean); the other factors were within-subjects factors. This 4-way ANOVA was performed on distance ratio. The ANOVA results are shown in Table 3.2.6.

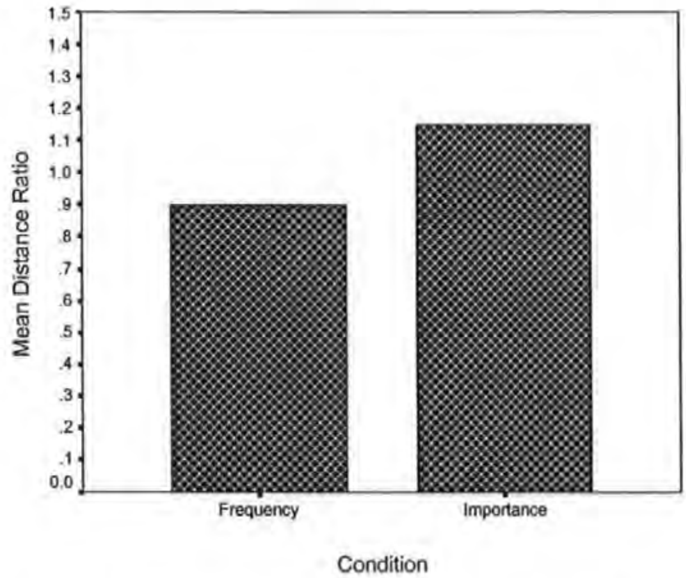
Table 3.2.6: Results of Four-Way ANOVA for Distance Estimations in Experiment 2.

Source	df and F value	MS	Significance
Condition (C)	$F_{(1, 68)} = 4.053$	4.397	*
Type of distance (T)	$F_{(1, 68)} = 2.667$	2.893	ns
Direction (D)	$F_{(1, 68)} = 0.244$	0.062	ns
Estimation (E)	$F_{(1, 68)} = 1.337$	0.028	ns
C x T	$F_{(1, 68)} = 1.983$	2.151	ns
C x D	$F_{(1, 68)} = 0.505$	0.127	ns
C x E	$F_{(1, 68)} = 0.585$	0.012	ns
D x T	$F (1, 68) = 0.985$	0.248	ns
D x E	$F (1, 68) = 0.098$	0.001	ns
E x T	$F_{(1, 68)} = 0.243$	0.005	ns
D x C x T	$F_{(1, 68)} = 0.050$	0.012	ns
E x C x T	$F_{(1, 68)} = 0.060$	0.001	ns
D x E x C	$F_{(1, 68)} = 0.000$	0.000	ns
D x E x T	$F_{(1, 68)} = 1.500$	0.023	ns
D x E x C x T	$F_{(1, 68)} = 2.776$	0.043	ns

Note. ns: $p > .05$; * : $p < .05$

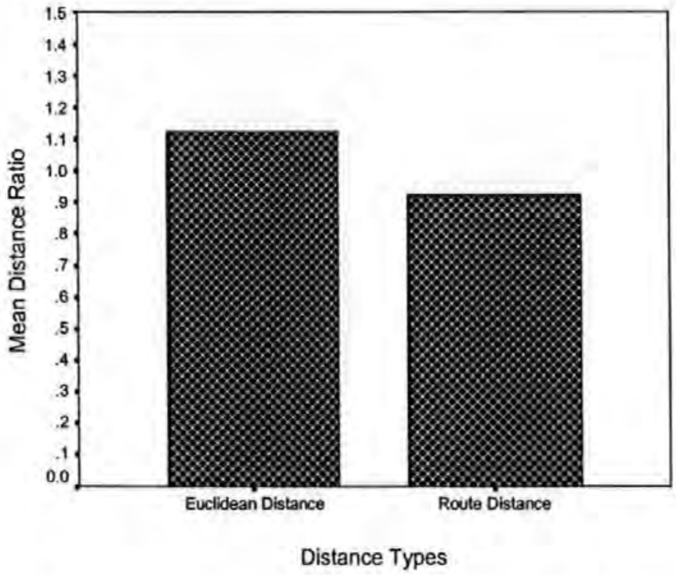
There were no main effects of direction, types of distance, or time of estimation (initial/final estimation). However, there was a significant main effect of condition on distance ratio. Overall, participants in the importance condition gave longer distances (mean = 1.15), whereas those in the frequency condition gave shorter distances (mean = 0.90); and in terms of accuracy, the frequency condition underestimated, whereas the importance condition overestimated (see Figure 3.2.1).

Figure 3.2.1: Main Effect of Condition on Distance Estimation, in Experiment 2.



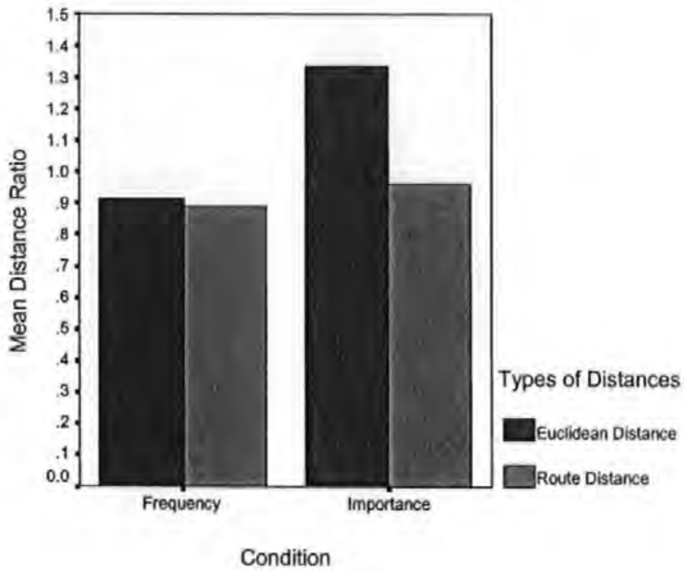
The main effect of distance type did not reach significance ($F_{(1, 68)} = 2.67$, $p = 0.11$). However, we can observe the trend of distance estimation. Participants who made Euclidean estimates tended to give larger distances (mean = 1.12), whereas those who gave route estimates tended to give shorter distances (mean = 0.92); and in terms of accuracy, the Euclidean groups tended to overestimate, whereas the route groups tended to underestimate (see Figure 3.2.2).

Figure 3.2.2: Trend of the Estimations of Euclidean Distances and Route Distances, in Experiment 2.



No significant interaction effects were found. Although, the interaction between condition and type of distance estimation did not reach significance as expected ($F_{(1, 68)}$ = 1.98, $p = 0.16$), we can observe the following trends (see Figure 3.2.3). In the frequency condition, the FE and FR groups gave shorter distance estimates, and in terms of accuracy they underestimated distances (FE = 0.91, FR = 0.89). As far as the importance condition was concerned, the IE group gave larger estimates and overestimated distances (1.33); whereas the IR group gave more accurate distance estimates (0.96).

Figure 3.2.3: Trend of the Distance Estimations in the Interaction between Condition and Types of Distance, in Experiment 2.



3.2.3.3. Route Description Analysis

As each participant produced two route descriptions, there were 144 route descriptions in total (72 participants x 2 routes), which generated 3237 propositions overall.

We wanted to examine whether there are differences in the use of perspectives in descriptions between the groups of participants. Table 3.2.7 displays the overall percentage of participants who used survey only, route only, mixed (survey and route) or other categories of expressions exclusively.

Table 3.2.7: Mean percentage of participants who used survey only, route only, mixed (survey and route), and other categories expressions in Route Descriptions in Experiment 2.

	Frequency		**Importance**	
	Euclidean	**Route**	**Euclidean**	**Route**
Use of perspectives				
Survey	32 %	26 %	25 %	6 %
Route	8 %	16 %	10 %	44 %
Mixed	18 %	18 %	25 %	17 %
Other Categories	42 %	40 %	40 %	33 %
	N = 18	N = 18	N = 18	N = 18

Table 3.2.7 shows that the FE and the FR groups used more survey perspective expressions than route perspective expressions in their descriptions. On the other hand, the IE group used more survey perspective expressions as well as mixed type expressions than route perspective expressions; while the IR group seemed to use predominantly route perspective expressions.

To test for significance in the use of perspective expressions, a 2-way ANOVA was used to examine the effects of condition (frequency vs. importance), and type of distance estimation (route vs. Euclidean), on the ratio of route to survey perspective expressions. The results of the analysis are displayed in Table 3.2.8.

Table 3.2.8: Results of 2-Way ANOVA on Route Descriptions, in Experiment 2.

Source	df and F value	MS	Significance
Condition (C)	$F_{(1, 89)} = 5.872$	0.126	*
Distance Types (T)	$F_{(1, 89)} = 13.853$	0.296	**
C x T	$F_{(1, 89)} = 4.244$	0.091	*

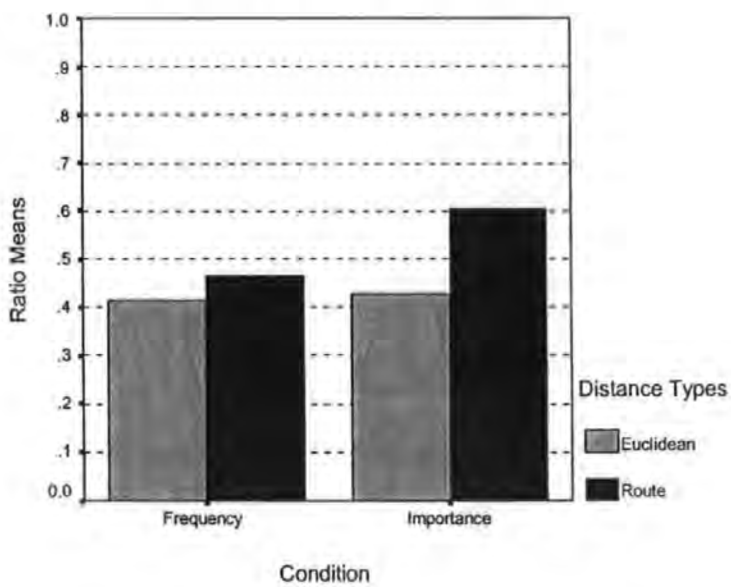
Notes. ns: p > .05; * : p < .05; ** : p < .001

The significant main effect of condition on the ratio indicated that overall participants who, prior to giving distance estimation and route description, based their ratings of landmarks on the importance of activity, used significantly more route perspective expressions than survey perspective expressions in their descriptions (mean = 0.52). Participants who based their ratings of landmarks on the frequency of visitation, used significantly more survey perspective expressions than route perspective expressions in their descriptions (mean = 0.44).

The significant main effect of type of distance estimation on the ratio indicated that overall participants who estimated Euclidean distances used significantly more survey perspective expressions than route perspective expressions in their descriptions (mean = 0.42); those who estimated route distances produced more route perspective expressions than survey perspective expressions in their descriptions (mean = 0.54).

There was also a significant interaction effect between condition and type of distance estimation on the ratio (displayed in Figure 3.2.4). The result indicated that in the frequency condition, the FE and FR groups used more survey perspective expressions than route perspective expressions; in the importance condition, the IE group used more survey perspective expressions than route perspective expressions, whereas the IR group used more route perspective expressions than survey perspective expressions.

Figure 3.2.4: Interaction Effect between Condition and Distance Type for Route Descriptions in Experiment 2.



Follow up analyses indicated that in the importance condition, the use of perspective differed significantly between the IE group and the IR group, $t_{(41)} = 4.567$, $p < 0.001$; but not in the frequency condition, $t_{(40)} = 1.025$, $p > .05$.

In sum, the analyses on route descriptions revealed that in general participants in the frequency condition used more survey perspective expressions than route perspective expressions in their route descriptions. The participants in the importance condition who had to give Euclidean distance estimates, used more survey perspective expressions in their descriptions, while those who had to give route distance estimates, used more route perspective expressions than survey perspective expressions in their route descriptions.

3.2.4. Discussion

The data in Experiment 2 replicated that of Experiment 1 in terms of the influence of the ratings on distance estimation.

With regard to the effect of direction, again the observation of any asymmetrical distance effect in both route and Euclidean distances has failed. It may be that the asymmetry distance does not occur when verbal responses are required.

Again, the distance estimation between the same pairs of landmarks differed as a function of which rating dimensions the participants used to undertake the evaluation of the landmarks prior to making distance estimation; distances estimated under frequency of visitation were systematically smaller than under importance of activity performed.

With regard to the types of distance estimation, the results did not support our hypothesis; we did not observe the participants in the frequency condition giving more accurate Euclidean distance estimates, or the participants in the importance condition giving more accurate route distance estimates. It may be the case that the types of distance estimation to be made also influence the judgements. It can be argued that the lack of the interaction between condition and types of distance as we hypothesized may be due to the fact that the priming contexts established by the rating dimensions were so powerful that participants were unable to adjust for the types of distance estimation that has been currently required to be made. In other words, although it seemed that the ratings for importance of activity taps route based knowledge, and the ratings for frequency taps survey knowledge, participants were unable to adjust the knowledge accessed when the types of distance estimation were not congruent with the knowledge they had access to.

Although in relation to distance estimation participants appeared to be unable to adjust for the types of distance estimation they were being asked for, they seemed to be primed by the latter when they came to give route descriptions. Irrespective of being given Euclidean distance or route distance to be estimated, the frequency groups seemed to favour survey based knowledge, and in terms of route description, they used more survey perspective expressions than route perspective expressions in their descriptions. For the importance groups, participants in the route distance group used more route perspective expressions than survey perspective expressions in their descriptions; however, having given Euclidean distance to be estimated, they were actually able to use more survey perspective expressions than route perspective expressions in their descriptions.

Overall, Experiment 2 data suggested that spatial representation could be retrieved flexibly according to which context was primed prior to making the judgements. In the context of frequency of visitation the access of survey knowledge seemed to be facilitated. The use of this survey representation only produced relatively short distance estimation in general, and an overall substantial use of survey perspective expressions in descriptions. Recall that in survey perspective description, the locations of landmarks were described with respect to one another in terms of the cardinal system North, South, East, and West (NSEW); a survey description took a perspective from above (Taylor & Tversky, 1996). Therefore, it seemed that a person who drew upon survey information only was using spatial knowledge gained through secondary knowledge, i.e., knowledge gained through maps study of that environment (Presson, DeLange, & Hazelrigg, 1989). This view was in line with Taylor and Naylor (2002)'s study where the goals at learning and spatial tasks were congruent. On the other hand, in the context of importance of activity performed the access of route knowledge was facilitated. The use of route based knowledge information produced more accurate route distance estimations and a substantial use of route perspective expressions in descriptions. Taylor and Tversky (1996) indicated that in a route perspective description, the locations of landmarks in the environment were described in relation to the changing position of the speaker or the listener in terms of his or her left/right/front/back (LRFB). Therefore, it seemed that a person who drew upon route based knowledge was using spatial knowledge gained through active navigation about an environment, i.e., through primary knowledge of that environment (Presson, DeLange, & Hazelrigg, 1989). Again, this view was in line with Taylor and Naylor (2002)'s study where the goals at learning and spatial tasks were congruent.

Experiments 1 and 2 showed that participants were primed by the criteria (frequency of visitation or importance of activity performed) that they used to rate landmarks prior to making distance estimation and route description. However, in Experiment 2, when route based knowledge was accessible, participants seemed to be able to adjust their descriptions according to whether previously they had made route distance estimation or Euclidean distance estimation. If the criteria that was used for the ratings exerted a powerful influence on subsequent distance estimation and route description, then a cognitive conflict could arise when both dimensions were used to anchor landmarks prior to making distance estimation and route description. It followed that the influence of the resulting priming effect would weaken as this treatment forced participants to privilege one dimension or the other. Additionally, this manipulation allowed us to examine how the priming actually functions, whether the first dimension exerted a primacy effect, or whether it was the recency exerted by the second dimension.

To examine this, we set up Experiment 3 in which we required participants to give ratings for both frequency of visitation <u>and</u> importance of activity to individual landmarks at the start of the test. Experiment 3 used the same methodology as in Experiment 1 but with slight modification. Two groups of participants were used. The FI group rated for frequency of visitation followed immediately by importance of activity ratings, and the IF group rated for importance of activity followed by frequency of visitation ratings.

If it was the case that the first dimension induced a primacy effect, then we would expect that in the FI group, distance would be underestimated and route description would use more survey perspective expressions than route perspective expressions; in the IF group, distance would be more accurate, and route description would use more route perspective expressions than survey perspective expressions.

If it was the case that the second dimension exerted a recency effect, then we would expect that in the FI group, distance would be more accurate, and route description would use more route perspective expressions than survey perspective expressions; in the IF group, distance would be underestimated, and route description would use more survey perspective expressions than route perspective expressions.

3.3. Experiment 3

3.3.1. Introduction

Data from Experiments 1 and 2 suggested that participants were primed by the first dimension (frequency of visitation or activity of importance) they used to rate landmarks prior to making distance estimation and route description.

If the first rating dimension exerted a powerful influence, then when both dimensions were used to anchor landmarks a cognitive conflict could arise, as this treatment forced participants to privilege one dimension or the other for the conceptualisation of landmarks. Furthermore, the influence of the resulting priming effect would weaken the difference in distance estimation between groups, and route description would produce mixed perspectives. The consequence of this manipulation was that it allowed us to examine whether there was a primacy effect due to the first rating dimension given, or whether there was a recency effect due to the second rating dimension that was given immediately afterwards.

If there was a primacy effect, in the FI group distance would be underestimated and route description would use more survey perspective expressions than route perspective expressions; and in the IF group distance would be more accurate, and route description would use more route perspective expressions than survey perspective expressions.

Otherwise, if there was a recency effect, in the FI group distance would be more accurate, and route description would use more route perspective expressions than survey perspective expressions; in the IF group, distance would be underestimated, and route description would use more survey perspective expressions than route perspective expressions.

Finally, if there was a cognitive conflict due to having to give ratings for both dimensions, the difference in distance estimation would weaken, and we would observe a mixed use of perspective expressions in route descriptions.

3.3.2. Method

The methodology was similar to that of Experiment 1, but only one session was used and with slight modification in relation to the sequence of ratings of landmarks. Otherwise the general structure of the method remained unchanged with regard to the materials and the interview procedure.

All participants initially screened a series of landmarks presented to them in order to establish which landmarks they knew with certainty and which ones they did not know. This was done through landmark ratings using a 10-point Likert scale. Participants were explained that the score 1 represents "I don't know" and the score 10 represents "I am certain". Participants were further explained that the score 10 would mean that they knew the location of that landmark and that they were able to direct other people to that place from anywhere within the campus if asked to do so. Landmarks that were given a rating of 1 were eliminated.

Then participants were asked to give ratings for frequency of visitation <u>or</u> importance of activity performed to the remaining landmarks using a 10-point Likert scale.

Note that for frequency of visitation ratings, participants were explained that the score 1 represents "Never go" and the score 10 represents "Very frequently". For importance of activity ratings, participants were explained that the score 1 represents "Not at all important", and the score 10 represents "Very important".

Then followed the initial distance estimation and route description tasks. After that, participants were asked to evaluate the distance from memory one more time (final estimation).

All participants gave route distance estimates and route descriptions for two distinct pairs of landmarks; one pair of landmarks represents direction high → low (denote *Route A*), and the other pair represents direction low → high (denote *Route B*). The order of presentation of route A and route B was counterbalanced within each group. The distance estimation data as well as the route description data were treated in the same manner as in Experiment 1.

3.3.2.1. Experimental Design

The design used was a 2 group (FI vs. IF) x 2 direction (high - low vs. low - high) x 2 estimation (initial vs. final) mixed design with repeated measures on the last two factors. Each participant was tested under all levels of direction and estimation therefore each participant produced four distance estimates and two route descriptions.

3.3.2.2. Participants

Thirty-two undergraduate students between 18 and 45 year olds (mean age = 20.31, SD = 5.23) took part in the experiment in exchange for course credit. Participants had attended the university between two and three months (mean time of attendance = 2.97 months, SD = 0.18). They were individually tested and were randomly assigned to FI or IF groups.

3.3.2.3. Procedure

Participants were tested individually. The test lasted about 15 minutes. The structured interviewed was slightly changed. Table 3.3.1 displays the precise sequence of questions that was used during the interview.

Table 3.3.1: Diagram of the Sequence of the Interview, in Experiment 3.

• Initial Screening for known landmarks

↓

Ratings for First Dimension (Frequency or Importance)

↓

Ratings for Second Dimension (Importance or Frequency)

↓

Filler questionnaire

↓

Route A Initial Distance Estimation

↓

Route A Route Description

↓

Route B Initial Distance Estimation

↓

Route B Route Description

↓

Filler questionnaire

↓

Route A Final Distance Estimation

↓

Route B Final Distance Estimation

↓

General information (genre, age, attendance) •

3.3.3. Results

We wanted to examine whether the resulting effect of having given ratings for both dimensions to landmarks produced a cognitive conflict, a primary effect, or a recency effect on distance estimation and route description.

3.3.3.1. Distance Estimation Descriptive Statistics

Now let us examine the relationship between distance estimates and their corresponding actual distances as measured from the route descriptions.

As each participant produced four distance estimates, there were 128 distance estimates in total (32 participants x 2 routes x 2 estimates). We found an overall significant correlation between estimate and actual distances, the Pearson's Correlation Coefficient $r_{(128)} = 0.21$, $p < .05$.

In each group, there were 64 distance estimates (18 participants x 2 routes x 2 estimates). In the FI group, there was no significant correlation between estimate and actual distances, $r_{(64)} = 0.19$, $p > .05$; in the IF group, the correlation between estimate and actual distance was marginal $r_{(64)} = 0.23$, $p = .067$.

This result suggests that having given ratings for frequency of visitation and importance of activity performed to landmarks prior to make the distance estimations has weaken the correlation between estimate and actual distances.

The descriptive statistics for distance estimations and actual distances for both FI and IF groups are displayed in Table 3.3.2a and Table 3.3.2b.

Table 3.3.2a: Descriptive Statistics for Distance Estimations (expressed in metres), for FI Group, in Experiment 3.

		Distance Estimated		Actual Distance	
	Direction				
		High - Low	Low - High	High - Low	Low - High
	Minimum	20.00	10.00	150.00	175.00
FI Group	Maximum	728.00	800.00	437.00	500.00
	Mean	221.75	204.41	293.62	327.31
	Std. Dev.	228.87	265.30	90.69	92.94
	Skewness	0.95	1.29	0.09	-0.01

Table 3.3.2b: Descriptive Statistics for Distance Estimations (expressed in metres), for IF Group, in Experiment 3.

		Distance Estimated		Actual Distance	
	Direction				
		High - Low	Low - High	High - Low	Low - High
	Minimum	35.00	25.00	150.00	175.00
IF Group	Maximum	2000.00	1200.00	575.00	575.00
	Mean	401.53	395.00	326.50	302.25
	Std. Dev.	454.85	309.65	111.11	101.57
	Skewness	2.90	1.48	0.26	1.32

Between groups, on average the FI group gave smaller estimates than the IF group. On average, within each group the distance in the high to low direction was slightly larger than the distance in the low to high direction. There was large variability as well as some positive skewness, and a negative skewness. We decided not to transform the data for the same reason we provided in previous experiments.

Now we turn to examining whether there are any significant differences in distance estimation between FI and IF groups that are due to the influence of direction, and version of estimation (initial vs. final). We performed the analysis of variance on distance ratio, and fixed the level of significance of the analysis at $p < 0.05$ throughout the analysis.

3.3.3.2. Distance Estimations Analysis

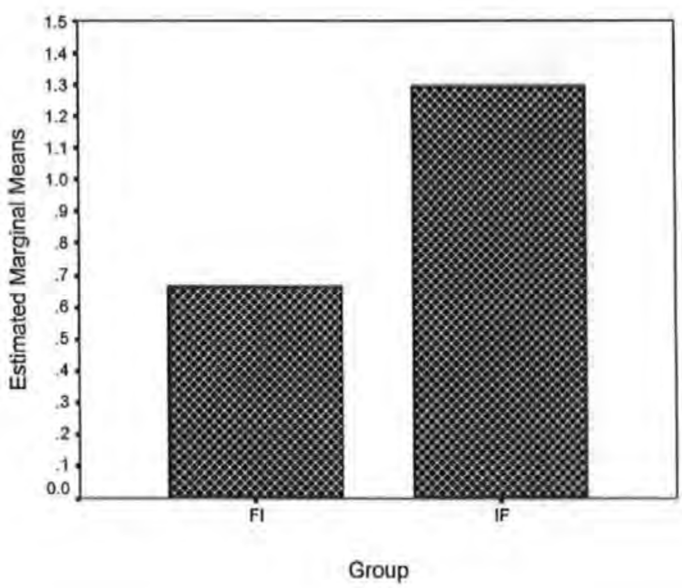
The analysis used was a 2 group (FI vs. IF) x 2 direction (high to low vs. low to high) x 2 estimation (initial vs. final) 3-way analysis of variance with repeated measures on the last two factors. This 3-way ANOVA was performed on distance ratio. The ANOVA results are shown in Table 3.3.3.

Table 3.3.3: Results of 3-Way ANOVA on Distance Estimation in Experiment 3.

Source	**df and F value**	**MS**	**Significance**
Group (G)	$F_{(1, 30)} = 3.621$	12.612	0.067
Direction (D)	$F_{(1, 30)} = 0.087$	0.036	ns
Estimation (E)	$F_{(1, 30)} = 1.203$	0.115	ns
G x D	$F_{(1, 30)} = 0.129$	0.054	ns
G x E	$F_{(1, 30)} = 0.647$	0.062	ns
D x E	$F_{(1, 30)} = 1.337$	0.019	ns
D x E x G	$F_{(1, 30)} = 2.519$	0.035	ns

No main effects of direction or version of estimation were found. However, there was a marginal main effect of group, displayed in Figure 3.3.1; participants in the FI group gave shorter distance estimates (ratio mean = 0.67) than participants in the IF group (ratio mean = 1.29).

Figure 3.3.1: Main Effect of Group on Distance Estimation, in Experiment 3.



No significant interactions were found.

In sum, the analysis on distance estimation revealed that overall having given ratings for both frequency of visitation and activity importance prior to evaluating distances from memory, the effect of group diminished. The FI group tended to give shorter and underestimated distances, whereas the IF group tended to give longer and overestimated distances. There was no asymmetry distance effect.

3.3.3.3. Route Descriptions Analysis

As each participant produced two route descriptions, there were 64 route descriptions in total (32 participants x 2 routes), which produced 1089 propositions overall.

Now let us examine whether there are any differences in the use of spatial perspectives in descriptions between FI and IF groups. Table 3.3.4 displays the overall percentage of participants who used survey only, route only, mixed (survey and route) or other categories of expressions exclusively.

Table 3.3.4: Mean percentage of participants who used survey only, route only, mixed (survey and route), and other categories expressions in Route Descriptions in Experiment 3.

	Groups	
	FI	**IF**
Use of Perspectives		
Survey	30%	10%
Route	13%	30%
Mixed	-	17%
Other Categories	57%	43%
	N = 16	N = 16

Table 3.3.4 shows that participants in the FI group used more survey perspective than route perspective expressions in their descriptions, while participants in the IF group used more route perspective than survey perspective expressions in their descriptions.

To test for significant differences in the use of perspective in route description between FI and IF groups, a t-test was performed on the ratio of route to survey perspective expressions. The result indicated that the ratio was significantly greater in the IF group (mean ratio = 0.56) than in the FI group (mean ratio = 0.38), $t_{(30)} = 2.73$, $p < .05$. This finding indicated that participants in the IF group privileged route perspective more than survey perspective in their descriptions, whereas participants in the FI group privileged survey perspective more than route perspective in their descriptions.

3.3.4. Discussion

Overall, the results replicated the findings in Experiment 1 and Experiment 2. However, in Experiment 3, the resulting priming effect of having rated both dimensions weakens the effect of group on distance estimation (marginal effect). Participants in the IF group tended to give larger distance estimates and overestimated distances, and in relation to route descriptions used more route perspective expressions than the FI group. The latter group tended to give shorter distance estimates, and underestimated distances, and produced more survey perspective expressions than the FI group.

The general pattern of the results in Experiment 3 seemed to suggest that although they were given both dimensions to rate, participants seemed to be primed by the first dimension they used for the ratings as reflected in subsequent distance estimation and route description. This finding supported our hypothesis on the primacy effect of the first rating dimension.

To assess whether the effect of rating landmarks with one dimension (Experiment 1) differed significantly from the effect of rating the same landmarks with both dimensions (Experiment 3), we wanted to compare the data from the first session in Experiment 1 with that of Experiment 3. The experiments were the same in all respects except that participants in Experiment 1 rated a single dimension whereas participants in Experiment 3 rated both dimensions.

3.3.5. Comparison

The analysis of variance was used to examine whether there was any significance in distance estimation as a function of the number of rating dimensions used to evaluate landmarks prior to making those estimations.

The analysis used was a 2 experiment (one dimension versus two dimensions) x 2 group (frequency F/FI versus importance I/IF) x 2 direction (high - low versus low - high) x 2 estimation (initial vs. final) 4-way analysis of variance with repeated measures on the last two factors. The 4-way ANOVA was performed on distance estimation, with N = 68 (36 + 32 participants in Experiment 1 and 2 respectively). The results of the analysis are displayed in Table 3.3.5.

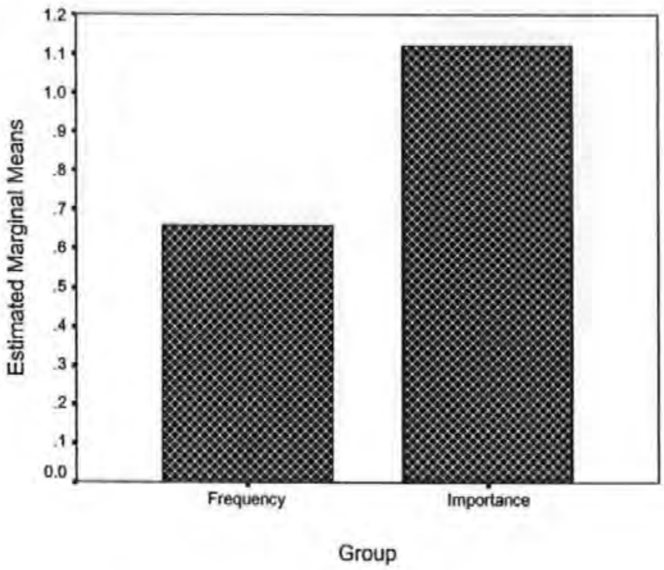
Table 3.3.5: Results of the Four-Way ANOVA on Distance Estimation in the Comparison between Experiment 1 and Experiment 3.

Source	df and F value	MS	Significance
Group (G)	$F_{(1, 64)} = 6.492$	14.468	*
Experiment (Exp)	$F_{(1, 64)} = 0.959$	2.137	ns
Direction (D)	$F_{(1, 64)} = 0.157$	0.066	ns
Estimation (E)	$F_{(1, 64)} = 0.324$	0.041	ns
G x Exp	$F_{(1, 64)} = 0.835$	1.861	ns
G x D	$F_{(1, 64)} = 0.068$	0.028	ns
G x E	$F_{(1, 64)} = 0.534$	0.067	ns
D x Exp	$F_{(1, 64)} = 0.001$	0.000	ns
D x E	$F_{(1, 64)} = 0.019$	0.001	ns
E x Exp	$F_{(1, 64)} = 3.825$	0.485	0.055
D x G x Exp	$F_{(1, 64)} = 0.615$	0.258	ns
E x G x Exp	$F_{(1, 64)} = 0.082$	0.010	ns
D x E x G	$F_{(1, 64)} = 0.170$	0.014	ns
D x E x Exp	$F_{(1, 64)} = 0.311$	0.025	ns
D x E x G x Exp	$F_{(1, 64)} = 0.297$	0.024	ns

Note. ns : $p > .05$; ** $p < .01$

No main effects of experiment, direction and estimation were found. However, there was a significant main effect of group on distance estimation as expected (see Figure 3.3.2). Overall, the frequency F/FI groups gave shorter distance estimates (ratio mean = 0.66) than importance I/IF groups (ratio mean = 1.12).

Figure 3.3.2: Main Effect of Group on Distance Estimation in the Comparison between Experiment 1 and Experiment 3.



There was a marginal interaction effect between estimation and experiment (displayed in Figure 3.3.3).

Figure 3.3.3: Interaction between Estimation and Experiment in the Comparison between Experiment 1 and Experiment 3.

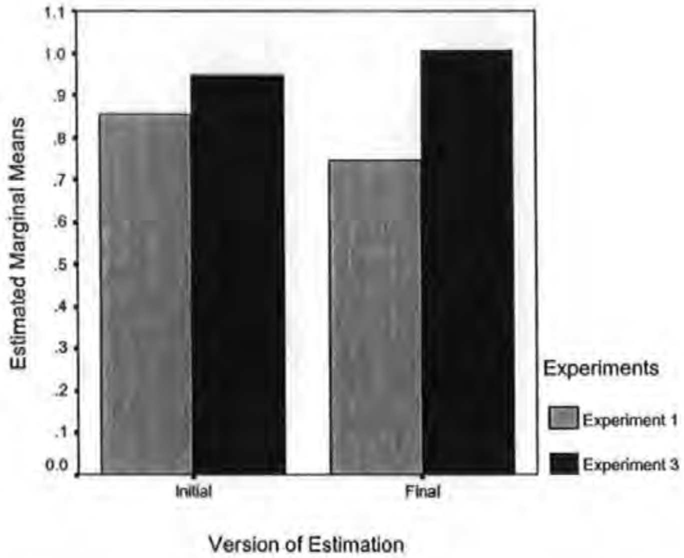


Figure 3.3.3 shows that while participants in Experiment 1 who rated a single dimension (frequency of visitation or importance of activity performed) revised their distance estimations downward, those in Experiment 3 who rated both dimensions (frequency of visitation and importance of activity performed) revised their estimations upward.

Now let us examine whether there were any differences in the use of perspective expressions in descriptions between Experiment 1 and Experiment 3. The analysis used was a between-subjects 2-way analysis of variance with 2 experiment (one dimension vs. two dimensions) x 2 group (frequency F/FI vs. importance I/IF). The 2-way ANOVA was performed on the ratio, with N = 68 (36 + 32 participants in Experiment 1 and 2 respectively). The result of the analysis is displayed in Table 3.3.6.

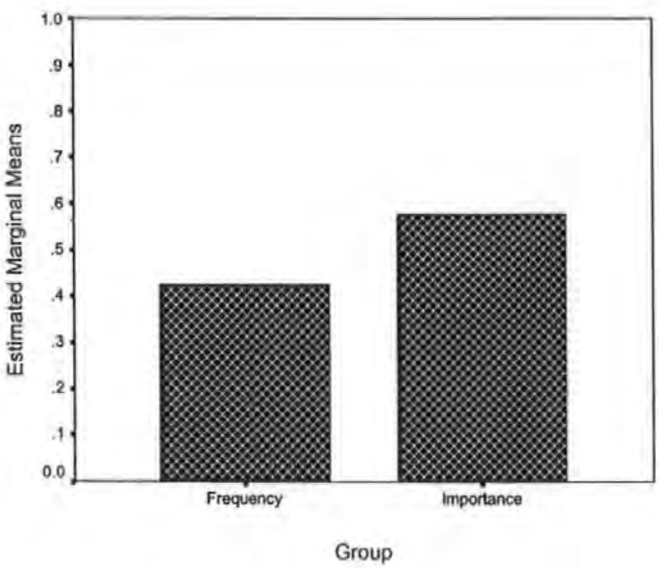
Table 3.3.6: Route Descriptions Comparison between Experiment 1 and Experiment 3.

Source	df and F value	MS	Significance
Group (G)	$F_{(1, 54)} = 9.277$	0.281	**
Experiment (Exp)	$F_{(1, 54)} = 1.374$	0.041	ns
G x Exp	$F_{(1, 54)} = 0.363$	0.011	ns

Note. ns : $p > .05$; ** $p < .01$

There was a highly significant main effect of group on the ratio as expected. Overall, participants in the frequency F/FI groups used more survey perspective expressions in their descriptions, while those in the importance I/IF groups used more route perspective expressions in their descriptions (see Figure 3.3.4).

Figure 3.3.4: Main Effect of Group on Route Descriptions in the Comparison between Experiment 1 and Experiment 3.



There was no significant interaction.

3.3.6. Further Discussion

The pattern of results in Experiment 3 suggested that although they were given both dimensions to rate, participants seemed to be primed by the first dimensions they used to undertake the ratings of landmarks prior to making distance estimations and giving route descriptions.

The distance estimated using importance of activity as first cue produced larger distance estimates, while the use of frequency of visitation as first cue produced shorter distance estimates. In relation to route descriptions, there was also a priming effect on the use of perspectives. Giving ratings for frequency of visitation as first criteria for undertaking the evaluation of landmarks, primed towards the use of more survey perspective expressions, while having given ratings for importance of activity primed towards the use of route perspective expressions. This result replicated Experiment 1 and Experiment 2.

In our previous experiments, participants were given in advance lists of landmarks (22 landmarks) to rate for frequency of visitation or importance of activity (Experiments 1 and 2) or both dimensions (Experiment 3). The recall of landmarks from memory strongly relies on one's own cognitive maps of the environment. It would be of most interest to have participants generating their own lists of landmarks, and to examine whether they could recall/list more or fewer landmarks than the one that was used in the previous experiments, and at the same time to explore how they go about generating them. They may be generating them based on thinking about the activities that they are performing at those landmarks, or they may be generating based on a composite of the familiarity and the activities involved at those landmarks. We also approached the landmark's saliency through the rating scores differently in order to see whether we get the same effect with less difference in the rating scores. In that case, low saliency landmarks were selected as those that were given middle rating scores of the 1 to 10 Likert scale, in this case the rating of 5 (or near to 5), high-saliency landmarks were those given the highest rating scores, in this case 10 (or near to 10).

We wanted to assess the influence of contextual priming by using participants' own lists of landmarks, on which they rated for both frequency of visitation and importance of activity performed.

If the primacy effect were strong, then we would expect that the FI group would underestimate distances and would use more survey perspective expressions than route perspective expressions in descriptions. We expected the IF group to give overestimated distances and to use more route perspective than survey perspective expressions in descriptions.

However, if the recency effect prevailed over the primacy effect, then the FI group would overestimate distances, whereas the IF group would underestimate distances. In relation to route description, the FI group would use more route perspective than survey perspective expressions; the IF group would use more survey perspective than route perspective expressions.

In the next experiment, we manipulated direction as a between-subjects factor in an experimental design that combined the two levels of direction (high-low vs. low-high) with the two levels of condition (FI vs. IF). This procedure was used to avoid carry over effect of direction. All participants were initially required to produce their own exhaustive list of landmarks known to them on the same college campus; then they were asked to give ratings for both dimensions, frequency of visitation and importance of activity, prior to make distance estimation and route description. All participants gave one distance estimation and provided one route description.

3.4. Experiment 4

3.4.1. Introduction

The results of Experiments 1, 2, and 3 suggested that participants seemed to be primed by the first dimension they used to undertake the ratings of landmarks prior to making distance estimations and giving route descriptions. In all three experiments, participants were given lists of landmarks to rate for frequency of visitation or importance of activity performed.

However, the recall of known landmarks from memory would strongly rely on participants' individual cognitive maps of the university campus. In Experiment 4, we wanted to assess the influence of contextual priming by using participants' own lists of landmarks, on which they rated for both frequency of visitation and importance of activity performed (FI and IF). We also approached the landmark's saliency through the rating scores differently in order to see whether we get the same effect with less difference in the rating scores. In the present experiment, low saliency landmarks were those with middle rating scores of the 1 to 10 Likert scale, i.e., the rating of 5 (or near to 5), high-saliency landmarks were those with the highest rating scores, i.e., 10 (or near to 10).

It was assumed that if the primacy effect prevailed, then we would expect that the FI group would underestimate distances, and would use more survey perspective than route perspective expressions in descriptions; we would expect the IF group to overestimate distances and to use more route perspective than survey perspective expressions in descriptions.

On the other hand, if the recency effect prevailed over the primacy effect, then we would observe the FI group to overestimate distances, and to use more route perspective than survey perspective expressions; whereas the IF group would underestimate distances, and would use more survey perspective than route perspective expressions.

Experiment 4's design combined the two levels of direction (high-low vs. low-high) with the two levels of condition (frequency vs. importance) resulting in four distinct groups in order to avoid any carry-over effects with regard to the direction of estimation. All participants were initially required to produce their own exhaustive list of landmarks known to them on the same college campus; then they were asked to give ratings for both dimensions, frequency of visitation and importance of activity prior to making distance estimations and giving route descriptions. All participants gave one distance estimation, and provided one route description.

3.4.2. Method

The method was similar to that used in Experiment 3, but instead of providing participants with a list of landmarks of the university campus, they had to generate their own list of landmarks they knew within the campus. Low-saliency landmarks were those with the rating score 5 (or near to 5), high-saliency landmarks were those with the rating score 10 (or near to 10).

To measure the actual distances, the experimenter walked the routes as described in route descriptions; this procedure was to ensure that the actual distances were similar to those measured on the scaled map in the previous experiments. The general structure of the methodology remained unchanged.

3.4.2.1 Experimental Design

The design used was a 2 condition (frequency vs. importance) x 2 direction (high - low vs. low - high) x 2 estimation (initial vs. final) mixed design with repeated measures on the last factor. The between-subjects factors were condition and direction.

All participants gave distance estimates and descriptions for one pair of landmarks in one direction only (high - low or low - high).

3.4.2.2 Participants

Sixty-four undergraduate students between 18 and 45 years old (mean age = 24.17, SD = 7.72) took part in the experiment in exchange for course credit. Participants had attended the University between three and six months (mean time of attendance = 3.79 months, SD = 1.01).

An equal number of participants were randomly assigned to one of four conditions as shown in Table 3.4.1 below.

Table 3.4.1: Experimental groups in Experiment 4.

		Direction	
		High to Low	Low to High
Condition	Frequency	FIHi	FILo
	Importance	IFHi	IFLo

Two groups of participants were anchored with frequency of visitation ratings and then gave importance of activity ratings (hereafter FIHi group and FILo group), and another two groups of participants were anchored with importance of activity ratings and then gave frequency of visitation ratings (hereafter IFHi group and IFLo group). Additionally, while one frequency group (FILo) and one importance group (IFLo) estimated the distances in the low to high direction, the other two groups (FIHi and IFHi) estimated the distances in the high to low direction.

Each participant had the task of producing their own lists of landmarks first, then they were asked to rate landmarks for frequency of visitation and importance of activity. Then they were asked to make distance estimation followed by route description.

3.4.2.3 Procedure

The procedure used was similar to that used in Experiment 3, however instead of screening for known landmarks on the list provided, participants had to produce their own lists of landmarks.

Participants were tested individually. The test lasted about 15 minutes. At the beginning, participants were given two minutes during which to write down on a sheet of paper as many landmarks on the campus as they could recall.

After they had listed landmarks in the campus known to them, half the participants (the FI groups) were asked to give ratings for frequency of visitation first to be written in one of the margins on the paper opposite individual landmarks. Once the ratings were done participants handed over the paper to the experimenter. The experimenter scanned the list and picked up 2 landmarks, one with the highest score (10), and another with a middle score (5), and then she folded the paper margin over. She then handed the paper back to the participants and asked them to give ratings for the second dimension (activity importance) in the other paper's margin opposite individual landmarks - the paper's margin was folded to avoid interference with the second set of ratings. In the same manner, the remaining participants (the IF groups) were asked to give importance of activity ratings first followed by the ratings for frequency of visitation.

The pair of landmark chosen from the first set of ratings was then presented back as direction high to low (10 $\rightarrow$ 5) or as direction low to high (5 $\rightarrow$ 10) to the participants for distance estimation and route description. Table 3.4.2 displays the sequential procedure used in this experiment.

Table 3.4.2: Diagram of the Sequence of the Interview, in Experiment 4.

• **Participants generating their own lists of landmarks**
↓
Ratings for Frequency (or Importance)
↓
Ratings for Importance (or Frequency)
↓
Filler questionnaire
↓
Initial Distance Estimation
↓
Route Description
↓
Filler questionnaire
↓
Final Distance Estimation
↓
Giving general information (genre, age, attendance) •

3.4.3. Results

3.4.3.1. Landmarks' Lists

Before we go onto the analyses of distance estimation, first, we want to examine the selection of landmarks between groups.

As shown in Table 3.4.3, participants in both conditions listed similar landmarks. This was expected given that participants were all students sharing many common goals and routines, and they had all been on campus for a relatively short period of time. It is not surprising that the buildings rated high and low in frequency of visitation or importance of activity were similar between groups, and hence were selected for distance estimation and route description.

Table 3.4.3: List of Landmarks used for Distance Estimation and Route Description for Frequency and Importance Groups, in Experiment 4.

	Frequency Group	**Importance Group**
Subjects		
1	Pitts – Students Union	Library – Students Union
2	Link – Davy	Link – Babbage
3	Robbins – Link	Pitts – Hoe
4	Link – Mary Newman	Link – Portland Villas
5	Library – Portland Villas	Robbins – Students Union
6	Pitts – Link	Link – Babbage
7	Pitts – Students Union	Pitts – Portland Villas
8	Library – Babbage	Pitts – Mary Newman
9	Pitts – Babbage	Library – Portland Villas
10	Sherwell – Library	Pitts - Babbage
11	Sherwell - Babbage	Sherwell – Robbins
12	Link – Cash Point	Link – Babbage
13	Students Union – Babbage	Merrifield – Mary Newman
14	Isaac Foot – Babbage	Sherwell – Ocean Science
15	Link – Portland Villas	Link – Babbage
16	Pitts – Squash Courts	Library – Babbage
17	Bookshop – Library	Students Union – Library
18	Students Union – Robbins	Robbins – Students Union
19	Babbage – Pitts	Babbage – Link
20	Library – Pitts	Portland Villas – Pitts
21	Davy – Pitts	Scott – Library
22	Davy – Pitts	Babbage – Robbins
23	Babbage – Pitts	Portland Villas – Scott
24	Main Hall – Babbage	Robbins – Mary Newman
25	Babbage – Mary Newman	Pitts – Library
26	Scott – Pitts	Scott – Link
27	Babbage – Link	Row Street – Sherwell
28	Library – Students Union	Fitzroy – Sherwell
29	Library – Davy	Isaac Foot - Link
30	Students Union – Link	Isaac Foot – Link
31	Library – Link	Isaac Foot - Link
32	Mary Newman - Sherwell	Library - Scott

Now let us look at the correlation between the ratings for landmarks. There were 144 ratings in total (64 participants x 2 ratings). There was a highly significant correlation between the rating dimensions (frequency of visitation and importance of activity), the Pearson Correlation Coefficient $\underline{r}_{(128)} = 0.77$, $\underline{p} < 0.0001$.

In the FI groups, the correlation between the rating dimensions was also highly significant, $\underline{r}_{(64)} = 0.62$, $\underline{p} < 0.0001$; in the IF groups, similarly the correlation between the rating dimensions was also highly significant, $\underline{r}_{(64)} = 0.88$, $\underline{p} < 0.0001$. These results were expected.

3.4.3.2 Distance Estimation Descriptive Statistics

As each participant produced two distance estimates (one initial and one final), there were 128 distance estimates in total (64 participants x 2 estimations). There was a highly significant correlation between distance estimates and actual distances, the Pearson's Correlation Coefficient $\underline{r}_{(128)} = .42$, $\underline{p} < .0001$.

Table 3.4.4, displays descriptive statistics in relation to the number of landmarks listed by participants, distance estimation, and actual distance. It shows that participants in both conditions recalled on average 11 landmarks; however in distance estimation on average the FI groups gave larger estimates than the IF groups.

There were also large variability and some skewness, suggesting departure from normality. However, we decided not to transform the variables for the same reason given in the previous experiments.

Table 3.4.4: Descriptive Statistics in Experiment 4.

		Frequency (FI)	Importance (IF)
Number of Landmarks	Minimum	6.00	8.00
	Maximum	17.00	19.00
	Mean	10.68	11.41
	Std. Dev.	2.57	2.54
	Skewness	0.39	0.81
Estimated Distances (in metres)	Minimum	25.00	14.00
	Maximum	1500.00	800.00
	Mean	383.64	309.31
	Std. Dev.	278.91	234.84
	Skewness	1.16	0.74
Actual Distances (in metres)	Minimum	20.00	22.00
	Maximum	524.00	1092.00
	Mean	281.10	329.59
	Std. Dev.	142.43	230.22
	Skewness	0.01	1.52

Now let us examine whether there are any significant differences between FI and IF groups. We performed the analysis of variance on distance ratio, and fixed the level of significance of the analysis at $p < 0.05$ throughout the analysis.

3.4.3.3. Distance Estimation Analyses

The analysis used was a 2 condition (FI vs. IF) x 2 direction (high - low vs. low - high) x 2 estimation (initial vs. final) 3-way analysis of variance with repeated measure on the last factor. This 3-way ANOVA was performed on distance ratio. The results are displayed is Table 3.4.5.

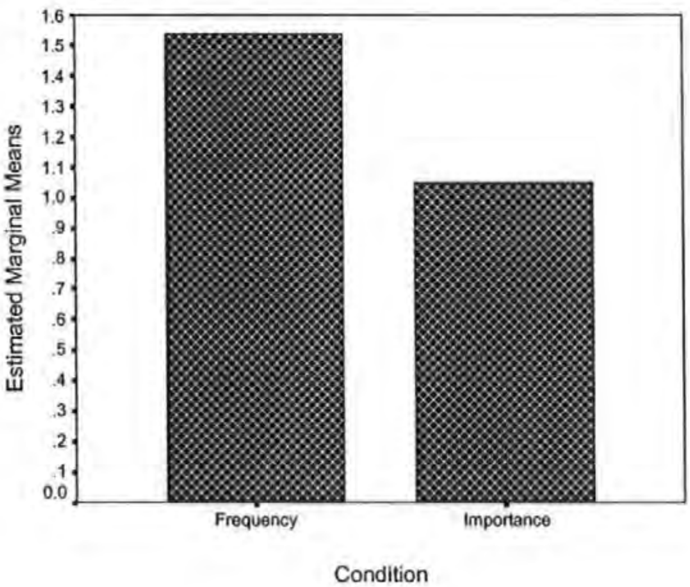
Table 3.4.5: Results of the 3-Way ANOVA on Distance Estimation in Experiment 4.

Source	df and F value	MS	Significance
Condition (C)	$F_{(1, 60)} = 4.357$	7.561	*
Direction (D)	$F_{(1, 60)} = 0.000$	0.000	Ns
Estimation (E)	$F_{(1, 60)} = 0.148$	0.032	Ns
C x D	$F_{(1, 60)} = 0.212$	0.368	Ns
C x E	$F_{(1, 60)} = 0.225$	0.048	Ns
D x E	$F_{(1, 60)} = 0.134$	0.029	Ns
D x E x C	$F_{(1, 60)} = 0.002$	0.000	Ns

Note. ns: $p > .05$; *: $p < .05$

No main effects of direction or estimation were found. However, there was a main effect of condition on distance ratio. Overall, participants overestimated distances; the IF groups gave smaller distance ratios (mean ratio = 1.05) than the FI groups (mean ratio = 1.54), displayed in Figure 3.4.1. Note that this is the first time the frequency groups produced over-estimation in the series of experiments outlined thus far.

Figure 3.4.1: Main Effect of Condition on Distance Estimation, in Experiment 4.



None of the interaction effects were significant. Now let us examine the analysis of route descriptions.

3.4.3.4. Route Description Analysis

As each participant provided one route description, there were 64 route descriptions in total, which produced overall 1113 propositions. Now we want to examine whether there are any differences in the use of spatial perspectives in route descriptions between FI and IF groups. Table 3.4.6 displays the overall percentage of participants who used survey only, route only, mixed (survey and route) or other categories of expressions exclusively.

Table 3.4.6: Overall percentage of participants who used survey only, route only, mixed (survey & route) or other categories of expressions in Route Descriptions, in Experiment 4.

	Groups	
	FI	**IF**
Use of Perspectives		
Survey	31%	25%
Route	22%	25%
Mixed	6%	9%
Other Categories.	41%	41%

As shown in the Table 3.4.6, participants in the FI groups produced more survey perspective than route perspective expressions; while those in the IF groups produced the same proportions of route and survey perspective expressions.

To look for significant differences in the use of perspective in route description, a t-test was used on the ratio of route to route plus survey perspectives. The result showed no significant difference, $t(20) = 0.98$, $p > .05$. Although the difference between groups did not reach significance, the IF groups tended to use more route perspective than survey perspective expressions (the mean ratio was 0.52); the FI groups tended to use more survey perspective than route perspective expressions (the mean ratio was 0.48).

3.4.4. Discussion

The manipulation in Experiment 4 showed the influence of groups on distance estimation as in Experiments 1, 2, and 3. However, Experiment 4 also revealed a few new results:

1) The distances were overestimated in general
2) The FI groups exaggerated distances
3) No difference in the use of perspective expressions in descriptions between groups.

It was assumed that if there was a primacy effect the FI group would underestimate distances, and would use more survey perspective than route perspective expressions in descriptions; the IF group would overestimate distances and would use more route perspective than survey perspective expressions in descriptions. If there was a recency effect, the FI group would overestimate distances, would use more route perspective than survey perspective expressions; whereas the IF group would underestimate distances, and would use more survey perspective than route perspective expressions. The results in Experiment 4 did not support our hypotheses regarding primacy or recency effects.

In general, the distance estimation was more pronounced in Experiment 4 as compared across experiments. How do we explain the overall overestimation in both conditions in Experiment 4?

The general overestimation in Experiment 4 may be due to a combination of task demands and the implicit scaling process. Prior to making distance estimations and giving route descriptions participants in Experiments 3 and 4 had made the evaluations of landmarks based on both rating dimensions (frequency of visitation and importance of activity). In Experiment 4, although the effect of condition was strong, it may have reduced the implicit scale, i.e., the availability of the number landmarks (near or distant or both) in working memory. This claim is supported by the fact that in Experiment 4, the number of landmarks generated by the participants themselves was much reduced (mean = 11) compared to the 22 landmarks given to rate in Experiments 1 to 3 ($t_{(98)} = 25.61$, $p < .0001$). According to implicit scaling models (Holyoak & Mah, 1982; McNamara & Diwadkar, 1997), a small implicit scale would increase the discriminability between landmarks, therefore overestimation of the distances would be expected, which was the case in Experiment 4 where both groups of participants overestimated distances.

There was no difference between groups in the use of perspective expressions in route descriptions in Experiment 4. It may be that because the lack of power in the study (the number of participants is quite low) and because there was only one route description per participant, this was not powerful enough to yield significant effect of condition on the use of perspectives in route descriptions.

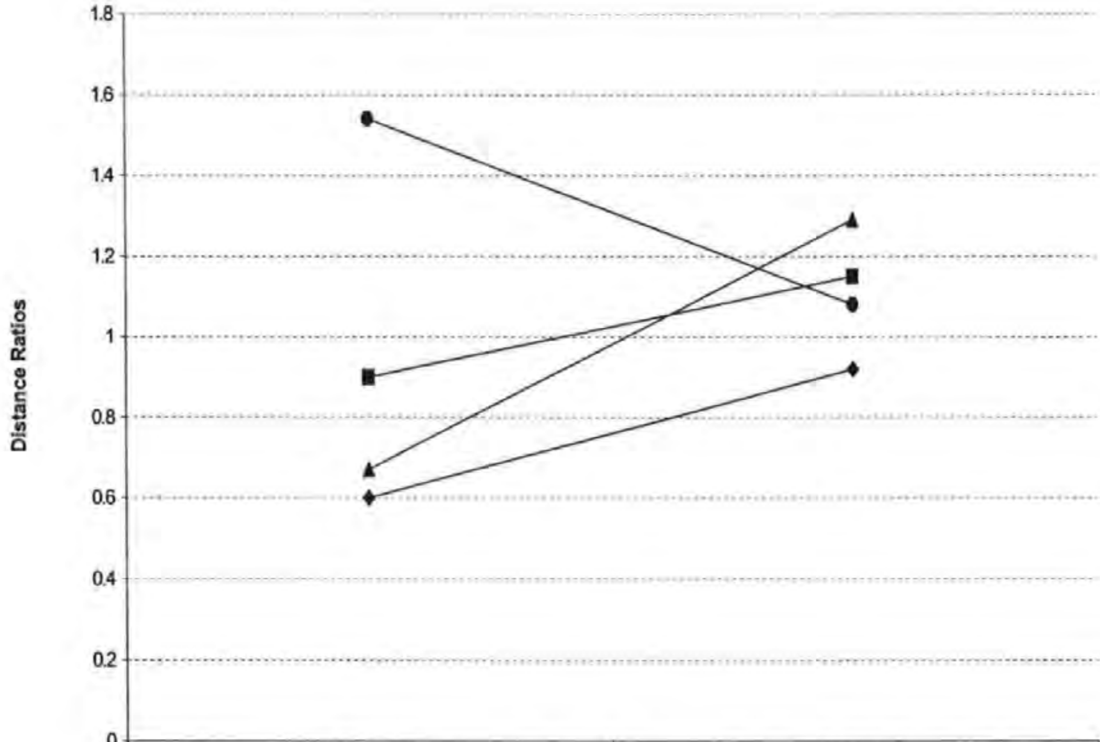
How could we explain the fact that the FI groups gave overestimation of distances in Experiment 4 whereas they gave underestimated distances in Experiment 3, and the frequency groups gave underestimates in Experiments 1 and 2?

To begin with, in experiments 1, and 2 it is meaningless to talk about a recency effect because only one dimension (frequency of visitation or importance of activity) was used to rate landmarks prior to making distance estimations and giving route descriptions.

In experiment 3 however, it looks like primacy effects were present in distance estimation and route description. Indeed, the distance estimated using importance of activity as first cue (the IF group) produced larger distance estimates, while the use of frequency of visitation as first cue (the FI group) produced shorter distance estimates. Additionally, giving ratings for frequency of visitation as first criterion for undertaking the evaluation of landmarks (the FI group), primed towards the use of more survey perspective expressions, while having given ratings for importance of activity (the IF group) primed towards the use of route perspective expressions.

Figure 3.4.2 displays the summary of distance ratios across experiments assuming primacy effects in Experiments 3 and 4. It may be the case that because of the primacy effect, the FI groups drew upon survey representation from memory to derive route distance estimates. This however would result in underestimation of distances as we had seen in previous experiments (Experiments 1 - 3). Therefore, the results of Experiment 4 cannot be explained in terms of primacy effects.

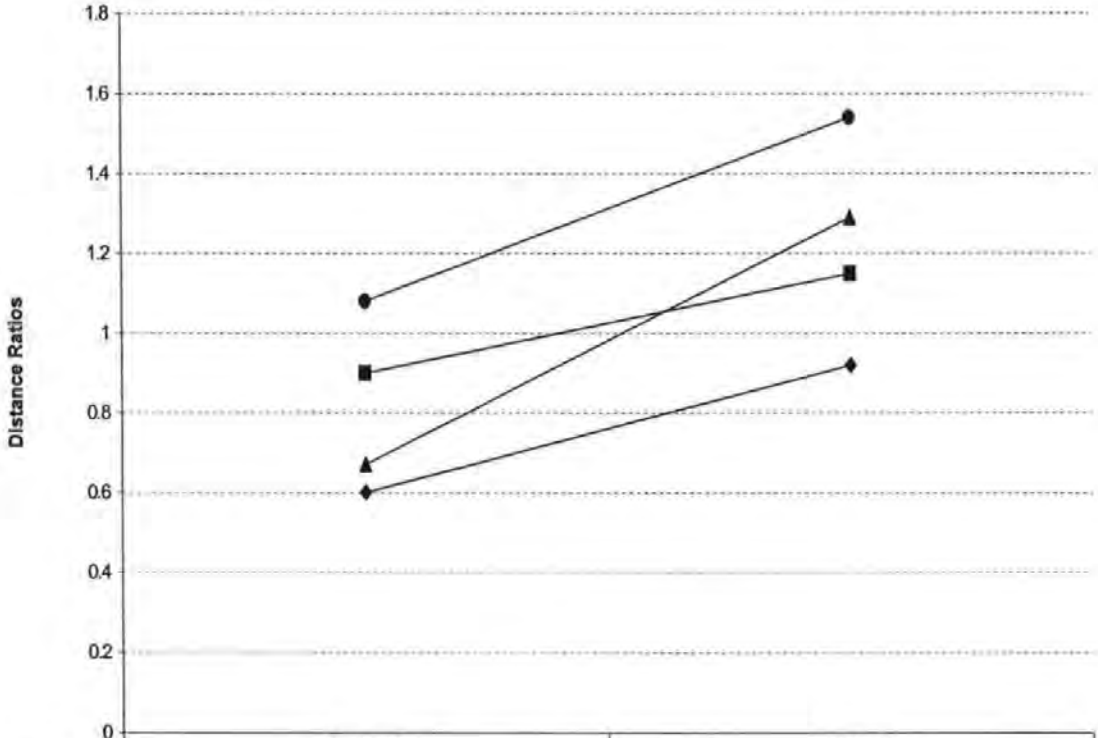
Figure 3.4.2: Summary of the Distance Ratios across Experiments in the case of Primacy Effects in Experiment 4.



	Frequency	Importance
Exp.1	0.6	0.92
Exp.2	0.9	1.15
Exp.3	0.67	1.29
Exp.4	1.54	1.08

Alternatively, let us examine the possibility of a recency effect in Experiment 4. Figure 3.4.3 displays the summary of distance ratios across experiments in the case of a recency effect in Experiment 4.

Figure 3.4.3: Summary of the Distance Ratios across Experiments in the case of Recency Effects in Experiment 4.



	Frequency	Importance
Exp.1	0.6	0.92
Exp.2	0.9	1.15
Exp.3	0.67	1.29
Exp.4	1.08	1.54

In Experiment 4 because of a recency effect, the group FI drew upon route based representation from memory to derive route distance estimates which resulted in relatively larger and overestimated distances, therefore, the result was similar to those results we observed in previous experiments (Experiments 1 - 3). However, a recency effect was only partly conclusive in explaining the overestimation produced by the FI group, as route description data did not support the claim.

To explore further the inconsistency between Experiment 3 and Experiment 4, we have to consider the differences between experiments. In Experiment 4, the choice of landmarks for distance estimations and route descriptions was based on mid ratings for the non-landmarks. Compared to Experiment 3, the difference between the ratings of the origin and destination landmarks was reduced considerably in Experiment 4. The difference in the saliency of landmarks may have affected the type of distance estimates participants have produced. However, one might have expected that would have affected distance estimates for both groups (FI and IF) not just for one of the groups. This seems unlikely as a satisfactory explanation.

A second possible explanation may be that because participants must first generate their own list of landmarks, it could be that individually they were thinking about landmarks based on a range of dimensions, prior to giving ratings for frequency of visitation and importance of activity to those landmarks. Therefore, it seems plausible that they were anchored in the generation of landmarks rather than in the ratings of landmarks.

Most interestingly, the individual differences in the generation of landmarks were not explored in any studies. In future experiments, we may want to examine more carefully how people generate the landmarks, for example by separating people out based on how they are generating the landmarks rather than just the rating dimensions.

Finally, there were no asymmetrical distance effects. It may be the case that the asymmetry does not exist for route distances that were estimated from memory.

3.5. General Discussion

The aim of the series of experiments we have just reported was to investigate a potential explanation for the errors and the asymmetry effects in distance estimation. We considered a new possibility that the contexts established at the time of retrieving spatial information from memory cued action related representations, which subsequently influenced distance estimation and route description.

The results of the first three experiments were consistent. However, the generalisation of the findings across the first three experiments did not fit with the results of Experiment 4, in which participants generated their own landmarks. It is still uncertain why these results occurred. A future study should investigate the generation process, and examine if there is indeed the case that there are individual differences in the criteria participants actually used to generate landmarks. This may lead to systematic relations between how landmarks are generated and distance estimates that are produced subsequently.

In relation to the asymmetry distance effect, we failed to replicate the effect found by Sadalla, Burroughs, and Staplin (1980), and predicted by the implicit scaling models (Holyoak & Mah, 1982; McNamara & Diwadkar, 1997). This may have been due to differences in the methods of measurement used. While Sadalla et al. measured Euclidean distance estimates using a distance placement method, we recorded verbal distance estimates and measured route distances as traversed by participants in their descriptions. Other studies have also reported the failure to replicate asymmetry in distance estimation (e.g., Holding, 1992), suggesting that either the asymmetry effect in cognitive distance does not exist or exists only under certain circumstances.

The use of this different methodology however has unveiled other context effects, which have been hitherto undocumented. People were being primed by the dimension or perspective they were taken on the landmarks during the ratings, but in Experiment 2 they appeared to be primed by the types of distance estimation to be estimated as well (route distance or Euclidean distance). Furthermore, the perspectives that they took of the landmarks also influenced subsequent route descriptions.

Our results can be interpreted in three different ways. One possibility is that cognitive maps may not be in a single form (e.g., survey or route), but rather a composite of types of representations, which allow flexibility in use and contextual manipulation. Another possibility is that cognitive maps are partial and incomplete representations, which require cueing to flesh them out. The final possibility is that cognitive maps are complete and are in a single format, but that cueing on retrieval contaminates this representation in some way.

In our view, the first two possibilities seem most likely. In the present study, participants learned about their environments probably through navigation aided by maps. It is likely therefore that the cognitive maps they have of their environments involve survey and route information (either complete representations or partial representation), and that priming on retrieval cues or selectively activates the relevant aspects of the representation.

In relation to distance estimation, priming in terms of frequency leads to access of survey type representations, leading to underestimation of route distances, while priming in terms of importance leads to access of route knowledge, leading to more accurate route distance estimates. This pattern of results is consonant with those found by Taylor and Naylor (2002). However, while Taylor and Naylor found that spatial goals and learning method affect distance estimation, our results show for the first time a similar pattern of results for retrieval context effects. Furthermore, the way in which the task is presented can also affect the implicit scaling process used, consonant with the work of McNamara and Diwadkar (1997).

It is likely that learning about one's environment over time leads to rich flexible representations, which can be accessed in different ways dependent on contexts (Golledge & Spector, 1978). In the present study, the contexts evoked during the ratings for landmarks, produce a particular conceptualisation of the relationship between landmarks. This simulation may trigger action-based representation in memory which selectively activates relevant information that is subsequently used for distance estimation and route description. This view is in line with the evidence from the embodied cognition literature (e.g., Barsalou, 1999; Glenberg, 1997). Following Barsalou (1999), thinking in one perspective or in another consists of the perceptual simulation of the corresponding interaction with the environment in order to retrieve distance information from memory. In terms of the frequency of visitation, the processing of the relationship between landmarks involves thinking of how many times one has visited those places. This representation may tap the survey knowledge of that environment, and the use of survey representation produces short route distance estimates (Taylor & Naylor, 2001; Thorndyke & Hayes-Roth, 1982). On the other hand, the processing of the relationship between the same landmarks in terms of the importance of activity involves the simulation of the interaction at those landmarks, which cue action based representation. This representation may tap the route knowledge of that environment, and the use of route representation produces longer and accurate route distances (Taylor & Naylor, 2001; Thorndyke & Hayes-Roth, 1982). Supporting evidence for this is that the importance group also produced a greater ratio of route style descriptions to route and survey style descriptions than the frequency group.

A third category of route description was found, as a good proportion of the participants across the experiments were not using perspective expressions in their route descriptions. Rather they produced procedural commands, which suggested that they mentally simulated the walk from one place to another and verbalised the instructions as route descriptions. Although these participants differ in the way they produce distance estimation as a function of the rating dimensions used, they seem to privilege procedural memory, which encodes motor skills and other kinds of automatic processing.

It seems clear from the present study that action or motor representation is implicated in the processing of distance and route description from memory. Redish (1999), having reviewed the vast literature on the rodent hippocampus (and other animals as well), notes that there are two key empirical effects on the existence of cognitive maps in the hippocampus. First, place cells only show activity in a limited portion of the environment; second, lesions of the hippocampus in rodents degrade navigational ability, and in primates (particularly humans) cause severe anterograde amnesia. Anterograde amnesia is a selective memory deficit, resulting from brain injury, in which the individual is severely impaired in learning new information. Memories for events that occurred before the injury may be largely spared, but events that occurred since the injury may be lost. Each of these two effects (the decrease in navigational ability and the anterograde amnesia) has driven a major theory, (1) that the hippocampus stores a cognitive map for navigation, and (2) that the hippocampus stores memories of events temporarily for eventual long term storage in the cortex.

The results of the series of experiments we have just reported also suggest that memory of events or memory of action may also be important in human cognitive maps. As our study is about human spatial memory in general, we ask ourselves the following question: <u>what are cognitive maps for?</u> We daily experience numerous situations in which we have to find our way travelling in spatially complex environments. In this context, cognitive maps are for enabling us to recognise important places in an environment and enabling us to physically move around and interact with the environment, therefore, what cognitive maps are for would be to facilitate action.

The next chapter moves on to examine more directly the role of action on cognitive maps. The main goal in Chapter 4 is to examine the influence of action on distance estimation during navigation through the environment. We conduct three experiments in which visual information was strictly controlled in order to isolate the influence of action on distance estimation. The investigation will focus on the effect of turns on walking distances to assess the mental mechanisms that mediate why complex routes (with many turns) were estimated differently from less complex ones.

In Chapter 4, we will describe in detail the reason why visual information and motor feedback information must be experimentally controlled, and the methodology we develop to investigate the influence of action on distance estimation.

4. CHAPTER 4: INFLUENCE OF ACTION

4.1. Introduction

The series of experiments undertaken in Chapter 3 has shown that there is flexibility in the way spatial information is reconstructed.

People are primed by the dimension or perspective they take during the ratings of landmarks. But they appear to be primed by the types of distance (route distance or Euclidean distance) to be estimated as well. The perspectives they take on the landmarks also influence subsequent route descriptions. In terms of the frequency of visitation, the processing of the relationship between landmarks involves thinking of how many times one has visited those places. This representation may tap the survey knowledge of that environment, and the use of survey representation produces short route distance estimates (Taylor & Naylor, 2002; Thorndyke & Hayes-Roth, 1982). On the other hand, the processing of the relationship between the same landmarks in terms of the importance of activity performed at those landmarks involves the simulation of the interaction at those landmarks, which may cue action-based representations. This representation may tap the route knowledge of that environment, and the use of route representations produces accurate route distances (Taylor & Naylor, 2002; Thorndyke & Hayes-Roth, 1982).

Supporting evidence for this is that the importance group also produced a greater ratio of route to route plus survey perspective expressions than the frequency group.

It seems clear from the results of our first series of experiments that action or motor representation may be implicated in the processing of distance and route description from memory; cognitive maps are not only abstract representations of the environment, but they are also action-based representations. However, the experiments reported thus far have not manipulated action when learning routes; rather they cued remembering action. If the explanation put forward is correct, manipulating action when learning a route should also affect cognitive distance.

In the following chapter, we report the results of three experiments that directly manipulated action and measured distance estimation under strict control of visual information. We manipulated the influence of number of turns on traversed distances to assess the mental mechanisms that mediate why complex routes were estimated differently from less complex ones.

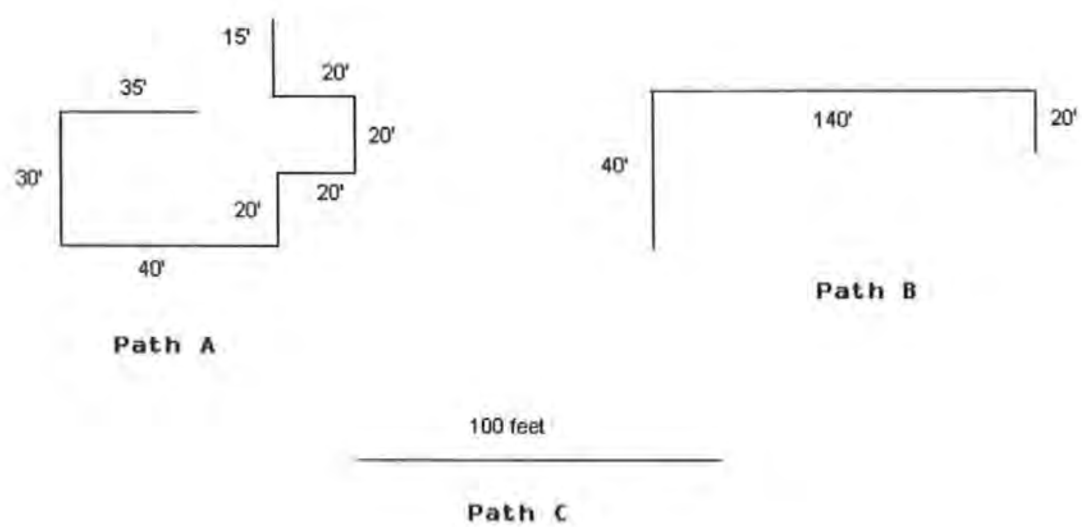
In this chapter we consider previous studies where action has been manipulated during learning. The aim of the chapter is to illustrate some problems regarding issue of control in these studies and also the interpretations of the results.

In the next section we examine in more detail literature on the manipulation of the number of turns and models of the explanation of the effect of turn on distance estimation. We also examine literature that tests the idea that action and spatial representation are related.

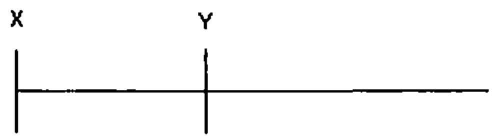
4.2. Influence of Number of Turns

Sadalla and Magel (1980) asked participants to walk paths that were laid out with masking tape on the hallway floors of the psychology building of the Arizona State University. Two paths were of equal lengths (200 feet), one contained 7 right angle turns (Path A), the other contained 2 turns (Path B). Another path measuring 100-feet was a straight path (Path C) which was always presented last (see Figure 4.1). Participants were allowed to walk up and down the path once or three times (familiarity). The amount of time taken to walk the paths was measured for each participant.

Figure 4.1: Paths layout (Illustration adapted from Sadalla & Magel, 1980)



Immediately after completing the task, participants were asked to make a distance estimation using ratio estimation: they were told that line XY represents the length of Path C they walked.



So beginning with X as one point, they had to mark off the length of Paths A and B on this line. Participants were also asked to draw Paths A and B. Responses to both distance estimation and the drawing tasks were measured in millimetres. The most interesting results were that number of turns contained in each path had a highly significant influence on the perception of length. Paths with 7 turns were estimated as being longer than those with 2 turns. Drawings of the paths also yielded data supporting the number of turns effect. Paths with 7 turns were drawn significantly longer than those with 2 turns. No effect of travel duration on distance estimation was found; participants required no more time to walk the 7 turn pathways (average 95 seconds) than they required to walk the 2 turn pathways (average 93 seconds).

The result supports the "segmentation" hypothesis. The segmentation hypothesis claims that a right angle turn divides the pathway into segments and that the perceived length of the segments are combined to produce an estimate of total pathway length. Given two pathways of the same objective length but differing in the number of turns contained in each, the pathway with fewer turns will necessarily have longer segments. These segments will be psychologically compressed. Assuming that subjects obtain the total pathway distance estimates by summing the separate segment estimates, the combination of a number of compressed segments will yield an estimate of total pathway length which is relatively underestimated. This underestimation will be greater for the pathway with fewer turns.

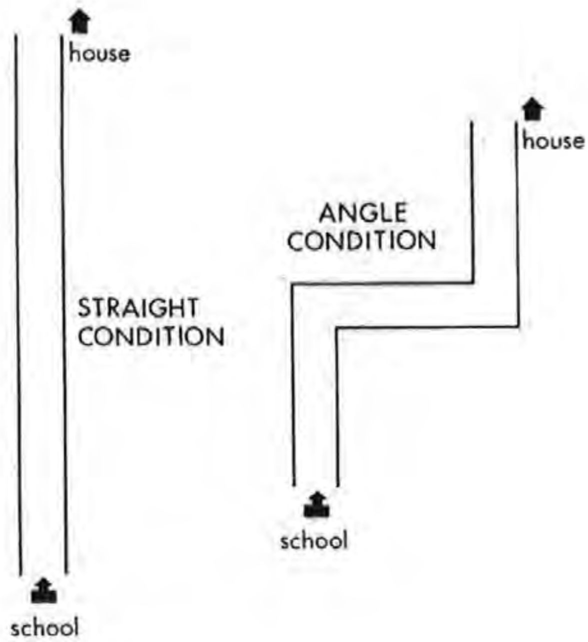
In another study, Sadalla and Staplin (1980b) asked college students to walk along a specified route in the environmental laboratory in the psychology building of the university. The route was marked with masking tape on the floor. Along the route participants encountered 15 intersections (formed by masking tape) that intersected the route at 90 degree angles. In the high-frequency condition these intersections were labelled with names in the English language that had a relatively high frequency of occurrence (e.g., the names Smith, Edward, Charles, Thomas, Richard each have the relative frequency of occurrence per 100,000 words equal to 206, 252, 237, 244, and 254 respectively). In the low-frequency condition the intersections were given names with a low frequency of occurrence (e.g., the names Lowry, Elliot, Hilda, Randall, each appear only 2, 6, 7, 8 times respectively out of 100,000 words). Participants wore a specially designed headpiece with an adjustable horizontal blinder during their pathway traversal. The headgear was used to restrict participants' forward visual field to approximately 1 metre. The headpiece prevented participants from instantaneously obtaining visual cues of the total pathway length. Participants were instructed to walk one of the paths and to try to remember the names of the intersections. The results showed that participants remembered significantly more items in the high- than low-frequency condition, and estimated that the distance traversed was longer in the high- than low-frequency condition. The result supports the "information storage" model. According to the information storage model complex pathways contain more information, therefore require more information processing activity, and produce more stored information. Participants may judge the complex pathways to be longer because they have stored more information about them and reason that paths that have more attributes must be longer.

The studies conducted by Sadalla and Magel (1980), and Sadalla and Staplin (1980) have provided a framework for understanding distance distortions in cognitive maps. However, not all studies have replicated the effect of number of turns on distance estimation. A study by Herman, Norton, and Klein (1986) suggested that the number of turns encountered along a path might not be a robust phenomenon after all when they examined this effect developmentally. Herman et al (1986) asked 7, 9, and 11 year old children from local schools to walk along paths between two locations separated by different number of turns and then to estimate the walking distances. The environments used were a large hallway built in a school recreation room (shown in Figure 4.2). Participants walked alongside the experimenter – who had practiced walking the paths and was therefore able to maintain a relatively even walking pace – from the starting place to the destination. Children were given the following instruction:

"You and I are going to take a walk through this hallway. It is very important that you stay right alongside me during this walk. When we reach the end of the hallway we will see a model house".

Immediately after reaching the end of the walk the experimenter pointed to the location-destination and verbally labelled it. At the end of the walk, participants were taken immediately to another hallway on the same floor as the studied environment for distance estimation. Participants were instructed to walk from the start place down the hallway and stop where they thought the same distance had been walked.

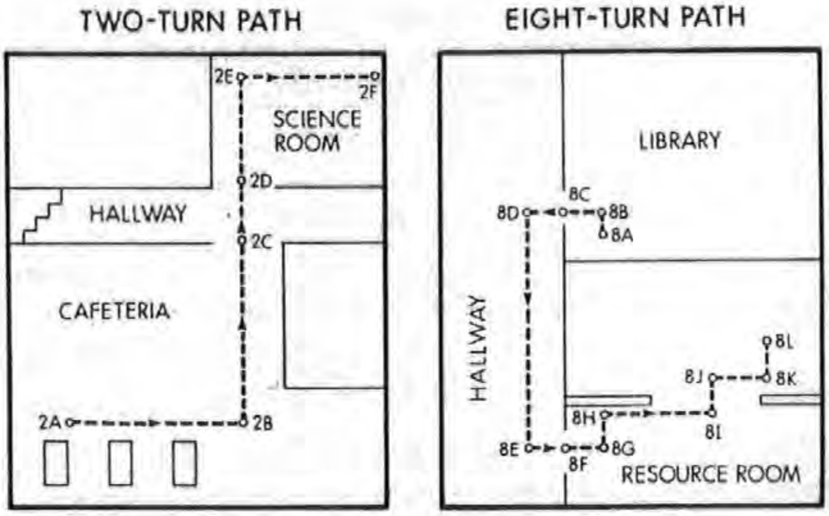
Figure 4.2: Schematic of the paths walked used in the study (Illustration taken from Herman, Norton, and Klein, 1986).



The results showed no evidence for the effect of number of turns; straight paths and cornered paths had no influence on participants' distance estimation.

In a follow up experiment, the number of turns in the paths varied; one path contained 8 turns and the other contained 2 turns (Figure 4.3). The procedure was identical to the one used in the previous experiment. The results again showed no evidence for the effect of number of turns on distance estimation, even though, the two paths differed by six turns. However, participants remembered correctly that there were more turns in the eight-turn paths than in the two-turn paths.

Figure 4.3: Schematic of the paths walked used in the study (Illustration adapted from Herman, Norton, and Klein, 1986).



Herman et al. (1986) suggest that the number of turns encountered on a walk through the environment may not significantly influence children's perceptions of path lengths. They explained the discrepancy between their study and that of Sadalla and Magel (1980), aside from the obvious age difference of participants, in terms of the type of test paths used, and particularly to differences in visual information. While in Sadalla and Magel's study the paths were in relatively homogeneous environments (non differentiated, non segmented environments), in Herman et al's study the visual environment was much richer as they used naturalistic environments (e.g., school recreation rooms, school corridors).

The studies by Sadalla et al. and Herman et al. indicate that visual information is an important factor in determining the influence of turns on distance estimation. However, there are still many other factors that must be controlled if the influence of turns is to be isolated. For example, the changes in participants' rate of motion, vertical direction (stepping up or down), and horizontal direction (a turn), must be controlled experimentally. Rieser, Pick, Ashmead, and Garing (1995) pointed out that participants change some features of their gait (such as cadence, number of paces, and stride length) as a function of traversed distances.

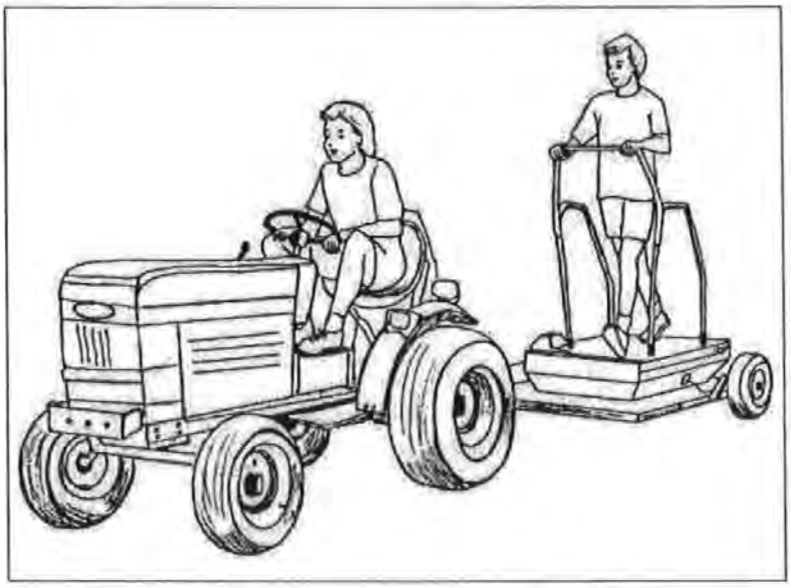
4.3. Walking Calibration

Reiser, Pick, Ashmead, and Garing (1995) in one of 10 experiments, asked participants to practice walking without vision on their own for 2 to 3 min in order to build their confidence so that they could travel safely and accurately when walking without vision.

In the pre-tests, a tape measure started at the participant's feet and stretched straight ahead of the participant along the ground for 16 m. The target-tester (a target person and data recorder) stood 8, 9, or 10 m straight ahead of the participant. Participants were asked to study the target's position, put the blindfold on, and attempt to walk to the target's position. The tester recorded the distance of the stopping point. At this point the participant was guided back to the starting position by a guide. Participants were asked to keep the target in mind while they walked; they were also asked to guess whether they tended to err too far or too short a distance.

Participants were then asked to pay attention to the surroundings as they walked on a treadmill at one speed while being towed through the surroundings at a different speed. In the fast condition, the treadmill operated at 8 kph and the trailer at 5 kph. In the slow condition, the treadmill operated at 7 kph and the trailer at 17 kph. Figure 4.4 illustrates the arrangement in relation to the use of the treadmill.

Figure 4.4: Experimental arrangement in Rieser, Pick, Ashmead, and Garing (1995)'s study (Illustration adapted from Rieser et al, 1995).



The method for the post-tests trials was exactly the same as the pre-tests trials, i.e., participants were asked to study the target's position, put the blindfold on, and attempt to walk to the target.

The most interesting result was that after the faster condition participants walked too far, and not far enough after the slower condition. Analysis of the gaits showed that after the faster condition they significantly increased their numbers of steps walked from the pre-tests to the post-tests, but after the slower condition no difference in the numbers of steps walked from the pre-tests to the post-tests. For the faster condition, participants averaged 9 steps on the pre-test versus 11 steps on the post-test; for the slower condition, participants averaged 10 steps on the pre-test versus 10 steps on the post-test. The Rieser et al.'s study implies that mental representations of the surroundings preserve the same spatial relationships as visual perceptions and that actions are calibrated in the scale of the remembered surroundings.

Klatzky, Loomis, Beall, Chance, and Golledge (1998) have shown that imagining walking through a space and making turns results in systematic errors, which do not occur when the person walks a path blindfolded. Klatzky et al. (1998) asked subjects to imagine walking forward a yard and then turning to the right and walking forward another yard. They asked subjects how much they would have to turn to face their original position. Typically, participants think they have to turn 225 degrees, although the real answer is 135 degrees. Klatzky et al. (1998) argue that this error is caused by the fact that participants update their positions through imagined trajectories, but fail to update their heading through imagined turns, but these errors were not found when the route had been physically walked. Moreover, the errors in the simulated condition were eliminated if participants were physically turned in a rotating chair simultaneously with the turn in the route. This result suggests that visual stimulation alone is not as effective for environmental cognition as the combination of visual and vestibular stimulation.

In sum in order to isolate the influence of action on distance estimation, it is necessary to have strict control over:

- the environment in terms of the features it contains;
- the visual information that participants could perceive and extract from the environment;
- the participants' actual movements (in walking, in turning).

There is yet another factor which is related to the performance of an action that was found to influence distance estimation. Past studies have shown that performing activity at landmarks contributed to children's consolidation of spatial knowledge. In the next section we review a study by Cohen and Cohen (1982) to show that performing action is an important factor that must be taken into consideration if our goal is to isolate the influence of action on distance estimation.

4.4. Performing Activity

Few studies have assessed the role of performing activity on the build-up of spatial knowledge. Cohen and Cohen in 1982 showed that landmarks which have functional value help consolidate the overall cognitive representation of the environment.

Cohen and Cohen (1982) assigned first (6-8 years olds) and sixth graders (10-12 years olds) to each of three activity conditions: walk-only, interact-only, interact-linked. Five common objects served as stimulus locations (chair, wastebasket, desk, TV table, box) arranged in an empty classroom. The child walked five of the 10 possible pair wise inter-object paths with an adult female experimenter. In each condition the child was encouraged to pay attention to the distances among environmental objects at the start of every trip and at locations desk, TV table, and box.

Children assigned to the interact-linked condition were given a "letter-writing and mailing" task that provided a functional link among four of the five locations (chair, desk, TV table, box). That is, the completion of an assignment at one location was necessary for engaging in an assignment at a subsequent location. Children in interact-only condition experienced no functional link of activities between locations, i.e., they performed an isolated activity at each of four of the five locations. Children in walk-only condition merely walked the series of paths, labelled each environmental location encountered and paused at each place to equal the time spent by children in the other groups. The results showed that children who engaged in activities, which functionally linked the locations within the route, were more accurate in their distance estimates than children who performed an isolated task at a location and children who merely walked through the environment. Thus, providing a theme improved the accuracy of the representation for the entire space rather than just for those specific paths, which were linked by activity.

If the activity means producing a series of movements in order to accomplish a meaningful purpose, then its influence was the result of a sum of related activities distributed on the entire route. To be able to test whether the action exerts an effect on distance estimation, one manipulation is to concentrate the activity theme at one critical landmark within the route – for instance at mid-route. Differences in distance estimation before versus after performing the action would be an indication of the influence of action. This manipulation is used in our methodology that will be described in detail in the next chapter.

We have identified the following factors that must be controlled experimentally in order to allow us to adequately measure whether action exerts an effect on distance estimation:

- the environment in terms of the features it contains;
- the visual information that participants could perceive and extract from the

environment;

- the participants' actual movements (in walking, in turning);
- the performance of action.

Given the limitation in the previous studies, we developed a new methodology that considers all these factors, which is described in detail in the next chapter. One of the main functions of developing a new methodology was to correct for the limitations we have just reviewed with past studies.

In the present study, the results of our first series of experiments have shown that action or motor representation may be implicated in the processing of distance and route description from memory. If the explanation put forward is correct, manipulating action when learning a route should also affect cognitive distance.

In the next chapter, we report the results of three experiments we undertook that directly manipulated action at mid-point within the same route and measured distance estimation under strict control of visual information. We manipulated the influence of number of turns on traversed distances to assess the mental mechanisms that mediate why complex routes were estimated differently from less complex ones.

5. CHAPTER 5: INFLUENCE OF ACTION ON DISTANCE ESTIMATION; THREE EXPERIMENTS

5.1. Overview

The present chapter reports three experiments which investigated the influence of action on distance estimation during navigation through the environment.

Given the problems with past studies, we developed a new methodology that incorporated factors that we identified must be controlled experimentally in order to allow us to adequately measure whether action exerts an effect on distance estimation.

In designing the experiments, a great deal of importance was attached to the authenticity of the large-scale space used as test environment and also allowed the control for the events or features in the environment. For this reason linguistic descriptions were used in which rich scene descriptions were constructed controlled for number of words. We created two such scene descriptions to form fictitious environmental settings. Each scene included the description of five landmarks (e.g., a school, a museum, a post office, a bank, a library, etc.); each landmark was associated with subsidiary features (e.g., tower clock, gate, statue, etc). Each landmark was described by specifying its physical or historical features; the subsidiary features were included in each landmark's description in order to define the landmark relationship to its surroundings. The environmental settings were formulated as guided tours so that a series of landmarks could be introduced. The environment descriptions were read by a female colleague and recorded for use in the experiments. Follows is a typical description of a landmark (the landmark is underlined, other features are subsidiary items):

"You are now standing at the gate of a place called Victoria Park. Victoria Park is renowned for its formal and shrub gardens, they are of interest and beauty in all seasons. During summer, Victoria Park hosts a folk music festival".

The control of visual information was achieved through the use of a blindfold. In this manner, any resulting effects would not be a function of any other features participants could have gathered from the test laboratory.

To restrict the body movement to performing action only, the biofeedback from actual walking was replaced with a mental walk. This measure was motivated by the fact that the use of a treadmill would not allow participants to perform turns. The method proposed here allowed strict control of walking movement. In the mental walk, we first calibrated each participant's natural walking speed with the number of beats produced by a metronome to match the exact number of steps per minute. We also measured the length of an average step for each participant. So instead of actually walking, the metronome beats informed participants about the speed of an imagined walk; in effect, participants heard a certain number of metronome beats which corresponded to the exact measure of the distance to be traversed. When the distance was mentally traversed the metronome beats ceased.

Between landmarks, there were turns. As participants were blindfolded, they were guided to move physically to the left or to the right. This measure allowed the control of the size of the degree of turning.

The action to be performed by participants occurred at mid-route. This manipulation allowed us to determine whether there is any difference in distance estimation before and after performing the action.

Upon reaching the destination, memories for traversed distances were measured through recalls. For the recalls, participants were told that they were now at the starting place again and had to "walk" on their own towards the destination. They had to describe what they "saw" on the way, and to instruct the experimenter to engage the metronome to signal the start of the walk or to stop walking. The traversed distances were again measured by the metronome clicks.

The key features of our methodology are:

- The use of blindfold,
- The use of verbal route description formulated as environmental setting,
- Auditory simulated navigation, i.e., mental walk inducing through hearing metronome beats that corresponded to participants' natural speed of walk,
- The control of action by moving the participants during turns.

In the next section, we report the first experiment that we carried out to examine the influence of action on distance estimation during navigation through the environment.

5.2. Experiment 5

5.2.1. Introduction

In relation to the effect of number of turns, a previous study (Sadalla & Magel, 1980) examined the difference between separate paths containing various numbers of turns. However, if the influence of number of turns is a robust effect, then it should also be observed within the same route. In the present study, we focused our attention on route segments within each path. We examined the patterns of the relationships between remembered distance and actual distance of paths containing several segments (many turns) against paths of equivalent length with fewer segments (fewer turns) within the same route. The "segmentation" model implies that when a route is recalled, it is remembered in terms of behavioural episodes that comprise the action of walking and the action of turning. How could the behavioural episodes translate into remembered distances? In the case where visual information is strictly controlled, maybe what happens is that as participants turn, this actually signals the attentional shifts during the retrieval of distance from memory. Therefore, when there are several turns this may lead to an increase perception of distance.

As we reviewed in the previous chapter, it was reported that providing a theme activity that functionally linked landmarks within a route improved the accuracy of the cognitive representation for the entire space rather that just for specific paths within that space (Cohen & Cohen, 1982). If the influence of action is important in people's memory in general, then it is possible to examine the difference between their spatial representation before and after performing action as well. To be able to test whether the action exerts an effect on distance estimation, one manipulation is to concentrate the activity theme at one critical landmark within the route – for instance at mid-route. The motivation behind locating action at mid-route is that there may be a cognitive effort associated with performing action. The goal of performing action may influence distance estimation (Naylor & Taylor, 2002). We hypothesised that since cognitive effort was required to accomplish the action, i.e., getting rid of the object through dispatching the book or the letter into a box, distance would seem much longer, whereas once the goal has been achieved the cognitive effort lessens, therefore distance would seem much shorter. In other words, we expect distances to be remembered as being longer before action than after action.

In Experiment 5, we manipulated the number of turns (4 turns vs. 1 turn) en route. Participants performed a simple action (dispatching an object into a box) at a landmark located mid-route.

5.2.2 Method

5.2.2.1 Materials

In the experiment we used two recorders, two headphones, one blindfold, a book, a letter, and a box. The box was a cardboard box with a large slit on one side allowing a book or a letter to go through it.

5.2.2.2 Environment Stimuli

To ensure route knowledge, two environmental descriptions were used, and they were labelled Route A and Route B. Each environment contained a series of five landmarks. Each landmark was described using characteristics such as its functionality, and its physical features. The description of each landmark was controlled for the number of words used. The environmental descriptions were read by a female researcher and recorded for use in the experiment. The detailed descriptions of Route A and Route B are given below (Figures 5.1.1a & 5.1.1b). The critical landmarks are shown in bold characters in the descriptions; the action is performed at a landmark located at mid-route shown in the descriptions with the border.

Figure 5.1.1a: Description of Route A used in Experiment 5

You are in a place called Charlestown, a typical New England town. Your starting place is Victoria Park. I am going to take you on a walk from Victoria Park to St John's Basilica.It is quite a nice walk with lots of thing to look at on the way.

You are now standing at the gate of a place called **Victoria Park.**
Victoria Park is renowned for its formal and shrub gardens. They are of interest and beauty in all seasons.
During summer, Victoria Park hosts a Folk Music Festival.

I am going to get you to walk away from Victoria Park along a route called Abbey Road.
Start walking now. Stop.

Now you turn onto a road called Mount Street. Start walking now. Stop.

You are now in front of a place called the **Museum.**
Look carefully at the Museum's front windows, you will see they contain fragments of figures of angels holding shields, some of which bear the arms of Henry VI.

I am going to get you to walk away from the Museum along a road called Maple Street. Start walking now. Stop.

Now you turn onto a road called Fore Street. Start walking now. Stop.

You are now at the entrance of a place called the **Central Library**.
Built of silverey-grey stone, the front of the building has columns and triple arches with elaborated decoration at the tops. Inside the Library, there is an intricately carved oak staircase.

> You are standing directly in front of the book return box.
> Now I let you post the book in the return box.
> You can actually feel the return box in front of you.
> So feel the box and post the book.

OK. Now I am going to get you to walk away from the Central Library along a road called Brunel Road. Start walking now. Stop.

Now you turn onto a road called Union Road. Start walking now. Stop.

You are now at the entrance of a place called **Blewcoat School.**
Blewcoat School is a picturesque building, which served as a grammar school.
It is half-timbered and thatched. The large shrub garden is particularly colourful in spring and early summer.

I am going to get you to walk away from Blewcoat School along a road called Fleet Street. Start walking now. Stop.

Now you turn onto a road called Bank Street. Start walking now. Stop.
Now you turn onto a road called Moorland Road. Start walking now. Stop.
Now you turn onto a road called Scott Road. Start walking now. Stop.
Now you turn onto a road called Alma Road. Start walking now. Stop.

You are now at your final destination, which is **St John's Basilica**. The beautiful stained glass window depicts events in the life of the Blessed Virgin Mary. The tower may be visited by climbing the spiral staircase of 176 steps".

Figure 5.1.1b: Description of Route B used in Experiment 5.

You are in a place called Charlestown, a typical New England town.
Your starting place is Trinity Bookshop.
I am going to take you on a walk from Trinity Bookshop to Kenwood House.
It is quite a nice walk with plenty to look at on the way.

I am going to start you at the front of a place called **Trinity Bookshop**.
Trinity Bookshop, a double-fronted building has elaborate cornices over the bows and a rather humble door in the centre. Copies of the most popular writers are displayed in the shop windows.

I am going to get you to walk away from Trinity Bookshop along a road called Silver Street.
Start walking now. Stop.

Now you turn onto a road called Carpenter Street. Start walking now. Stop.
Now you turn onto a road called Hazelwood Street. Start walking now. Stop.
Now you turn onto a road called Beacon Street. Start walking now. Stop.
Now you turn onto a road called Clink Street. Start walking now. Stop.

You are now at the front of a place called **Goldsmith**.
The double bow-fronted shop indulges the public with view of diamonds, pearls, rubies, emeralds, gold and silver, in most fascinating quantities. Fanciful clocks and watches are also attractively displayed.

I am going to get you to walk away from Goldsmith along a road called Ford Road. Start walking now. Stop.

Now you turn onto a road called King Street. Start walking now. Stop.

You are now at the entrance of a place called **The Post Office**.
One of the most characterful buildings in Charlestown, it has an antique-style double doors on either side of the central window. Through the window you can see a sculptural ornament representing Hermes supported on a globe.

> You are standing directly in front of the letterbox.
> Now I let you post the letter in the letterbox.
> You can actually feel the letterbox in front of you.
> So feel the box and post the letter.

OK. I am going to get you to walk away from the Post Office along a road called Cecil Street.
Start walking now. Stop.

Now you turn onto a road called Manor Road. Start walking now. Stop.

You are now at the entrance of a place called the **Visitor Centre**.
The main feature of the Visitor Centre is the Greek style colonnade situated at the front. The Centre regularly exhibits works of local as well as international artists.

Now I am going to get you to walk away from the Visitor Centre along a road called Blackfriars Road.
Start walking now. Stop.

Now you turn onto a road called Princess Street. Start walking now. Stop.

You are now at your final destination, which is **Kenwood House**.
The house has a fine collection of paintings and period furniture.
The beautiful formal garden includes a collection of lilies and water sculptures.
Outdoor concerts are organised every summer".

5.2.2.3 Characteristics of the Environments

Route A and Route B contained the same number of intervening turns, seven in total in each route. Figure 5.1.2a and 5.1.2b display the schema of the layout of Route A and Route B. Route B is the flip over plus 90 degrees to the right of Route A. Note that all turns are 90 degrees turns.

Figure 5.1.2a: Configuration of Route A, in Experiment 5.

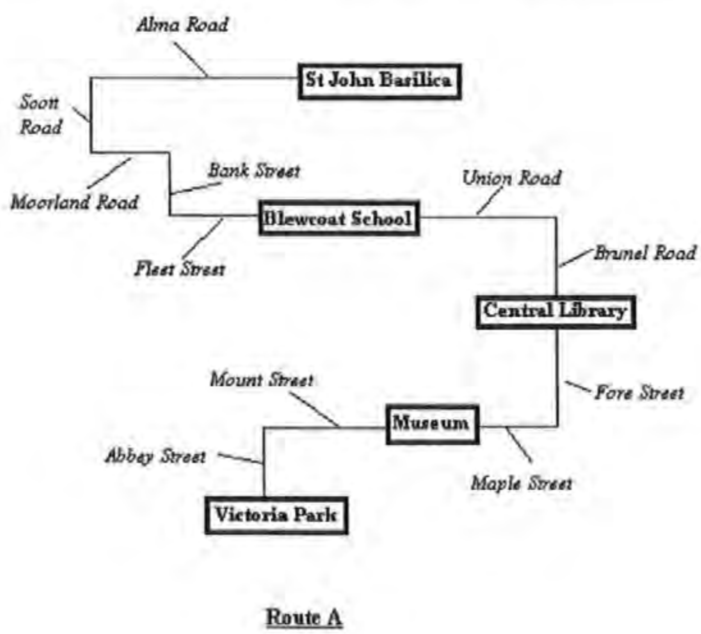
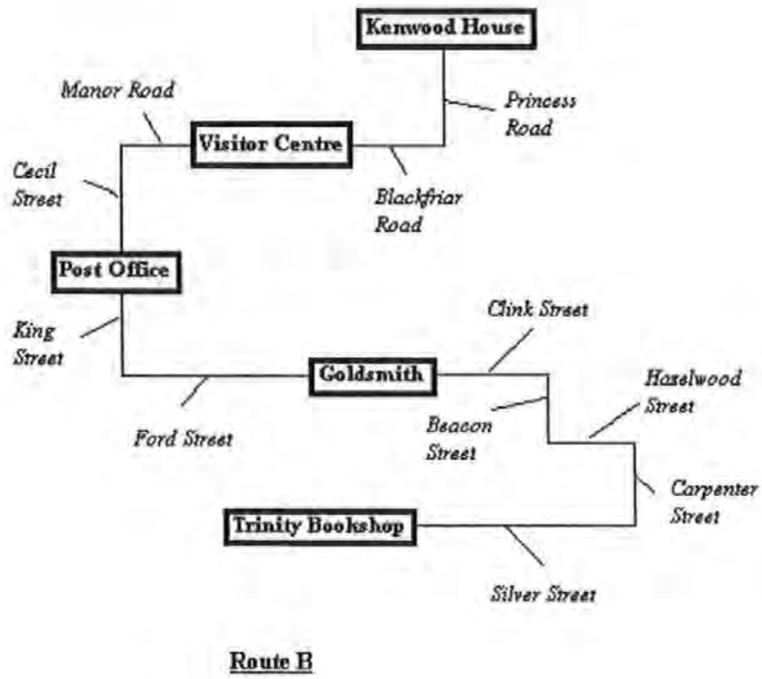


Figure 5.1.2b: Configuration of Route B, in Experiment 5.



The distance between 2 adjacent landmarks was called a path. Each path measured 64 metres in length. As each route contained 5 landmarks, there were therefore 4 paths in each route (called P1 to P4). The total route length measured 64 x 4 = 256 metres.

Note that Route A contains 3 paths with 1 turn each followed by 1 path with 4 turns; and Route B contains 1 path with 4 turn followed by 3 paths with 1 turn each.

A turn divides a path into segments. Route A and Route B contained 11 segments each. The segment lengths were fixed at 8, 12, 16, 24, 32, and 40 metres. These distances were combined to make up the length of 64 metres for each path. The following combinations were used respectively for Route A and Route B.

Route A: P1 = 24 + 40,

P2 = 32 + 32,

P3 = 40 + 24,

P4 = 16 + 12 + 16 + 12 + 8.

Route B: P1 = 8 + 12 + 16 + 12 + 16,

P2 = 24 + 40,

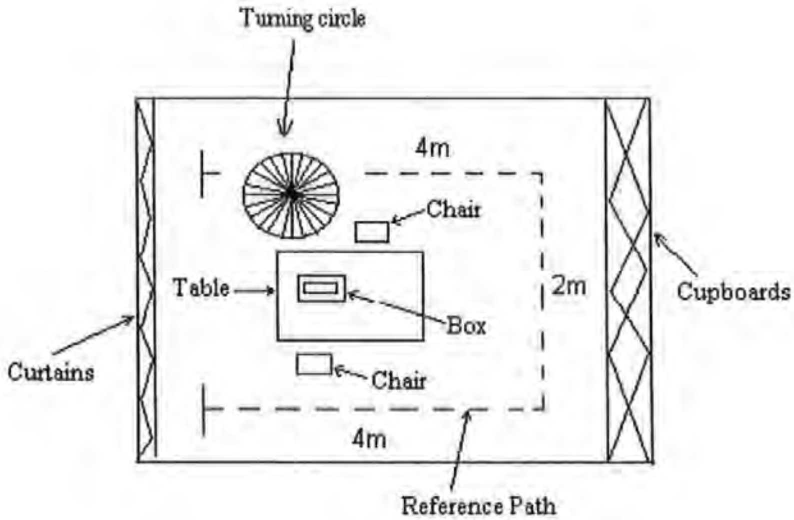
P3 = 32 + 32,

P4 = 40 + 24.

5.2.2.4 Room Arrangement

The experiment was conducted in the Social Laboratory in the Department of Psychology. A dispatch box was placed on a table within arm's reach of the participants. At about 50 cm from the table, a plus cross was marked on the floor with coloured tape to form a virtual circle of 60 centimetres diameter. Each quadrant had 6 marks representing 15 degrees each (see Figure 5.1.3).

Figure 5.1.3: Room Arrangement in Experiment 5.



5.2.2.5 Mental Walk

To restrict the body movement to performing action only, the biofeedback from the actual walk was replaced with a mental walk.

In the mental walk, we first calibrated each participant's natural walking speed with the number of beats produced by a metronome that matched their exact number of steps per minute. At the start of the test, subjects were asked to walk a U shaped reference path (marked by the dotted line in Figure 5.1.3). They walked at their own natural walking speed from one end of the U shaped path and when they reached the other end of the path, without stopping they returned back to the starting position. The time taken to traverse the reference path was measured as well as the number of steps. These measures served to compute the speed of walks and size of step for each participant individually.

The speed of walk was calculated as follows:

[Number of steps to walk reference path / Time taken to walk reference path] * 60 seconds. For example, a participant who had walked the reference path in 32 steps in 20 seconds would have the metronome set at 96 beats per minute for him or her (32 steps / 20 sec * 60 sec).

The participants' step lengths were also calculated by dividing the length of the reference path by the number of steps to traversed it. Continuing the above example, the step length of that participant measures 62.5 cm (20 m / 32). The participants were told that each metronome beat represented one footstep forward.

To translate the distance (X) to be traversed into the number of metronome beats, we used the following formula:

[Number of steps to walk reference path / Length of reference path] * X metres. Carry on the same example, he/she would hear exactly 19 beats to walk 12m; 38 beats to cover 24m; 64 beats to cover 40m, etc. For the experiment, we established in advance a numerical chart for several possible numbers of steps representing different distance lengths (See Appendix 7.2.1). This chart was attached to the back of the participant for reference during the test.

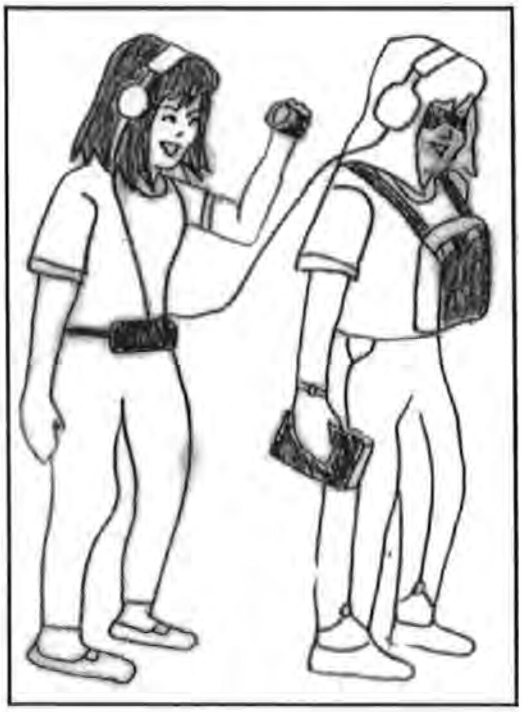
To ensure that participants would feel comfortable during the test, we asked them to close their eyes and to imagine walking in time with the metronome beats that were set to match their natural walking speeds. If the answers were positive, continuing the above example, the walking speed of 96 beats per minute was used during the test for this participant. Otherwise, participants had to walk the reference path one more time in order to find the correct speed of walk.

5.2.2.6 Arrangement

The participants were required to stand at the centre of the marked circle (see Figure 5.1.3). They were asked to wear a blindfold and headphones. A Y-split joint was used to allow both the participant and the experimenter to hear the route description simultaneously during tests.

The participants also carried a small backpack containing a tape recorder. On his or her back were attached the steps chart and the transcript of route description in order for the experimenter to monitor the progress of the test. The experimenter carried a tape player in a belt bag and always stood behind the participant (see Figure 5.1.4).

Figure 5.1.4: Arrangement in Experiment 5.

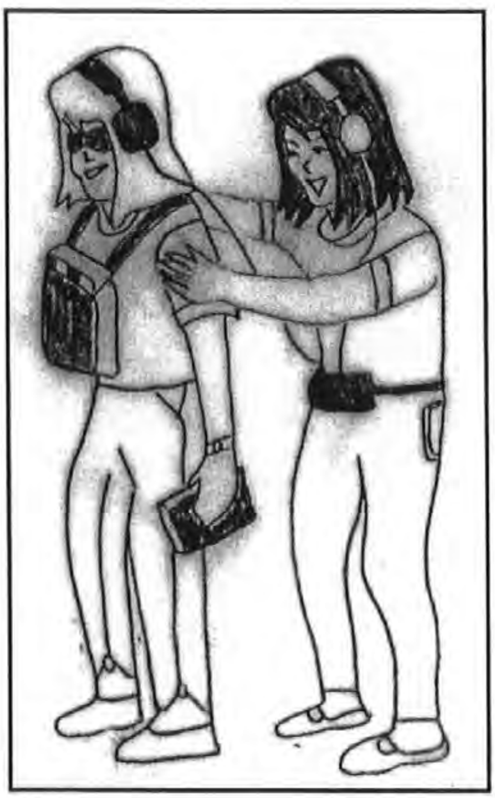


During the test, the experimenter consulted the steps chart as well as the route description script at appropriate times in order to engage the metronome she held at the level of the participant's head. During the free recall, the Y-split joint was disconnected

5.2.2.7 Turning

To familiarise participants with the sense of change of direction during the imaginary trip, before the test began, the experimenter gently spun the participant, once to the left, once to the right (Figure 5.1.5). All turns were 90 degrees turns.

Figure 5.1.5: Turning in Experiment 5.



Once the participant got used to the idea of being turned, the experimenter spun the participant one more time with a big turn (i.e., uninterrupted turns clockwise or anti clockwise) finishing by positioning the participant to face the box. In this position he/she was at the correct starting position to start the test.

Although the number of turns was fixed, the direction of turns were also fixed for each route, so that when "arriving" at mid-route (the critical landmark) the participant had to be in front of the box to perform the action.

5.2.2.8. Pilot Study

Before we ran the study, we tested the methodology on two pilot subjects in order to check whether they felt any discomfort during the test as they wore a blindfold and had to stand still while performing the mental walking.

We were particularly concerned that being turned with a blindfold on might be disorientating/mildly distressing for participants. However, the subjects commented that they were perfectly comfortable and relaxed during the test. We then proceeded to the first experiment using the new methodology.

5.2.2.9 Experimental Design

In the present experiment, participants learned two routes (Route A and Route B). The presentation of routes was counterbalanced among participants. Participants were not aware that Route B was the mirror image of Route A.

As each route contained 5 landmarks it made up 4 paths in each (denotes P1 - P4). The position of each path in relation to the action was denoted as follows:

- before action, P1 was denoted outer position, and P2 was denoted inner position;
- after action, P3 was the inner position, and P4 was the outer position.

In relation to the cluster of turns, in Route A it was located in P4 (outer position/after action), whereas in Route B it was in P1 (outer position/before action).

To examine the influence of action and the effect of number of turns on traversed distances, the experimental design used was a 2 route (Route A vs. Route B) x 2 position (inner vs. outer) x 2 action (before vs. after) within-subjects analysis of variance.

5.2.2.10 Participants

Twenty-nine undergraduate students agreed to participate in the experiment in exchange for course credit. They were between 18 and 35 years old (mean = 20.50, SD = 4.80). By agreeing to participate in the experiment, they were aware that they would wear a blindfold during the test.

5.2.2.11 Presentation

The methodology was designed such that the instructions led participants to focus on landmarks along the route so their walking through the environment was natural. Therefore, it was important to develop a set of instructions whereby participants would not just trying to remember distances, but they would imagine themselves walking around the environment naturally.

We proceeded by presenting the study to the participants as an investigation into people's memory for their environment, particularly for described places. The participants were told that they were going to listen to descriptions of imaginary walks through new environments. They were told that during the simulated walks they had to visualise the described landmarks. Additionally, they were asked to return a book or a parcel at some point en-route. The participants were not aware that their memory for distances was being tested.

5.2.2.12 Procedure

One group of participants was used, and they were tested individually. The session lasted about 45 minutes.

Initially, participants were instructed to walk the reference path at their own natural walking speed, and it was explained that this was done to compute their walking speeds. Next, they were asked to stand at the centre of the circle, and to put on the blindfold and headphones. Then the experimenter familiarised the participants with the turning procedure. She spun the participant around on the spot, finishing by positioning him/her in front of the table facing the box. At this time, the experimenter gave the participants the book or the parcel to carry with him/her. Then the participants were instructed to visualise the landmarks when they heard their descriptions, and to imagine themselves walking in time with the metronome clicks, and to stop imagining walking when the metronome ceased clicking.

The experimenter then started the tape player and both listened to route descriptions through headphones. At the appropriate times, the experimenter stopped the player and engaged the metronome to implement the mental walking. Participants imagined moving until the metronome stopped clicking, at which time participants had to stop imagining walking. During turns, the experimenter intervened by physically moving the participants on the spot. Note that all turns were 90 degrees turns. At mid-route, participant performed the dispatch task as instructed in route description, i.e., he/she extended his/her arm to reach the box, touched it to find the slot, and then dropped the object into the box. Once the destination was reached, the Y-joint was disconnected. Then the experimenter spun the participant around again and positioned him/her in front of the box. Still blindfolded, the participant's route memory was tested by free recall.

The two routes were presented straight one after each other, i.e., one route was presented to the participants, then it was re-walked (recall) by participants, immediately after that, the second route was presented which followed straight away by the recall.

For the free recall, participants were told that they were taken back to the starting place from which they had to re-walk the routes. They were asked to describe back as accurately as possible what they "saw" en-route. They had to tell when they wanted to walk away from the landmarks and when they wanted to stop walking, so that the experimenter could engage and disengage the metronome. At turns, they had to make the move themselves on the spot and to indicate verbally the direction of turns. Once it was established that participants understood the instructions, the experimenter switched on the recorder that participants carried with them.

5.2.2.13 Data Treatment

The participants' free recalls were transcribed. Then we proceeded to check the order of landmarks recalled by the participants. In order to ensure that participants had a good understanding of the environments they learned, the order of landmarks must be recalled in the correct order; if the order of the landmarks was wrong, the participants' free recalls could not be used for analyses.

The correct responses then served for data collection. The dependent variables were segments, paths, and landmarks' descriptions. Data were obtained by first translating the number of metronome clicks (= steps) into traversed distances expressed in metres.

5.2.2.14 Dependent Variables

The dependent variables were segments, paths, and landmark descriptions. We collected the segments from the participants' protocols as follows. First, we translated the number of metronome clicks (= number of steps) into traversed distances expressed in metres.

We calculated the length of recalled segments as follows:

1) Segment = [Recalled number of steps / Reference path steps] * 20 metres.

- Each segment was checked against the original route segment with regard to its name. When routes' names were not mentioned but the number of segments in the path mapped the original path they were recorded as such.
- When there were additional segments, for example participants recalled walking three segments instead of two as in the original path, only the first two recalled segment were recorded, the third segment did not map onto the original path was eliminated. However, for the path length all three segments were recorded.
- When there were fewer segments, for example, three segments instead of four as in the original path, the fourth path segment was considered as missing.

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

3) Landmark descriptions: they were recorded as follows:

- 1 point was given to any statement that replicated verbatim the original description of landmark, e.g., basilica, school, museum, etc.
- 1 point was given to any statement that has the same meaning as the original description, e.g., church instead of basilica, jeweller instead of goldsmith, etc.

The accuracy of turns with regard to amplitude and direction was not recorded in the present experiment.

5.2.3 Results

To be included in the analyses, participants' responses must show the correct sequences of landmarks in both routes. This measure was taken in order to ensure that they had a good understanding of the environments they learned; if the order of the landmarks was wrong, the participants' free recalls could not be used for analyses.

Responses from 13 participants (45%) were excluded (12 incorrect sequences of landmarks for one or both routes, one response was eliminated because of poor English). Responses from 16 participants were used in the analysis (55%).

5.2.3.1 Number of Steps

A crucial element in the methodology was that participants should focus on landmarks along the route they learned rather than on the distances between landmarks, so that while they imagined themselves walking naturally around the environment, they would not just consciously trying to remember distances.

It is therefore of interest to examine the characteristics of the mental walks. Table 5.1.1 displays the number of steps participants produced and the time taken to traverse the reference path (20 metres), the length of the steps, as well as the number of steps they produced per second. As displayed in Table 5.1.1, on average participants walked 2 steps per second and each step measured about 70 centimetres, which corresponded to an average imagined walking speed of about 5.04 km/h.

Table 5.1.1: Characteristics of the Mental Walks, in Experiment 5.

Descriptive Statistics	**Number of Steps**	**Duration (in seconds)**	**Step Length (in metres)**	**Number of Steps / sec.**
Minimum	21.00	11.00	0.54	1.26
Maximum	37.00	23.00	0.95	1.94
Mean	28.50	17.06	0.71	1.69
Std. Dev.	4.11	3.09	0.11	0.16

So did participants remember the number of clicks or did they remember distances?

To check this out we performed a correlation between the total number of steps to walk Route A and Route B and the re-walked distances of Route A and Route B across participants (N = 16). We found no significant correlation between the number of steps and the remembered distances (shown in Table 5.1.2) which indicated that participants were not just remembering the number of clicks. However, there was a highly significant correlation between Route A and Route B in remembered distances, which indicated that individual participants were consistent in their remembered distances for routes of the same length.

Table 5.1.2: Correlation between Number of Steps and Re-walked Distances, Experiment 5.

	Number of Steps	Re-walked Route A	Re-walked Route B
Number of Steps	-		
Re-walked Route A	-0.13	-	
Re-walked Route B	-0.22	0.59**	-

Note. **: correlation significant at the 0.01 level (1-tailed).

5.2.3.2 Landmark Descriptions

As participants learned a series of landmarks during navigation, it was of interest to examine how accurately they were described by participants during recall.

Before we proceed to the analysis proper, we need to categorise our landmark descriptions. Landmark's name, its features, such as size, composition (stone, iron, etc.), and its cultural and historical importance, were categorised as items and were given 1 point each. Using these criteria, we analysed participants' protocols.

The accuracy of the descriptions was measured as a ratio. This ratio was computed by dividing the correct recalled items with the actual number of items present in the original descriptions for each landmark.

Table 5.1.3 displays the descriptive statistics of the number of correct descriptions of each landmark across participants along with the actual number of items present in the original description for each landmark (L1 to L5 represent the series of landmarks for Route A and Route B respectively).

Table 5.1.3: Detail of landmarks descriptions, in Experiment 5.

		Actual	Mean (Std.Dev.)	Ratio (Std.Dev.)
Route A				
	L1	8	3.81 (1.60)	0.48 (0.20)
	L2	6	3.44 (1.36)	0.53 (0.23)
	L3	9	4.00 (1.82)	0.44 (0.20)
	L4	7	2.44 (1.31)	0.35 (0.19)
	L5	7	2.37 (1.36)	0.34 (0.19)
Route B				
	L1	8	2.94 (1.39)	0.37 (0.17)
	L2	6	3.62 (1.75)	0.72 (0.35)
	L3	9	3.19 (1.51)	0.35 (0.17)
	L4	7	2.31 (1.25)	0.38 (0.21)
	L5	7	2.69 (1.70)	0.38 (0.24)

As shown in Table 5.1.3, on average the ratio of the second landmarks (L2) in Route A and in Route B were larger than the other landmarks (Route A = 0.53; Route B = 0.72).

Now we wanted to examine whether there were significant differences between the ratio descriptions of landmarks in both routes. To test the accuracy of landmark descriptions, we used a within-subjects analysis of variance. The analysis used was a 2 route (Route A vs. Route B) x 5 landmark (5 in Route A vs. 5 in Route B) ANOVA on the ratio of the number of correct recalled items divided by the actual number of items present in the original descriptions. The results of the 2-way ANOVA are displayed in Table 5.1.4.

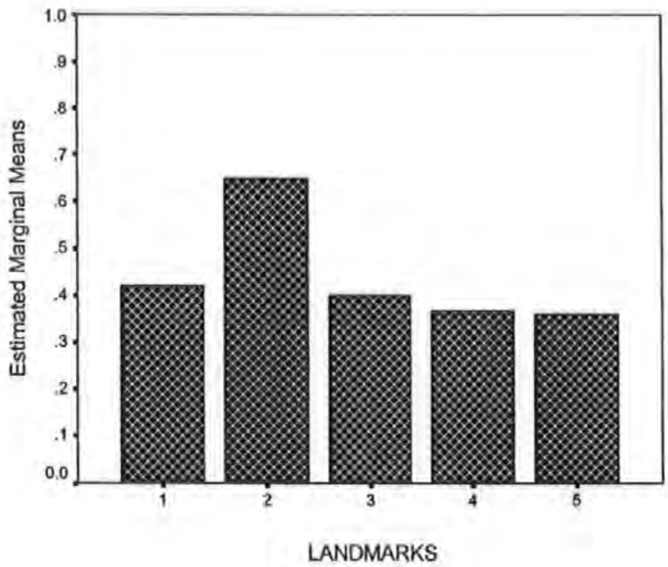
Table 5.1.4: Results of the 2-Way ANOVA on the Accuracy of Landmark Description in Experiment 5.

Source	**df and F value**	**MS (error)**	**Significance**
Route (R)	$F_{(1, 15)} = 0.05$	0.002	ns
Landmark (L)	$F_{(4, 12)} = 4.09$	0.457	*
R x L	$F_{(4, 12)} = 1.89$	0.09	ns

Note. ns: $p > .05$; *: $p < .05$.

The effect of route was not significant. However, there was a significant main effect of landmark, $F_{(4, 12)} = 4.09$, $p = 0.026$. Overall the second landmark (L2) was better remembered than the other four landmarks as displayed in Figure 5.1.6, and confirmed by pair-wise comparisons (the mean ratio for L2 was significantly larger than that for L1, L3, L4 and L5 respectively; all the significance levels $p < .001$). This result indicated that as L2 had fewer items (6 items) comparatively to the other landmarks (7 - 9 items), it was relatively easier to remember.

Figure 5.1.6: Main Effect of Landmarks on the Accuracy of their Descriptions in Experiment 5.



5.2.3.3 Distance Estimation

Now we turn to examine how accurate the recalls of segments across participants were. Figure 5.1.7a and Figure 5.1.7b illustrate the average estimated distance for each segment across subjects against the actual distances for the segments in Route A and Route B respectively. It can be seen that the small distances were on average over-estimated whereas larger ones were under-estimated. There was also large variability across subjects.

Figure 5.1.7a: Estimated Segments Against the Actual Distances for Route A, in Experiment 5.

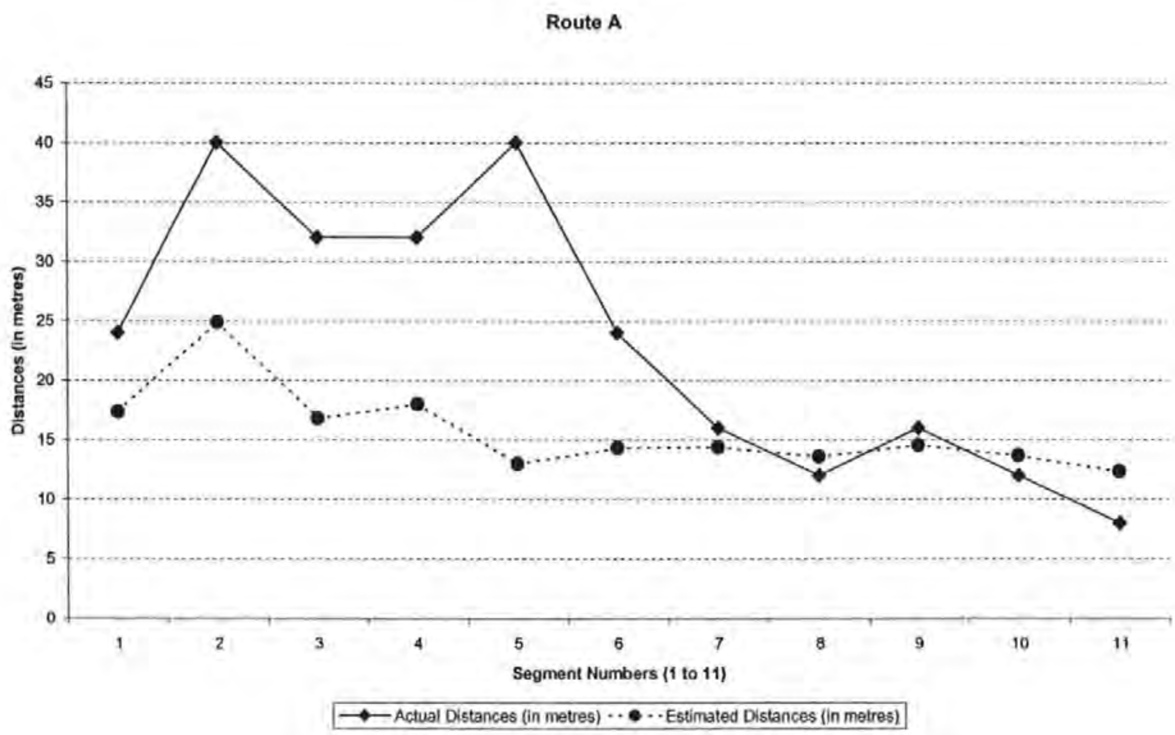


Figure 5.1.7a shows that in Route A, small segments up to 12 metres are over-estimated, while larger segments are under-estimated.

Figure 5.1.7b: Estimated Segments Against the Actual Distances for Route B, in Experiment 5.

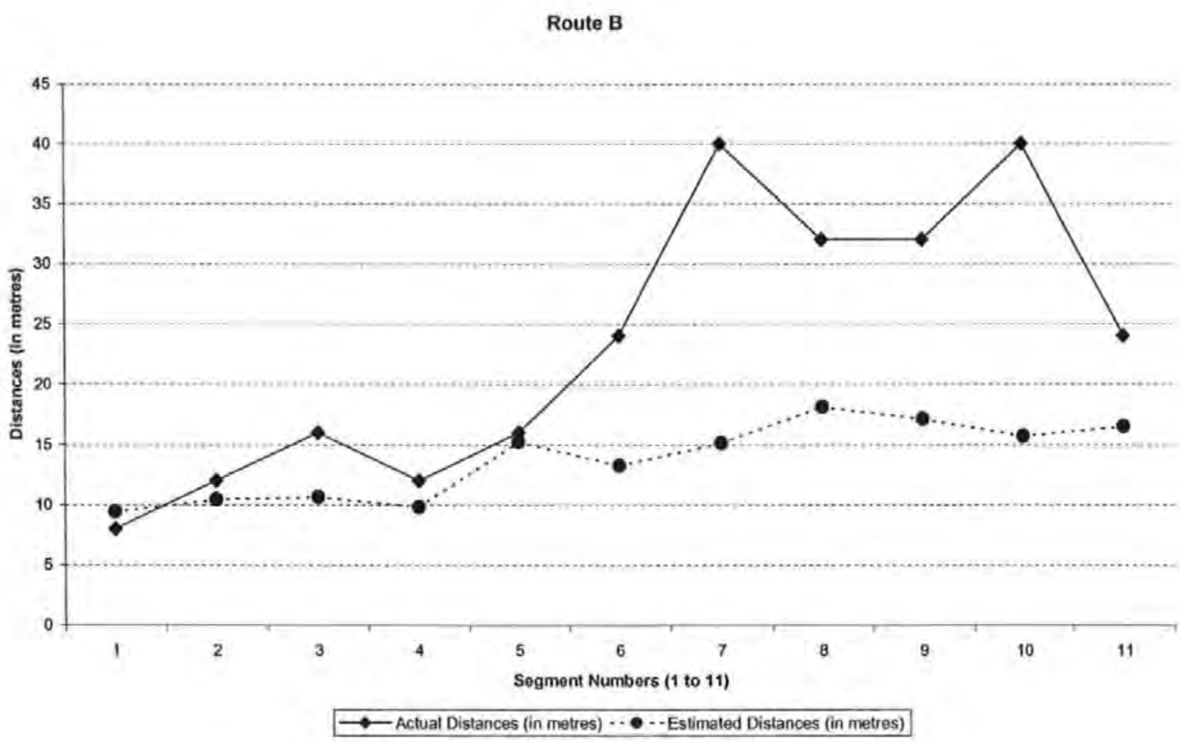


Figure 5.1.7b shows that in Route B small segments up to 8 metres are slightly over-estimated, and larger segments are under-estimated.

As both Route A and Route B contained 11 segments each, in total there were 22 segments. For each segment, we averaged the remembered distances across participants. This was used to compute the correlation with the corresponding actual distances. We found an overall significant correlation between actual and estimated distances, Pearson's

Correlation Coefficient $\underline{r}_{(22)} = 0.68$, $\underline{p} < .001$ (1-tailed), which indicates that longer segments were associated with walking longer distances on recall.

Now let us examine the influence of number of turns and the influence of action on remembered distances. Within each route, the position of each path in relation to the action was denoted as follows:

- before action, P1 was denoted outer position, and P2 was denoted inner position;
- after action, P3 was the inner position, and P4 was the outer position.

A within-subjects analysis of variance was used to examine the effects of route (Route A vs. Route B), position (outer vs. inner), and action (before vs. after) on path distance estimates. Given that the distances between landmarks were all the same lengths, it was unnecessary to convert estimated distances into ratios. The results of the 3-way ANOVA are displayed in Table 5.1.5.

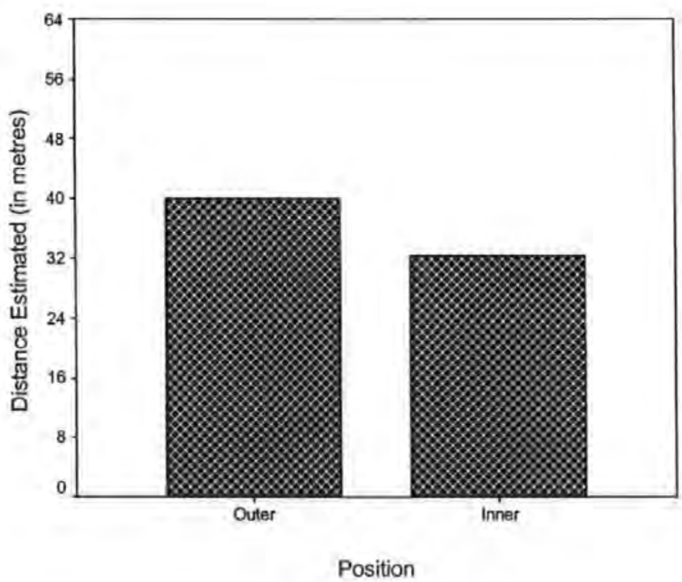
Table 5.1.5: Results of the 3-Way ANOVA on Distance Estimation in Experiment 5.

Source	**df and F value**	**MS (error)**	**Significance**
Route (R)	$F_{(1, 15)} = 1.89$	442.53	ns
Position (P)	$F_{(1, 15)} = 8.88$	1922.00	**
Action (A)	$F_{(1, 15)} = 0.93$	94.53	ns
R x P	$F_{(1, 15)} = 0.90$	105.12	ns
R x A	$F_{(1, 15)} = 0.85$	195.03	ns
P x A	$F_{(1, 15)} = 0.30$	128.00	ns
R x P x A	$F_{(1, 15)} = 8.44$	430.13	*

Note. ns: $p > .05$; *: $p < .05$; **: $p < .01$

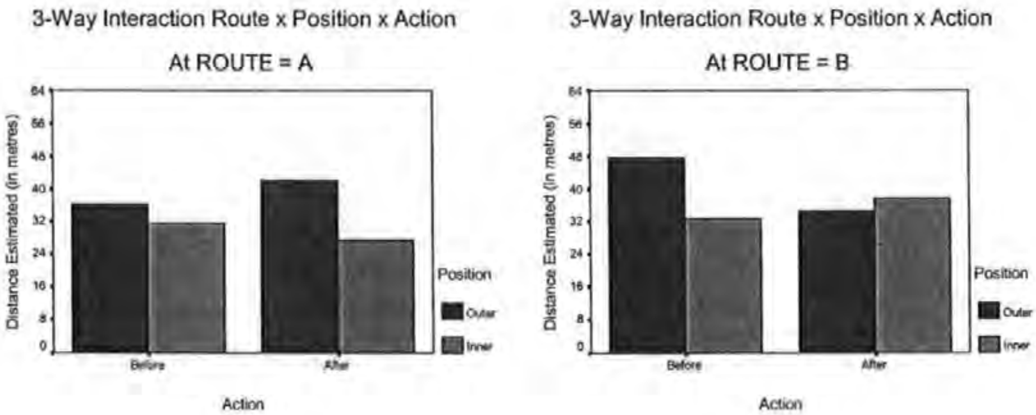
No main effects of route, or action were found. However, there was a main effect of position on path distance estimates, $F_{(1, 15)} = 8.88$, $p = .009$. Overall, path distances were under-estimated (the actual distance of each path measured 64 metres), however, participants remembered walking significantly longer on the outer paths (one of which contained four turns) than on the inner paths (which contained one turn), as displayed in Figure 5.1.8.

Figure 5.1.8: Main Effect of Position on Distance Estimation, in Experiment 5.



There was a significant 3-way interaction between route, position, and action, $F_{(1, 15)} = 8.44$, $p = .011$ (displayed in Figure 5.1.9).

Figure 5.1.9: Three-Way Interaction between Route, Position, and Action, on Distance Estimation, in Experiment 5.



In Route A, distances were remembered as being longer at the outer positions in general; and with regard to the influence of action, distances were remembered as being longer after action. In Route B, distances were remembered as being longer at the outer position, and before action.

Follow up analyses indicated that in Route A, after the action has been performed the outer path (4-turns path) was remembered significantly as being longer than the inner path (1-turn path), $F_{(15)} = 6.16$, $p = 0.025$. In Route B, it was the reverse situation; before the action the outer path was remembered significantly as being longer than the inner path, $F_{(15)} = 6.64$, $p = 0.021$. None of the other differences were significant. This result confirmed that the influence of turns was a robust effect on remembered distances.

Although there was no significant effect of action overall, let us examine whether the segments just before and just after action were more sensitive to the influence of action. To check the influence of action on segments, we selected segments S4 and S5 from Route

A, and segments S7 and S8 for Route B. For the comparisons, we used the segments ratios; these were obtained by dividing S4, S5, S7, and S8 by their corresponding actual distances. Table 5.1.6 displays the descriptive statistics for these segments.

Table 5.1.6: Descriptive Statistics for Before and After Action for Route A's and for Route B's Segments, in Experiment 5.

		Mean	Std. Dev.	N
Route A				
	Before Action S4	0.59	0.20	9
	After Action S5	0.29	0.06	8
Route B				
	Before Action S7	0.39	0.16	8
	After Action S8	0.58	0.43	8

Although on average there is under-estimation, in Route A before action distance estimates were longer than after action; in Route B however, before action distances were shorter than after action. To test for significance, we performed paired t-tests on Route A's segments and on Route B's segments; the results of the t-tests are displayed in Table 5.1.7.

Table 5.1.7: Comparing straight line distances just before and just after action, in Experiment 5.

	Before vs. Action	t statistics	Significance	N
Route A	S4 > S5	4.668	0.01	5
Route B	S7 < S8	0.935	ns	7

The difference between S4 and S5 in Route A was significant, $t_{(4)} = 4.668$, $p = 0.01$ (2-tailed); the difference between S7 and S8 in Route B was not significant; $t_{(6)} = 0.935$, $p = 0.386$ (2-tailed).

5.2.4 Discussion

Given the problems encountered in past studies, we developed a new methodology that incorporated factors that we identified must be controlled experimentally in order to allow us to adequately measure whether action exerts an effect on distance estimation.

During the experiment, none of the participants expressed any discomfort during or after the task, indicating that the methodology was appropriate. That said, however there was a large drop rate (45 %) due to participants not being able to reproduce the landmarks in the correct order (or to remember all the landmarks completely). The high drop rate was of some concern. It may be the case that the task was too difficult, or may be because participants were exposed to the environment only once.

Despite the high drop out rate, we found that within the same routes, distance estimation was influenced by the number of turns contained in a path; paths containing four turns were remembered as being longer than paths with one turn. This result is in line with evidence from other studies (Sadalla & Magel, 1980). However our experiment was conducted using much better control, in terms of environmental stimuli, the walking speed, and the turning.

We used free recall, a measure of memory that is congruent with learning. Our methodology allowed us to observe the effect of number of turns on the same route through auditory simulated navigation, while Sadalla and Magel (1980)'s result was on separate paths, and through actual walking with restricted visual information. Taking together, both studies indicate however that the influence of number of turns is a robust effect.

There was no effect of action performed at mid-route in this experiment. The absence of the effect of action may be due to the salience of the action itself. The movement of dispatching (dropping) an object into a box may be considered as a simple and routine activity therefore was not salient enough to exert an effect on spatial representation. A sequence of more pronounced movements to perform the dispatch task may make the action more memorable. This is examined in Experiment 7.

For the moment, we were concerned by the high drop rate. It may be that there was not enough exposure to the environment for participants to adequately learn about the environment. For that reason, in Experiment 6 we exposed participants to the same environments twice before their memories were tested using exactly the same methodology.

5.3. Experiment 6

5.3.1 Introduction

Our methodology allowed us to observe the effect of number of turns on remembered distances in a much better manner than in previous studies, in terms of environmental stimuli, walking speed, and turning. However, we were concerned by the high drop rate in Experiment 5 (45%). For that reason, in Experiment 6 we exposed participants to the same environments twice before their memories were tested using exactly the same methodology.

To examine whether the action exerts an effect on distance estimation, the action was performed at landmark located at mid-route. There may be a cognitive effort associated with performing action at landmark, i.e., the goal of performing action may subsequently influence distance estimation (Naylor & Taylor, 2002). We hypothesised that since cognitive effort was required to accomplish the action, i.e., getting rid of the object through dispatching the book or the letter into a box, distance would seem much longer, whereas once the goal has been achieved, the cognitive effort lessens. Since less effort is required distance would seem much shorter than when more effort is required. In other words, we expect distances were remembered as being longer before action than after action.

5.3.2 Method

The method used was the same as in Experiment 5, except that this time, participants were exposed twice to each environment. As in Experiment 5, participants learned two different routes (Route A and Route B), and then they had to reproduce each route trip in free recalls. Route A and Route B were presented to participants in counterbalanced order.

5.3.2.1 Participants

Twenty-three undergraduate students agreed to participate in the experiment in exchange for course credit. Participants were between 18 and 46 years old (mean = 24.17, SD = 7.84). They were tested individually.

5.3.2.2 Procedure

The procedure was the same as in Experiment 5, however here participants were guided through each route twice before their memories for each route were tested through free recall. The order of presentation of Route A and Route B was counterbalanced. The tests lasted about one hour.

5.3.3 Results

As in Experiment 5, to be included in the analyses participants' responses must show the correct sequences of landmarks in both routes.

Responses from 18 out of 23 participants (78 %) were used in the analyses. Responses from five participants (22%) were eliminated (4 incorrect sequences of landmarks, 1 bad recording). The exposure to the environment twice seemed to work as the rate of data inclusion has much improved, although there is still a relatively high rate of exclusion.

5.3.3.1 Number of Steps

As participants were instructed to focus on landmarks along the route they learned, this would encourage them to imagine themselves walking around the environment naturally so that they would not just consciously trying to remember distances during their imaginary navigation.

It is therefore of interest to examine the characteristics of the mental walks. Table 5.2.1 displays the number of steps participants produced and the time taken to traverse the reference path (20 metres), the length of the steps, as well as the number of steps they produced per second. As shown in Table 5.2.1, on average participants walked 2 steps per second and each step measured about 70 centimetres, which corresponded to an average imagined walking speed of about 5.04 km/h.

Table 5.2.1: Characteristics of the Mental Walks, in Experiment 6.

Descriptive Statistics	**Number of Steps**	**Duration (in seconds)**	**Step Length (in metres)**	**Number of Steps / sec.**
Minimum	27.00	13.00	0.59	1.55
Maximum	34.00	20.00	0.95	2.08
Mean	30.27	16.61	0.66	1.84
Std. Dev.	2.24	1.97	0.05	0.15

To check the fact that participants were not just remembering the number of clicks, we performed a correlation between the total number of steps to walk Route A and Route B and the re-walked distances of Route A and Route B across participants (N = 18). We found no significant correlation between the number of steps and the remembered distances (shown in Table 5.2.2) which indicated that participants were not just remembering the number the number of clicks. The correlation between Route A and Route B in remembered distance was not significant.

Table 5.2.2: Correlation between Number of Steps and Re-walked Distances, Experiment 6.

	Number of Steps	Re-walked Route A	Re-walked Route B
Number of Steps	-		
Re-walked Route A	-0.24	-	
Re-walked Route B	-0.15	0.12	-

5.3.3.2 Landmark Descriptions

As participants learned a series of landmarks during navigation, we wanted to know how accurately those landmarks were described by participants during recalls.

Table 5.2.3 displays the descriptive statistics of the number of correct descriptions of each landmark across participants along with the actual number of items present in the original description for each landmark (L1 to L5 represent the series of landmarks for Route A and Route B respectively). Recall that the accuracy of the descriptions was measured as a ratio, which was computed by dividing the correct recalled items with the actual number of items present in the original descriptions for each landmark.

Table 5.2.3: Detail of Landmarks Descriptions, in Experiment 6.

		Actual	Mean ± Std.Dev.	Accuracy ± Std.Dev.
Route A				
	L1	8	3.17 ± 1.38	0.39 ± 0.17
	L2	6	3.22 ± 1.11	0.54 ± 0.19
	L3	9	3.67 ± 1.45	0.41 ± 0.16
	L4	7	2.83 ± 1.72	0.40 ± 0.25
	L5	7	2.83 ± 1.04	0.40 ± 0.15
Route B				
	L1	8	3.11 ± 1.23	0.39 ± 0.15
	L2	6	3.28 ± 0.89	0.55 ± 0.15
	L3	9	3.72 ± 1.60	0.41 ± 0.18
	L4	7	2.17 ± 1.25	0.31 ± 0.18
	L5	7	3.61 ± 1.68	0.51 ± 0.24

As shown in Table 5.2.3, on average in both Route A and Route B the second landmarks (L2) were better remembered than the other landmarks.

A within-subjects analysis of variance was used to test for significant differences in the description of landmarks. The analysis used a 2 route (Route A vs. Route B) x 5 landmark (5 in Route A vs. 5 in Route B) ANOVA. The results of the 2-way ANOVA are displayed in Table 5.2.4.

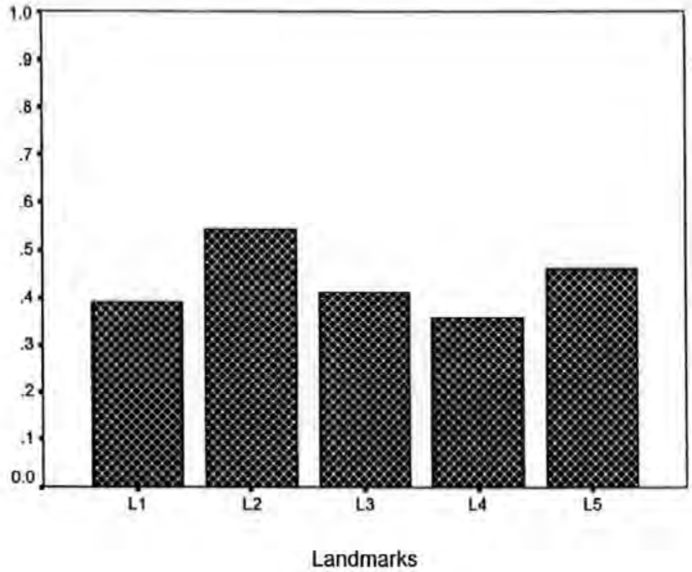
Table 5.2.4: Results of the 2-Way ANOVA on Landmark Description in Experiment 6.

Source	**df and F value**	**MS (error)**	**Significance**
Route (R)	$F_{(1, 17)} = 0.03$	0.001	ns
Landmark (L)	$F_{(4, 14)} = 7.59$	0.184	**
R x L	$F_{(4, 14)} = 1.54$	0.048	ns

Note. ns: $p > .05$; **: $p < .01$

The main effect of route was not significant. However, there was a main effect of landmark, $F_{(4, 14)} = 7.59$, $p = 0.002$. Overall the second landmark (L2) was better remembered than the other landmarks (displayed in Figure 5.2.1). This was confirmed by pair-wise comparison with regard to L1, L3, and L4 (at $p < .01$), but not for L5 (at $p = .06$). This result indicated that as L2 had fewer items (6 items) comparatively to the other landmarks (7 - 9 items), it was relatively easier to remember.

Figure 5.2.1: Main Effect of Landmarks on the Accuracy of their Descriptions in Experiment 6.



5.3.3.3 Distance Estimation

Now we turn to examine how accurate the recalls of segments were. Figure 5.2.2a and Figure 5.2.2b illustrate the average estimated distance for each segment across subjects against the actual distances for the segments in Route A and Route B respectively. It can be seen that small distances were on average over-estimated whereas larger ones were under-estimated. There was also large variability across subjects.

Figure 5.2.2a: Estimated Segments Against the Actual Distances for Route A, in Experiment 6.

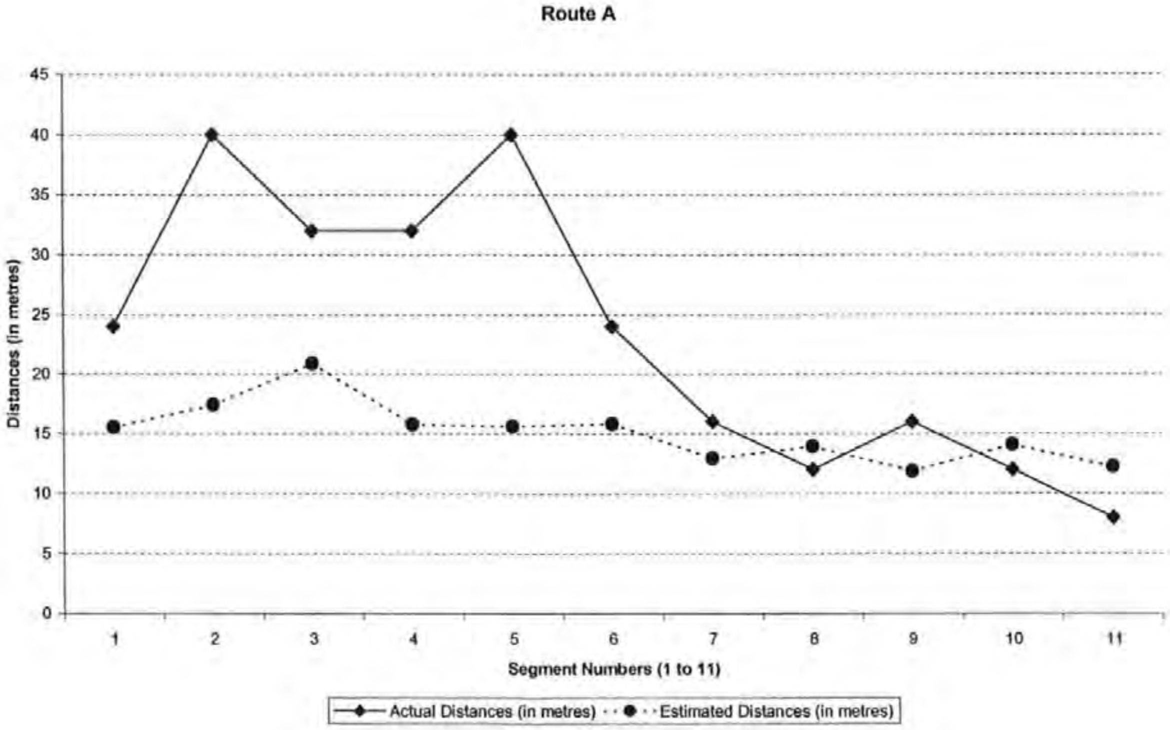
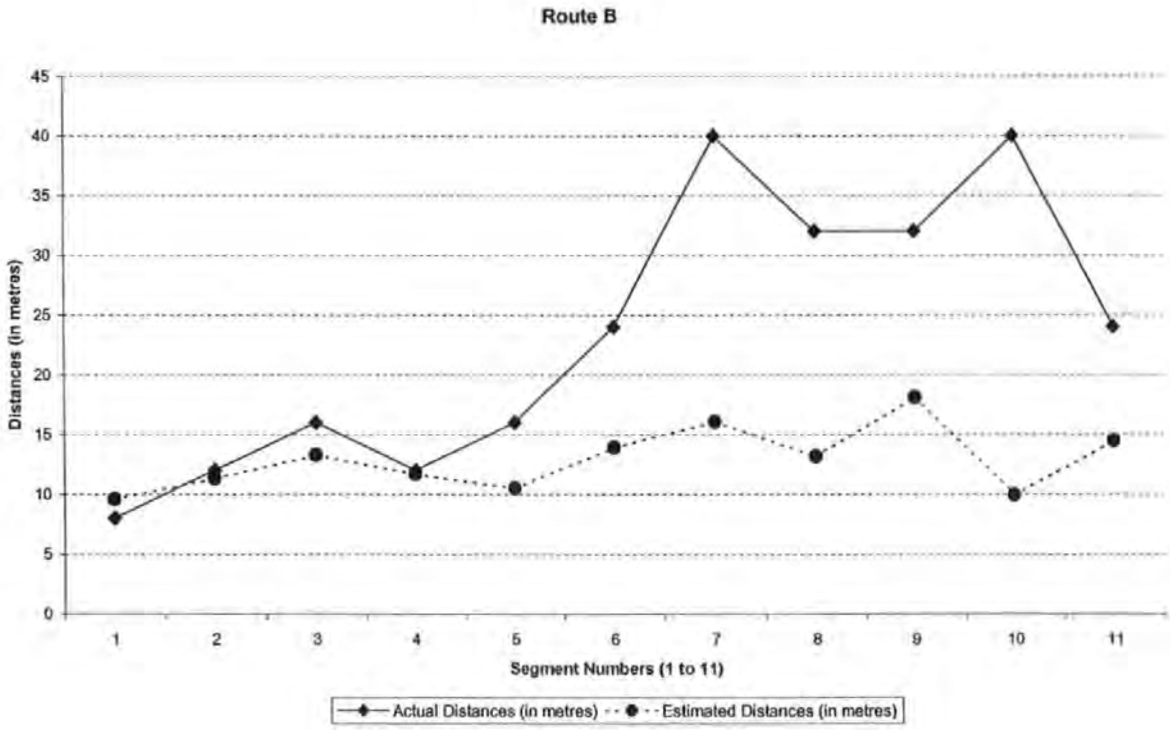


Figure 5.2.2a shows that in Route A, small segments up to 12 metres are overestimated, larger segments are underestimated.

Figure 5.2.2b shows that in Route B, small segments up to 8 metres are slightly overestimated, segments of 12 metres are remembered relatively accurately, and larger segments are underestimated.

Figure 5.2.2b: Estimated Segments Against the Actual Distances for Route B, in Experiment 6.



As both routes contained 11 segments each, in total there were 22 segments. The average segment lengths across participants for each segment were used to compute the correlation with the corresponding actual distances. The overall correlation between actual and estimated distances was highly significant, Pearson's Correlation Coefficient $\underline{r}_{(22)} = 0.68$, $\underline{p} < .001$ (1-tailed). This result indicates that if distances are longer, participants remember walking longer distances as well.

Now let us examine the influences of the number of turns, position, and action on path distance estimates. A 2 route (Route A vs. Route B) x 2 position (outer vs. inner) x 2 action (before vs. after) within-subjects analysis of variance was performed on path distance estimates. The results of the 3-way ANOVA are displayed in Table 5.2.5.

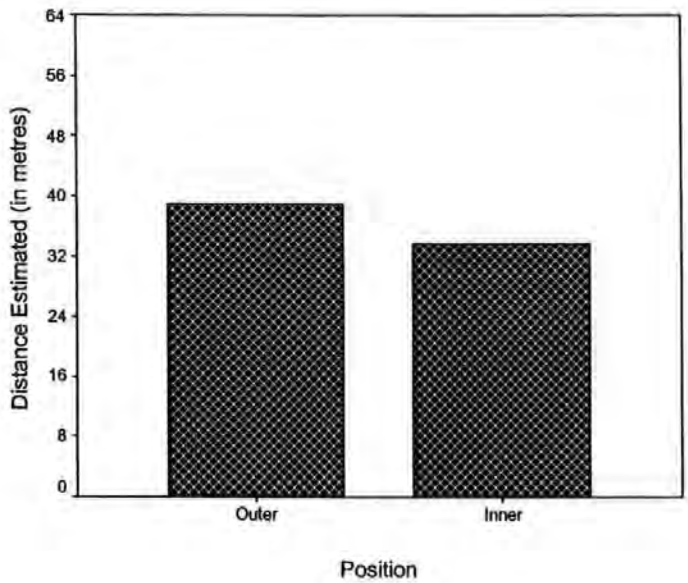
Table 5.2.5: Results of the 3-Way ANOVA on Distance Estimation, Experiment 6.

Source	**df and F value**	**MS**	**Significance**
Route (R)	$F_{(1, 17)} = 0.22$	113.78	ns
Position (P)	$F_{(1, 17)} = 6.82$	1013.36	*
Action (A)	$F_{(1, 17)} = 0.32$	53.78	ns
R x P	$F_{(1, 17)} = 0.01$	2.25	ns
R x A	$F_{(1, 17)} = 4.95$	1495.11	*
P x A	$F_{(1, 17)} = 1.35$	140.03	ns
R x P x A	$F_{(1, 17)} = 11.52$	103.41	**

Note. ns: $p > .05$; *: $p < .05$; **: $p < .01$

There were no significant main effects of route, or action. However, there was a main effect of position on distance estimates, $F_{(1, 17)} = 6.82$, $p = .018$ (displayed in Figure 5.2.3).

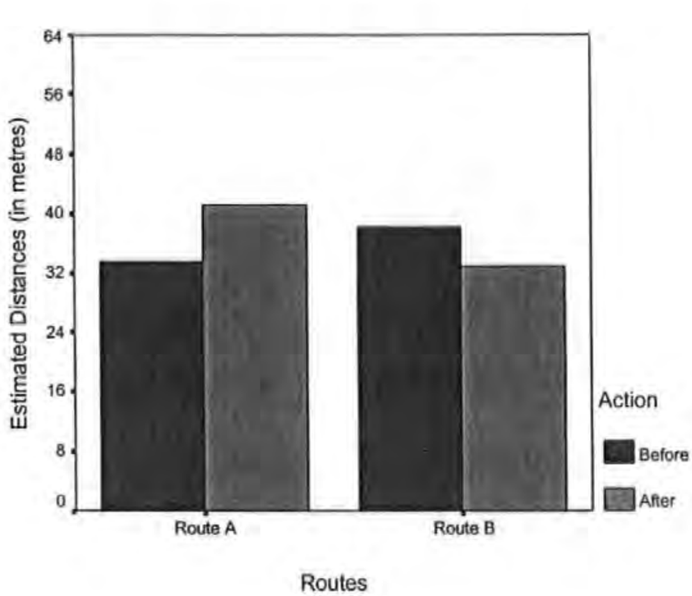
Figure 5.2.3: Main Effect of Position on Distance Estimates, in Experiment 6.



Overall, path distances were under-estimated, but participants remembered walking significantly longer in outer paths (one path contained 4 turns) than in 1-turn paths (inner paths).

There was a significant 2-way interaction between route and action, $\underline{F}_{(1, 17)} = 4.95$, $\underline{p} = .04$, displayed in Figure 5.2.4.

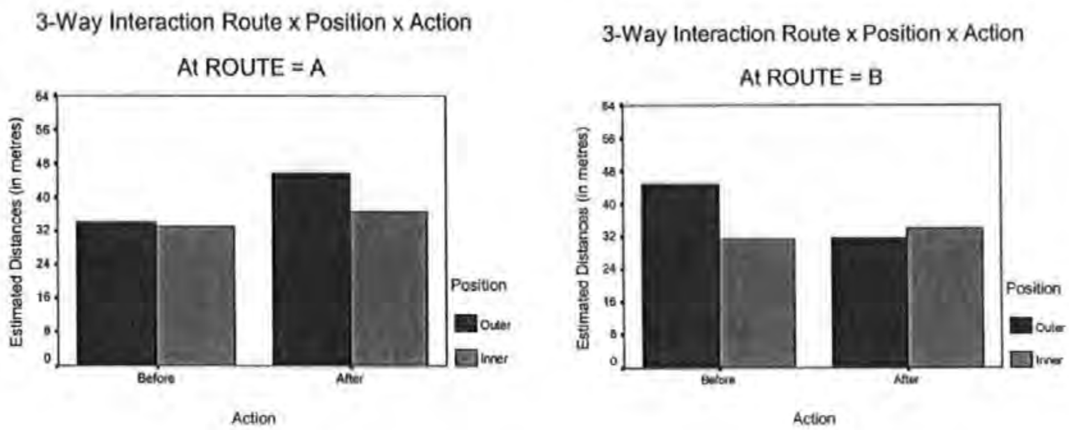
Figure 5.2.4: Two-Way Interaction between Route and Action on Distance Estimates, in Experiment 6.



Before action, estimated distances were shorter in Route A than in Route B; whereas after action, estimated distances were larger in Route A than in Route B. This effect was observed because of the number of turns.

There was also a significant 3-way interaction between route, position, and action, $\underline{F}_{(1, 17)}$ = 11.52, $\underline{p}$ = .003 (displayed in Figures 5.2.5).

Figure 5.2.5: Three-Way Interaction between Route, Position, and Action, in Experiment 6.



In Route A, before action on average estimated distances were of similar lengths at both outer and inner positions; whereas after action estimated distances were longer at both outer and inner positions. In Route B, before action estimated distances were longer at the outer position than at the inner position, after action estimated distances remained short at both outer and inner positions.

Follow up analyses indicated that in Route A, after the action has been performed the outer path (4-turn path) tends to be remembered as being longer than the inner path (1-turn path), $\underline{F}_{(17)} = 4.09$, $\underline{p} = 0.059$. In Route B, the reverse is the case; before the action the outer path (4-turn path) is remembered as being significantly longer than the inner path (1-turn path), $\underline{F}_{(17)} = 9.41$, $\underline{p} = 0.007$. None of the other differences were significant. What the 3-way interaction tells us is that the influence of turns is a robust effect on remembered distances; the inner paths immediately before and immediately after the action were not remembered significantly differently from each other.

Although there was no significant effect of action overall, we wanted to examine whether the segments just before and just after action were sensitive to the influence of action. In order to do this, we selected segments S4 and S5 from Route A, and segments S7 and S8 for Route B. For the comparisons, we used the segment ratios; these were obtained by dividing S4, S5, S7, and S8 by their corresponding actual distances. Table 5.2.6 displays the descriptive statistics for these segments.

Table 5.2.6: Descriptive Statistics for Before and After Action for Route A's and for Route B's Segments, in Experiment 6.

		Mean	Std. Dev.	N
Route A				
	Before Action S4	0.44	0.24	10
	After Action S5	0.37	0.23	10
Route B				
	Before Action S7	0.39	0.14	9
	After Action S8	0.45	0.17	9

Although on average there is under-estimation, we can see that in Route A before action the ratio was larger than after action; in Route B however, the reverse is the case, before action the ratio was smaller than after action. To test for significance, we performed paired t-tests on Route A's segments and on Route B's segments; the results of the t-tests are displayed in Table 5.2.7.

Table 5.2.7: Comparing straight line distances just before and just after action, in Experiment 6.

	Before vs. Action	t statistics	Significance	N
Route A	S4 > S5	1.26	0.24	10
Route B	S7 < S8	2.06	0.07	9

The difference between S4 and S5 in Route A was not significant, however, there was a marginal difference between S7 and S8 in Route B; $t_{(8)} = 2.06$, $p = 0.07$ (2-tailed).

5.3.4 Discussion

The fact that participants were exposed to the environments twice in order to acquire route knowledge substantially improved the data collection. Although the rate of exclusion was still high (22 %), suggesting that in some participants memories for routes were imprecise, the majority of participants produced the landmarks in the correct order, and therefore distance estimates could be analysed.

The results replicated those in Experiment 5. In relation to the accuracy of the landmark descriptions (as measured by dividing the correct recalled items with the actual number of items present in the original descriptions for each landmark), again we found that the second landmark (L2) was remembered better than the other landmarks. However, when we examined the actual number of items in descriptions more closely, it appeared that

L2 had fewer items (6 items) comparatively to the other landmarks (7 – 9 items). This may contribute to making L2 relatively easier to remember.

As expected, the effect of number of turns was also observed in this experiment; paths with more turns (in the outer paths) were remembered as being longer than paths with fewer turns (in the inner paths).

In terms of path distances just before and just after action, no effect of the action performed mid-route was observed. This may be due to the salience of the action itself. The movement of dispatching (dropping) an object into a box may be considered as a simple and routine activity therefore was not salient enough to exert an effect on spatial representation. A more pronounced sequence of movement to perform the dispatch task may make the action more memorable thereby the prediction of a difference between remembered distances before and after action would stance more of a chance of being found if present.

In order to examine more carefully the influence of action on distance estimation in the next experiment, we first proceeded by generating better controlled environment descriptions than those in Experiments 5 and 6. In Experiment 7, environment descriptions were controlled for landmarks' spatial relationship specifications, as well as landmarks' features, such as size, composition (stone, iron, etc.), and cultural and historical importance. The uniformity of the environmental descriptions was necessary in order to eliminate the bias of the recall of landmarks, which may also have affected remembered distances.

Most importantly, we wanted to increase the salience of action itself in order to observe its effect on remembered distances. One way of making the action more pronounced was to increase the sequence of movements as well as more bending movements leading up to the dispatching of the object into the box. In the next experiment, we used the following arrangement in order to make the action more pronounced. At the start of the imaginary walk, participants carried a bag containing a critical item (a book or a letter) in one hand, and in the other hand they carried an object (an umbrella). As they "arrived" at the critical landmark (at mid-route), they listen to the description of the landmark and then they were required to walk into the landmark. Then they were told they were in front of the box. Specifically, at this time they were instructed to bend down to deposit an object on the floor, then to take the critical item out of the bag, then to feel the box, then to dispatch the critical item into the box, then to bend down again to pick up the object from the floor. And finally they were instructed to walk out of the landmark.

By making the action more pronounced, and if the role of action is important during the processing of distance from memory, then the performance of the action becomes more marked in people's memory, thereby may lead to an increase perception of distance. Additionally, there may be a cognitive effort associated with performing action which may subsequently influence distance estimation; whereas once the goal has been achieved, the cognitive effort lessens. Hence, since less effort is required distance would seem much shorter than when more effort is required. We expect that during recall, distances are more accurately remembered before action than after action.

Another level of understanding the influence of action was to examine its relationship with the amplitude of turns during navigation through the environments. Large degree of turns, such as 180 or 270 degrees involve larger body movements as compared to 90 degrees turns. If action representation is important then large degrees of turns may be more salient than 90 degree turns in memory. Therefore, we hypothesised that paths containing 270 degrees turns would yield longer distance estimates than paths containing 90 degrees turns controlled for actual lengths.

In the next section we report Experiment 7. We used the same methodology as in Experiments 5 and 6. However, in Experiment 7, we manipulated the number of turns en route, as well as the amplitude of turn, and made the action more pronounced.

5.4 Experiment 7

5.4.1. Introduction

The main aim of Experiment 7 was to investigate the influence of action more carefully. The absence of a clear effect of action performed at L3 (mid-route) in Experiments 5 and 6 may be due to the salience of action itself. If this assumption was correct then increasing the sequence of body movements would lead to an increase of perception of distance.

Additionally, there may be a cognitive effort associated with performing action at mid-route. The goal of performing action may subsequently influence distance estimation (Naylor & Taylor, 2002). We hypothesised that since cognitive effort was required to accomplish the action, i.e., getting rid of the object through dispatching the book or the letter into a box, distance would seem much longer, whereas once the goal has been achieved, the cognitive effort lessens. Hence, since less effort is required distance would seem much shorter than when more effort is required. In other words, we expect distances to be remembered as being longer before action than after action.

While in Experiments 5 and 6, the turns happened at the beginning (Route B) or at the end (Route A) of the routes, we also wanted to examine the same effect of turns in the inner part of the route rather than only in the outer part of the route. Assuming the importance of action in the cognitive process, we also wanted to investigate whether paths containing 270 degrees turns would yield larger distance estimates than paths containing 90 degrees turns as turning 180 or 270 degrees involved larger body movements as compared to 90 degrees turns.

In Experiment 7, the same methodology as that in Experiment 6 was used, but the environment descriptions were slightly modified in terms of the uniformity with which the environmental descriptions were created. The uniformity of the environmental descriptions was necessary in order to eliminate the bias of the recall of landmarks, which may also have affected remembered distances.

5.4.2 Method

The method used was the same as in Experiment 6, except here four route descriptions were used instead of two.

5.4.2.1 Environment Stimuli

Four descriptions of the environments were used, and they were called Routes A, B, C, and D. Each environment contained a series of five landmarks. Each landmark was described using characteristics such as its functionality, and its physical features. Each landmark and surrounding items were described controlled for their sizes as well as the number of words used.

The detailed descriptions for Route A and Route C are shown in Figure 5.3.1a and Figure 5.3.1b (See Appendices 7.2.4 and 7.2.5 for Routes B and D). Note that, in terms of environmental layouts, Route B and Route D are mirror images of Route A and Route C respectively (see Figure 5.3.2); in terms of text contents, Route B used Route C's text content; and Route D used Route A's text content. In the descriptions shown below, the critical landmarks are in bold characters, and the action is performed at mid-route landmark (L3) shown in bold characters with border.

Figure 5.3.1a: Description of Route A (1-3-3-1) used in Experiment 7.

You are in a place called Charles-town. Your starting place is the Merchant House.
I am going to take you on a walk from the Merchant House to St John's Church.

I am going to start you at a place called **Merchant House**. It is a medieval house well preserved to this very day. The house has a very ornamental bay window. There is a beautiful shrubbery at the entrance. In front of the entrance, there is a decorative stone gatepost.

I am going to get you to walk away from the Merchant House along a road called Silver Street. Start walking now. Stop. Now you turn onto Beacon Street. Start walking now. Stop.

You are now in front of a place called the **Museum**. It is one of the most interesting museums in town. The museum has an antic style wooden door. There is a fossil's plaque at the entrance. In front of the entrance there is a sculpture on the ground.

Leaving the Museum behind, you continue walking straight ahead along Beacon Street. Start walking. Stop. You turn now onto South Street Start walking. Stop. You turn now onto Maple Street. Start walking. Stop. You turn now onto Hill Street. Start walking. Stop.

You are now in front of a place called the **Library**. It is very popular among people living in Charles-town. The library has a marble staircase at the front. There is a stone table carved with flowers at the entrance. In front of the entrance, there is a sundial.

> OK. Now you go into the library towards a counter. Start walking. Stop.
>
> Now you bend over to put down the umbrella on the floor.
> OK. Now you take the book out of the bag.
> OK. You are now standing directly in front of the book return box.
> You feel the return box in front of you.
> Now you post the book into the return box.
> OK. Now you bend over to pick up the umbrella.
>
> Now you walk out of the library. Start walking. Stop.

You are on Hill Street again. Now you continue walking straight ahead leaving the library behind you. Start walking now. Stop. Now you turn onto Summer Street. Start walking. Stop. You turn now onto Park Street. Start walking. Stop. You turn onto Ford Street. Start walking. Stop.

Now you are in front of a place called the **Concert Hall**. It is the home of the Charles-town Symphony Orchestra. The concert hall has a golden dome shaped roof. There is a water feature at the entrance. In front of the entrance there is a beautiful cast iron gate.

Leaving the concert hall behind, you continue walking along Ford Street. Start walking. Stop. You turn onto Cedar Street. Start walking. Stop.

Now you now in front of a place called **St John's Church** which is your final destination. Its Gothic architecture stands out against its surrounding. The Church has an imposing tower. There is a life-size figure of St John at the entrance. In front of the entrance, there is an intricately carved holly cross.

Figure 5.3.1.b: Description of Route C (3-1-1-3) used in Experiment 7.

You are in a place called Louistown. Your starting place is the Park School.
I am going to take you on a walk from the Park School to the Visitor Centre.

I am going to start you at a place called **Park School**. It was used as a grammar school until it was closed. Park School is a two-storey building. There is a Victorian style clock tower at the entrance. In front of the entrance, there is a mature oak tree.

I am to get you to walk away from Park School along a road called Mount Street. Start walking. Stop. Now you turn onto Princess Street. Start walking. Stop. You turn onto Alma Street. Start walking. Stop. You turn onto Castle Street. Start walking. Stop.

You are now in front of a place called **Crystal Bank**. It is one of the most modern buildings in town. Crystal bank has a glass façade. There is an artistic feature flowers bed at the entrance. In front of the entrance, there is a large cash point machine.

Leaving Crystal Bank behind, you continue walking straight ahead along Castle Street. Start walking. Stop. You turn onto North Street. Start walking. Stop.

You are now in front of a place called the **Post Office**. It is one of the most characterful buildings in Louistown. The Post office has a double entry door. There is a sculpture representing Hermes at the entrance. In front of the entrance, there is a large post box.

OK. Now you walk into the Post Office. Start walking. Stop.

Now you bend over to put down the umbrella on the floor.
OK. Now you take the parcel out of the bag.
OK. You are now standing directly in front of the letter box.
You feel the letter box in front of you.
Now you post the parcel into the letter box.
OK. Now you bend over to pick up the umbrella.

Now you walk out of the post office. Start walking. Stop.

You find yourself on North Street again. Now you continue walking straight ahead leaving the post office behind you. Start walking now. Stop. You turn onto Kings Street. Start walking. Stop.

You are now in front of a place called the **Town Hall**. It is the most picturesque town houses in Louisville. The Town hall has a patterned red brick external wall. There is a diminutive gate lodge at the entrance. In front of the entrance, there is an ornamental plaque.

You leave the town hall behind and continue walking straight ahead along Kings Street. Start walking. Stop. Now you turn onto Union Street. Start walking. Stop.
You turn onto Baker Street. Start walking. Stop.
You turn onto Scott Street. Start walking. Stop.

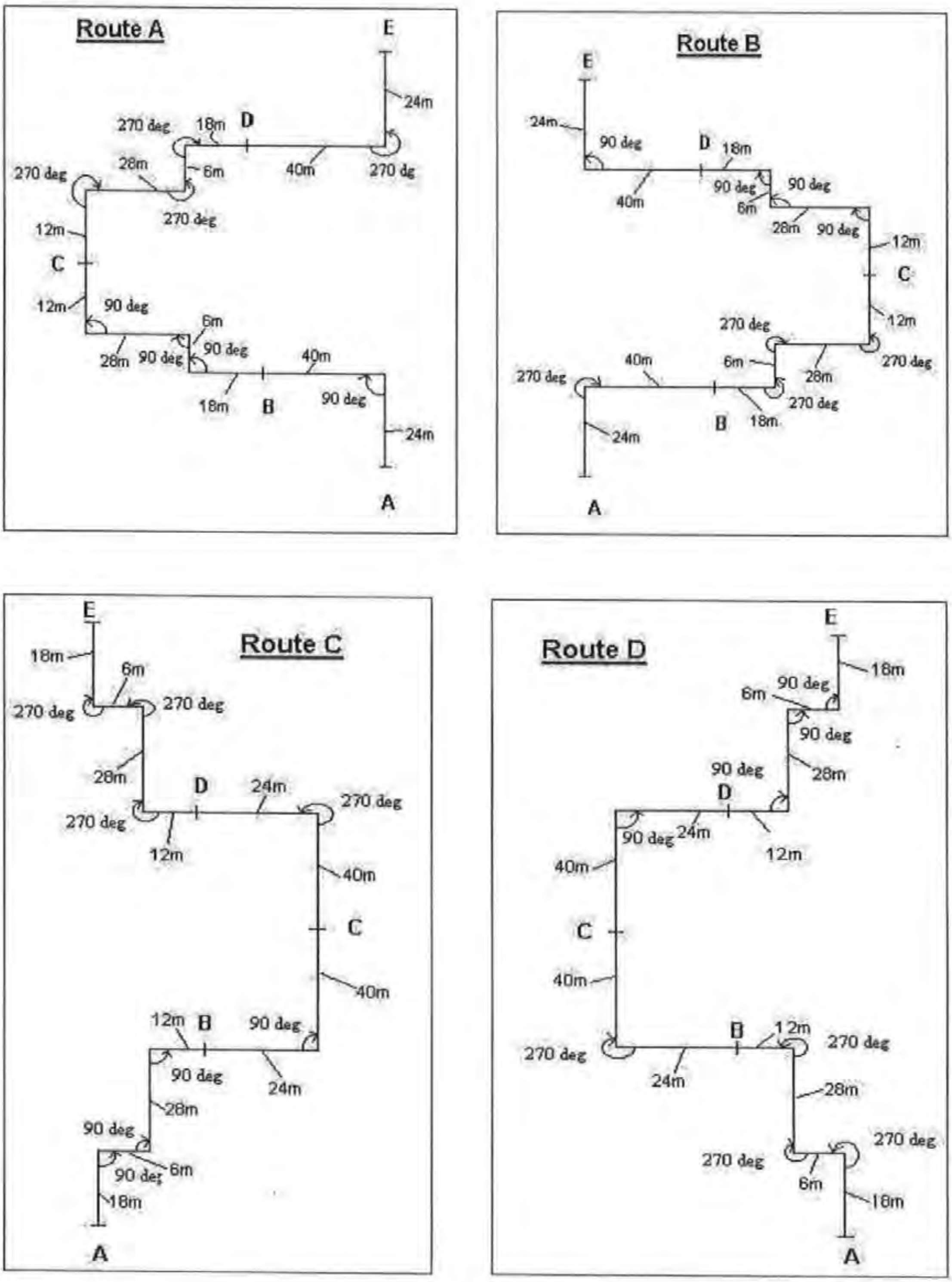
You are now in front of a place called the **Visitor Centre** which is your final destination. It regularly exhibits works of local as well as international artists. The Visitor centre has a marble colonnade at the front. The Centre's flag is displayed at the entrance. In front of the entrance, there is a signpost".

In terms of how turns are configured in each route, Routes A and B have 1331 configurations, i.e., each route starts with a path with 1 turn, followed by a path with 3 turns, followed by a path with 3 turns, followed by a path with 1 turn. Routes C and D have 3113 configurations, i.e., each route starts with a path with 3 turns, followed by a path with 1 turn, followed by a path with 1 turn, followed by a path with 3 turns.

Figure 5.3.2 shows the schemas of Routes A, B, C, and D with indications of degrees of turns in each route. Route A and Route C start with 90 degree turns; Route B and Route D start with 270 degree turns. After the action has been performed, Route A and Route C' s turns are 270 degrees, Route B and Route D, 90 degree turns.

Each participant learned two different routes with the same configuration. Within each configuration (1331 vs. 3113), routes were presented to the participants in counterbalanced order.

Figure 5.3.2: Schema of Routes A, B, C, and D used in Experiment 7.



Note. Capital letters represent different landmarks.

5.4.2.2 Experimental Design

In order to examine more carefully the importance of the role of action on distance estimation, we used four groups of participants. The four experimental conditions came from the combination of the two levels of route configuration (1331 vs. 3113) and the two levels of route presentation (90/270 vs. 270/90).

In the 1331 condition half the participants were exposed to Route A first followed by Route B (AB group); the remaining participants were exposed to Route B first then followed by Route A (BA group). In the 3113 condition, half the participants were exposed to Route C first followed by Route D (CD group); the remaining participants were exposed to Route D first followed by Route C (DC group) (see Table 5.3.1).

Table 5.3.1: Experimental conditions, in Experiment 7.

	1331	3113
90/270	AB	CD
270/90	BA	DC

The design used was a 2 configuration (1331 vs. 3113) x 2 route presentation (90/270 vs. 270/90) x 2 number of turns (one vs. three) x 2 amplitude of turns (90 degrees vs. 270 degrees) x 2 action (before vs. after) with repeated measures on the last three factors. The between-subjects factors were configuration and route presentation, and the remaining factors were within-subjects factors. Each participant was tested under each level of turn, amplitude, and action (see Table 5.3.2).

Table 5.3.2: Representation of the 2 Configuration x 2 Route presentation x 2 Number of Turns x 2 Amplitude of Turns x 2 Action Experimental Design used in Experiment 7.

		3-TURN				1-TURN			
		90/270		270/90		90/270		270/90	
		Before	After	Before	After	Before	After	Before	After
1331	AB								
	BA								
3113	CD								
	DC								

5.4.2.3 Participants

Seventy-eight undergraduate students agreed to participate in the experiment in exchange for course credit. They were between 18 and 46 years old (mean = 22.11, SD = 6.85). They were randomly assigned to one of four experimental conditions and were individually tested.

5.4.2.4 Procedure

The procedure was the same as in Experiment 6. Each participant learned two routes with the same configuration (1331 or 3113). They were exposed to each route twice. The test lasted one hour.

Unlike Experiments 5 and 6, the action was more pronounced in the present experiment. We used the following arrangement in order to make the action more pronounced. At the start of the imaginary walk, participants carried a bag containing a critical item (a book or a letter) in one hand, and in the other hand they carried an object (an umbrella). As they "arrived" at the critical landmark (at mid-route), they listen to the description of the landmark. Now they were required to walk into the landmark. Then they were told they were in front of the box. Specifically, at this time they were instructed to bend down to deposit the umbrella on the floor, then to take the book/letter out of the bag, then to feel the box, then to dispatch the book/letter into the box, then to bend down again to pick up the umbrella from the floor. And finally they were instructed to walk out of the landmark.

5.4.3 Results

As in previous experiments, to be included in the analyses participants' responses must show the correct sequences of landmarks in both routes. Responses from 17 participants (22 % of the total of 78 participants) were excluded from the analyses, as they did not satisfy the criteria for data inclusion. Data from 61 participants (78 %) were used in the analyses.

5.4.3.1 Number of Steps

The characteristics of the individuals' mental walks were examined. Table 5.3.3 displays the number of steps participants produced, the time taken to traverse the reference path (20 metres), the length of the steps, as well as the number of steps they produced per second.

Table 5.3.3: Characteristics of the Mental Walks, in Experiment 7.

Descriptive Statistics	**Number of Steps**	**Duration (in seconds)**	**Step Length (in metres)**	**Number of Steps / sec.**
Minimum	21.00	12.00	0.59	1.50
Maximum	34.00	20.00	0.95	2.14
Mean	27.82	15.67	0.73	1.78
Std. Dev.	3.07	2.08	0.08	1.45

As displayed in Table 5.3.3, participants produced about 2 steps per second and each step measured about 70 centimetres, similar to those in the previous experiments.

Now we examine the correlation between the total number of steps to walk the first and the second routes and their corresponding re-walked distances across participants (N = 61) in order to ensure that participants were not just remembering the number of clicks heard instead of imagining distance walked. We found no significant correlation (shown in Table 5.3.4), which indicated that participants were not remembering the number of clicks. The correlation between the first and the second routes in remembered distance was significant, which indicated that individual participants were consistent in their remembered distances for routes of the same length.

Table 5.3.4: Correlation between Number of Steps and Re-walked Distances, Experiment 7.

	Number of Steps	Re-walked Route A	Re-walked Route B
Number of Steps	-		
Re-walked Route A	-0.19	-	
Re-walked Route B	-0.06	0.41**	-

Note. **: $p < .01$.

5.4.3.2 Landmark Descriptions

Each participant learned two different routes within the same configuration. For the analysis, independently of route configurations, and route presentation, we called the two routes participants learned first route and second route respectively.

In each route participants learned, each critical landmark and its relationship to the surroundings were described uniformly. Table 5.3.5 displays the means of the number of correct descriptions for each landmark (L1 to L5 represent the series of landmarks) across subjects for each route they learned, and the means across all groups for each critical landmark. As shown in Table 5.3.5, across groups on average the first landmarks (L1) were better remembered than the other landmarks in both routes.

Table 5.3.5: Detail of Landmarks Descriptions, in Experiment 7.

	1331		3113		
	AB	BA	CD	DC	Average
First Route					
L1	4.07	4.67	5.69	3.93	4.49 ± 1.87
L2	3.33	3.13	4.50	3.60	3.56 ± 1.68
L3	3.47	2.80	4.62	4.53	3.76 ± 1.84
L4	4.33	3.67	3.87	4.20	3.92 ± 1.88
L5	4.07	3.47	4.50	4.27	3.98 ± 1.89
Second Route					
L1	4.00	3.73	3.75	5.93	4.21 ± 2.00
L2	4.27	2.80	2.87	4.93	3.61 ± 2.06
L3	3.20	3.07	5.06	4.00	3.77 ± 2.07
L4	1.93	3.73	4.50	3.60	3.38 ± 1.89
L5	3.07	4.00	3.75	3.07	3.40 ± 1.67

Although all landmarks were uniformly similarly described, we wanted to examine whether there was bias toward particular landmarks. A within-subjects analysis of variance was used to examine the accuracy of the description of landmarks.

The analysis used a 2 route (first vs. second) x 5 landmark (5 in first route vs. 5 in second route) analysis of variance. The results of the 2-way ANOVA are displayed in Table 5.3.6.

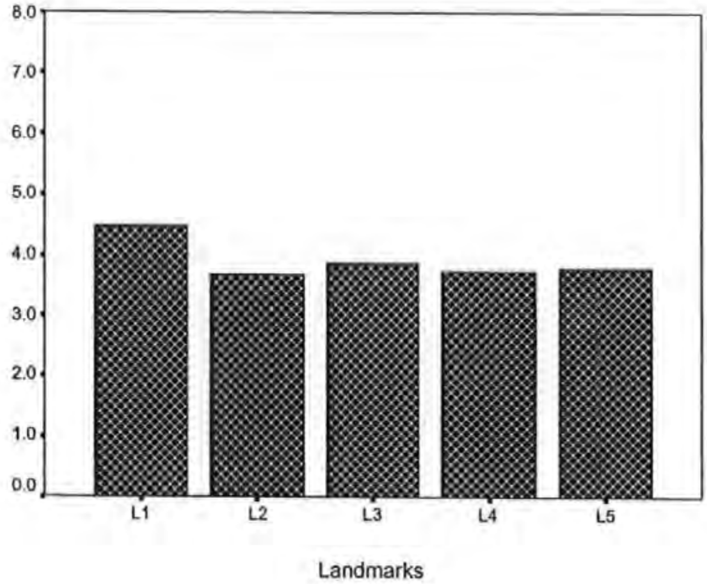
Table 5.3.6: Results of the 2-Way ANOVA on Landmark Description in Experiment 7.

Source	**df and F value**	**MS (error)**	**Significance**
Route (R)	$F_{(1, 60)} = 2.75$	11.84	ns
Landmark (L)	$F_{(4, 57)} = 5.94$	12.86	**
R x L	$F_{(4, 57)} = 1.33$	2.76	ns

Note. ns: $p > .05$; ** : $p < .01$

The main effect of route was not significant. However, there was a main effect of landmark, $F_{(4, 57)} = 5.934$, $p < 0.001$, displayed in Figure 5.3.3. Overall, L1 was better recalled than the other landmarks, and this was confirmed by pair-wise comparisons (the mean ratio for L1 was significantly larger than that for L2, L3, L4 and L5 respectively; at $p < .001$). This result indicates the primacy effect of L1 over the following landmarks. The interaction between route and landmark was not significant.

Figure 5.3.3: Main Effect of Landmarks on the Accuracy of their Descriptions in Experiment 7.



5.4.3.3 Distance Estimation

Now we turn to examine how accurate the memory for segments was. The figures shown below display the estimate for each segment averaged across participants in each group against the actual distances for both routes.

Figure 5.3.4a: Remembered Segments in the AB Group, Experiment 7.

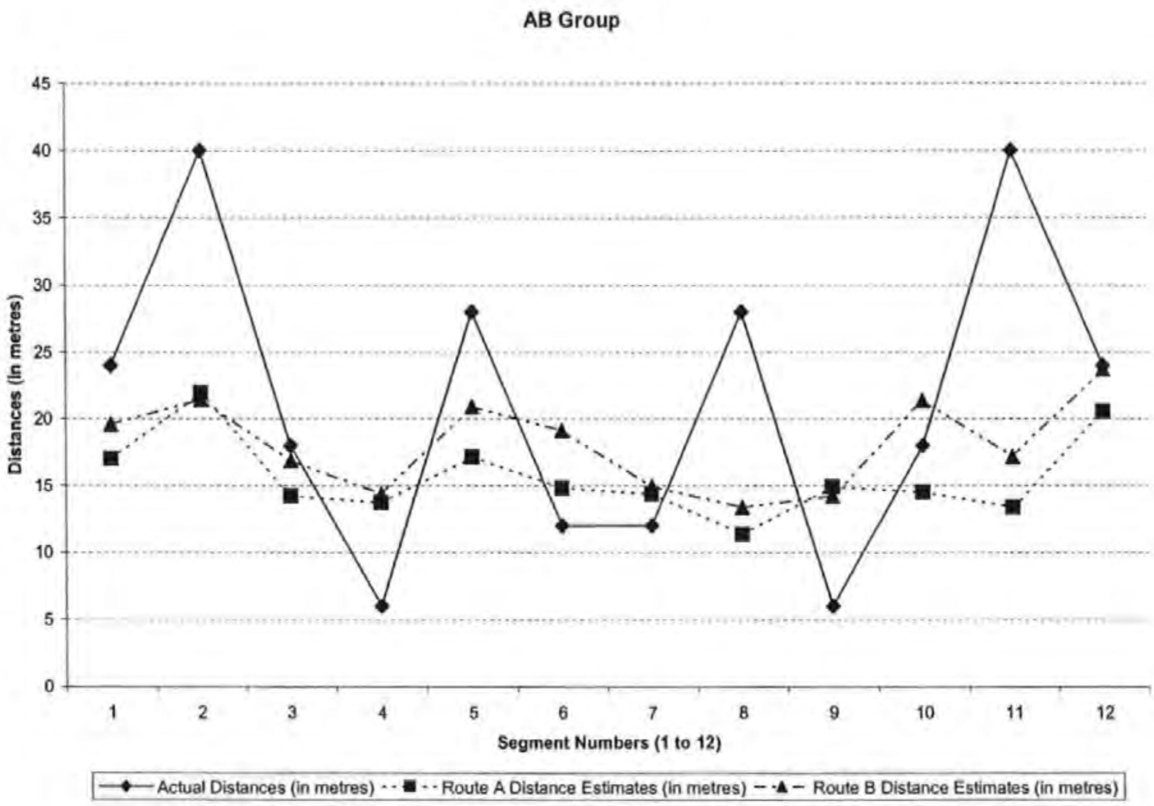


Figure 5.3.4b: Remembered Segments in the BA Group, Experiment 7.

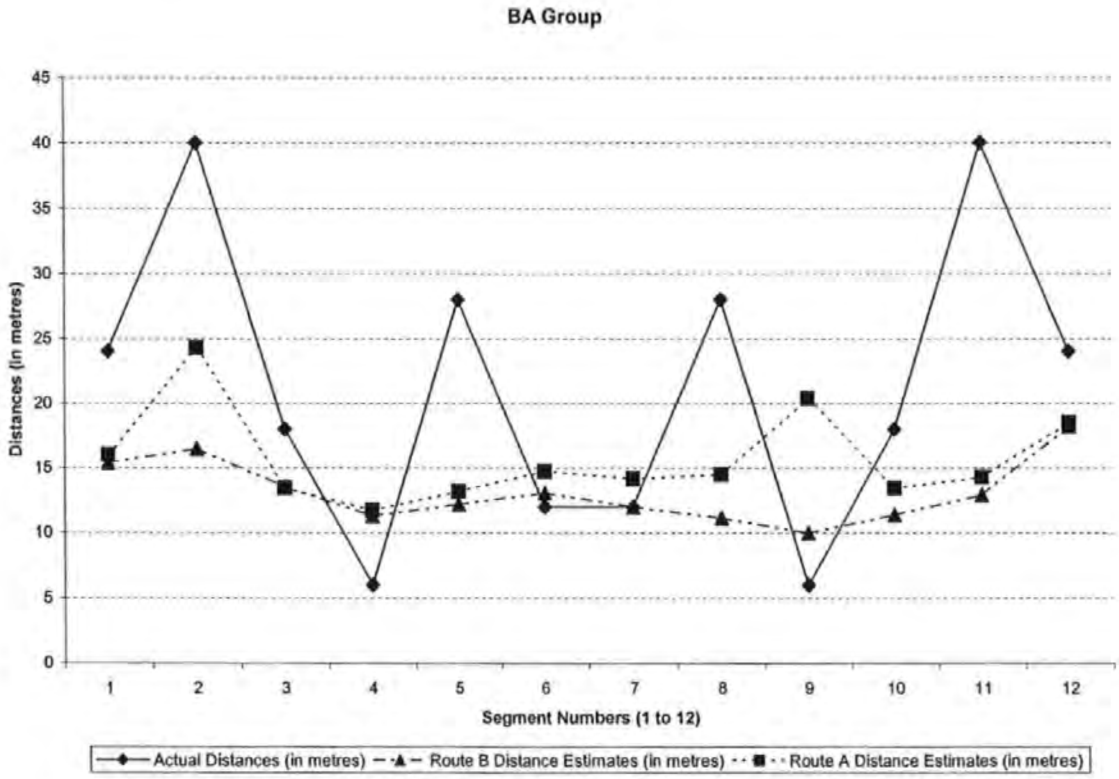


Figure 5.3.4c: Remembered Segments in the CD Group, Experiment 7.

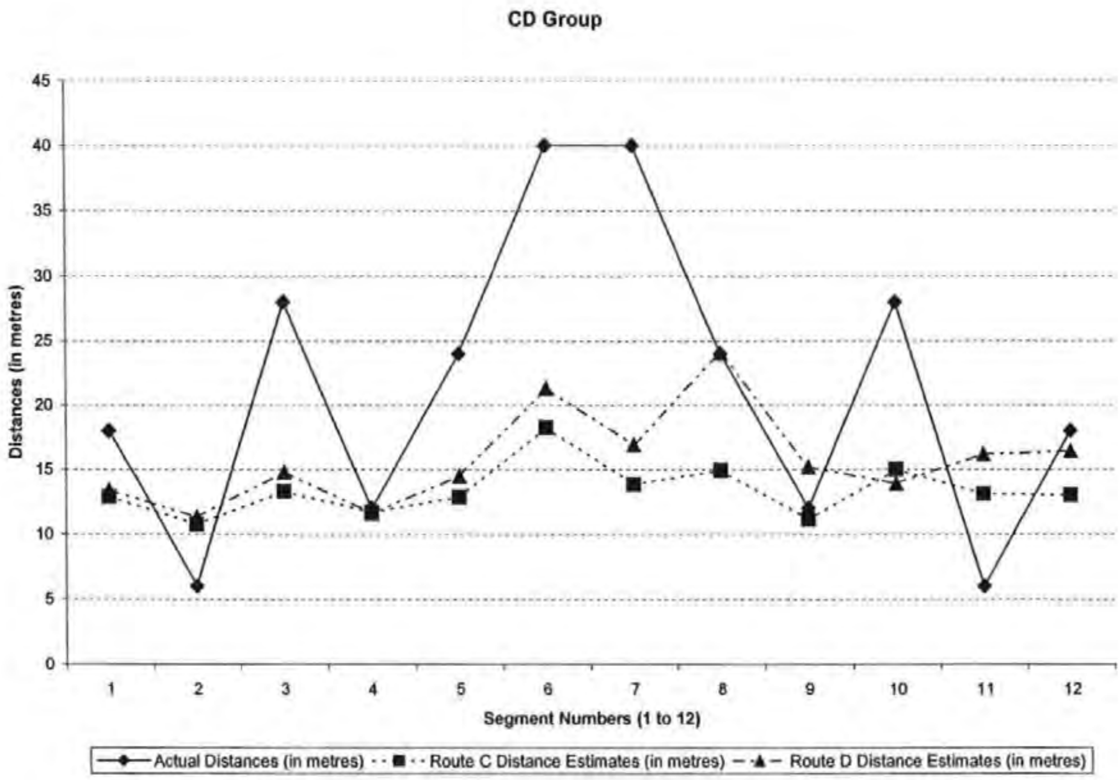
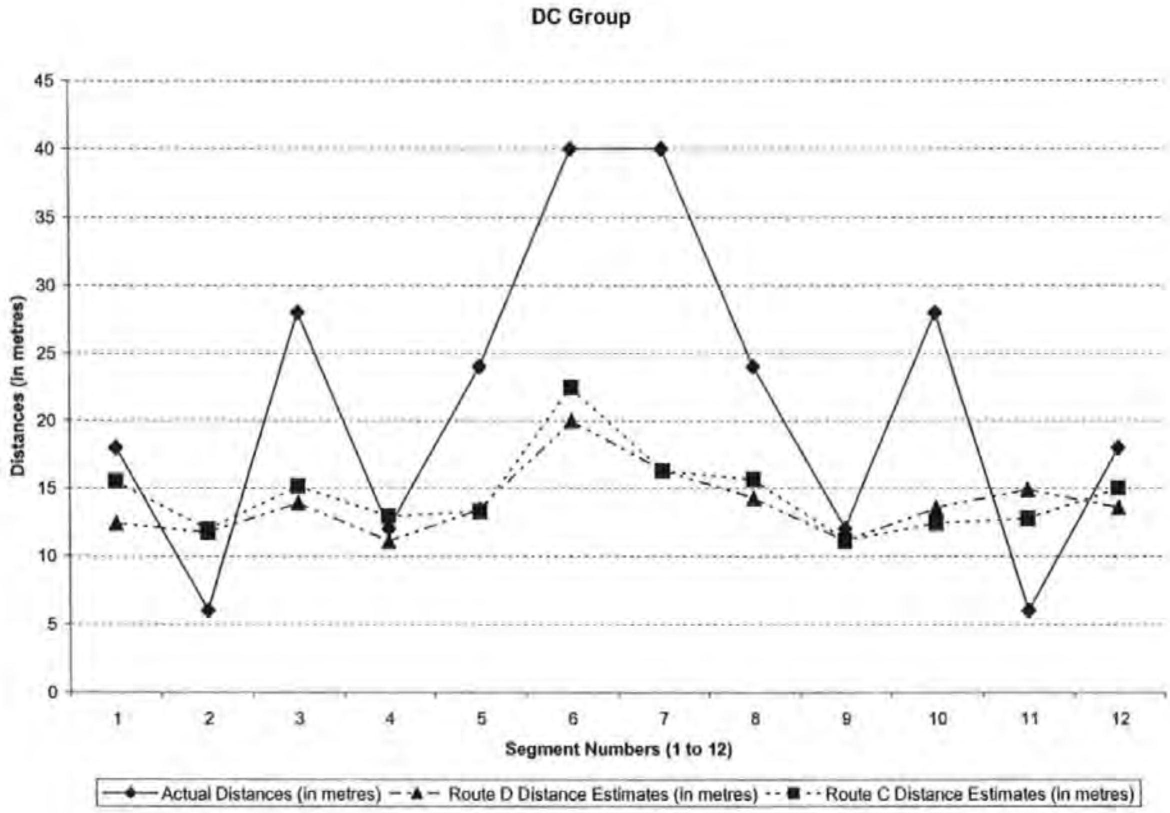


Figure 5.3.4d: Remembered Segments in the DC Group, Experiment 7.



Figures 5.3.3a and 5.3.3b shows that on average, in the AB group distances in Route B were better remembered than distances in Route A; in the BA group, distances in Route A were remembered better than distances in Route B. As shown in Figures 5.3.3c and 5.3.3d, on average the CD group remembered Route D better than Route C; the DC group remembered better Route C than Route D. This suggested that getting used to the task improves memory for distances.

As each participant learned two routes and each route contained 12 segments, there were overall 96 segments in total (12 segments x 2 routes x 4 groups). We found a highly significant correlation between recalled distances for segments and their actual distances, Pearson Correlation Coefficient $\underline{r}_{(96)} = 0.45$, $\underline{p} < .0001$ (1-tailed). This result indicates that if there were longer segments to traverse subjects remembered walking longer distances as well.

Now we want to examine whether there is difference between segments just before and just after action. As each participant learned two routes, we selected segments S6 and S7 from both routes. For the comparisons, we used ratios; these were obtained by dividing S6, S7, by their corresponding actual distances. Table 5.3.7 displays the descriptive statistics for these segments.

Table 5.3.7: Descriptive statistics for segments just before and just after action, in Experiment 7.

		Mean	Std. Dev.	N
First Route				
	Before Action S6	0.26	0.13	48
	After Action S7	0.21	0.10	48
Second Route				
	Before Action S6	0.31	0.17	55
	After Action S7	0.25	0.11	55

Table 5.3.7 shows that for both routes, on average segments just before action were longer than those just after action. T-tests confirmed that the difference was significant, for both the first route, $\underline{t}_{(47)} = 2.36$, $\underline{p} = 0.02$ (2-tailed), and for the second route; $\underline{t}_{(54)} = 2.72$, $\underline{p} = 0.009$ (2-tailed). In both routes, segments before action were remembered as being longer than segments after action.

Now let us examine the influences of configuration, route, turns, amplitude, and action on path distance estimates. A 5-way mixed analysis of variance was used that combined 2 configuration (1331 vs. 3113) x 2 route presentation (90/270 vs. 270/90) x number of turns (one vs. three) x amplitude of turns (90 degrees vs. 270 degrees) x 2 action (before vs. after). The results of the 5-way ANOVA are displayed in Table 5.3.8.

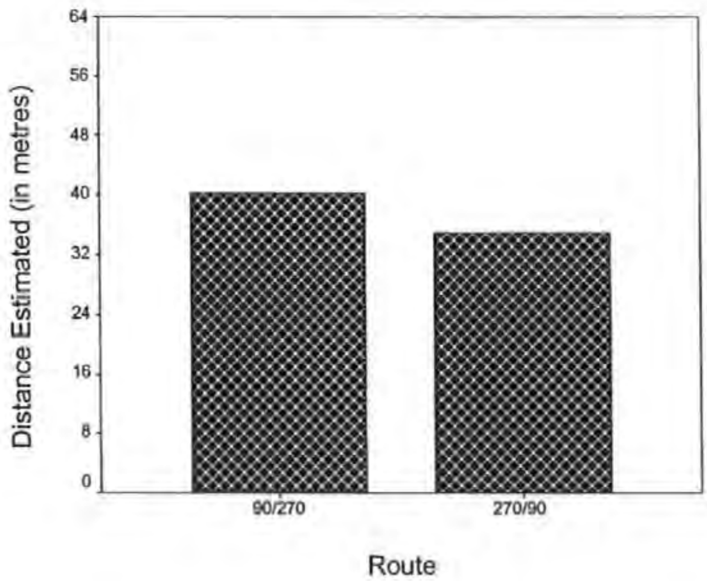
Table 5.3.8: Results of the 5-Way ANOVA on Distance Estimation, Experiment 7.

Source	df and F value	MS	Significance
Route presentation (R)	$F_{(57)} = 3.59$	3452.63	.063
Configuration (C)	$F_{(57)} = 0.07$	63.16	ns
Turn (T)	$F_{(57)} = 52.85$	11524.28	**
Amplitude (Am)	$F_{(57)} = 0.16$	29.91	ns
Before/After Action (A)	$F_{(57)} = 6.02$	901.76	*
R x C	$F_{(57)} = 1.17$	1123.97	ns
R x T	$F_{(57)} = 0.62$	136.00	ns
R x Am	$F_{(57)} = 0.01$	1.79	ns
R x A	$F_{(57)} = 2.30$	344.15	ns
C x T	$F_{(57)} = 1.91$	416.28	ns
C x Am	$F_{(57)} = 3.74$	704.31	.058
C x A	$F_{(57)} = 4.20$	629.20	*
T x Am	$F_{(57)} = 2.19$	381.15	ns
T x A	$F_{(57)} = 0.13$	20.12	ns
Am x A	$F_{(57)} = 0.08$	26.37	ns
R x C x T	$F_{(57)} = 1.72$	374.22	ns
R x C x Am	$F_{(57)} = 0.04$	7.84	ns
R x C x A	$F_{(57)} = 2.37$	354.47	ns
C x T x Am	$F_{(57)} = 2.25$	390.64	ns
C x T x A	$F_{(57)} = 0.04$	6.52	ns
R x T x A	$F_{(57)} = 0.13$	20.53	ns
R x Am x A	$F_{(57)} = 21.20$	6854.29	**
C x Am x A	$F_{(57)} = 0.02$	8.04	ns
T x Am x A	$F_{(57)} = 0.22$	38.79	ns
R x C x T x Am	$F_{(57)} = 0.35$	61.43	ns
R x C x T x A	$F_{(57)} = 0.09$	15.11	ns
R x C x Am x A	$F_{(57)} = 0.29$	93.67	ns
R x T x Am x A	$F_{(57)} = 2.78$	494.50	ns
C x T x Am x A	$F_{(57)} = 1.53$	272.19	ns
R x C x T x Am x A	$F_{(57)} = 4.91$	874.00	*

Note. ns: $p > .05$; *: $p < .05$; **: $p < .01$

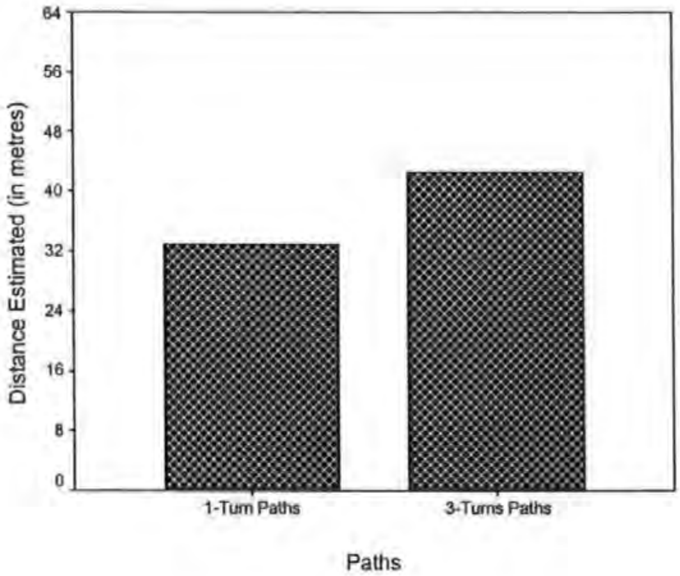
The main effects of configuration and amplitude were not significant. There was a weak effect of route presentation on remembered path distances, $\underline{F}_{(57)} = 3.59$, $\underline{p} = .063$. As displayed in Figure 5.3.5, overall the groups who learned 90/270 routes (i.e., Route A or Route C), remembered longer path distances than the groups who learned 270/90 routes (i.e., Route B or Route D), the difference amounts to about 5 metres on average.

Figure 5.3.5: Main Effect of Route on Path Distance Estimated, in Experiment 7.



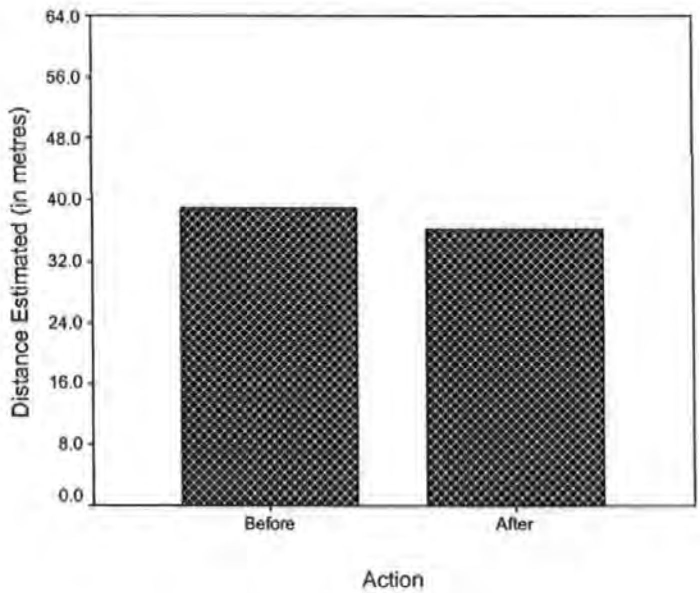
There was a significant effect of number of turns on remembered path distances. As displayed in Figure 5.3.6, overall 3-turn paths were remembered as being longer than 1-turn paths. The difference amounts to about 10 metres on average. This finding supports our hypothesis which assumed that paths containing several turns would be remembered as being longer than paths with fewer turns.

Figure 5.3.6: Main Effect of Turns on Distance Estimated, in Experiment 7.



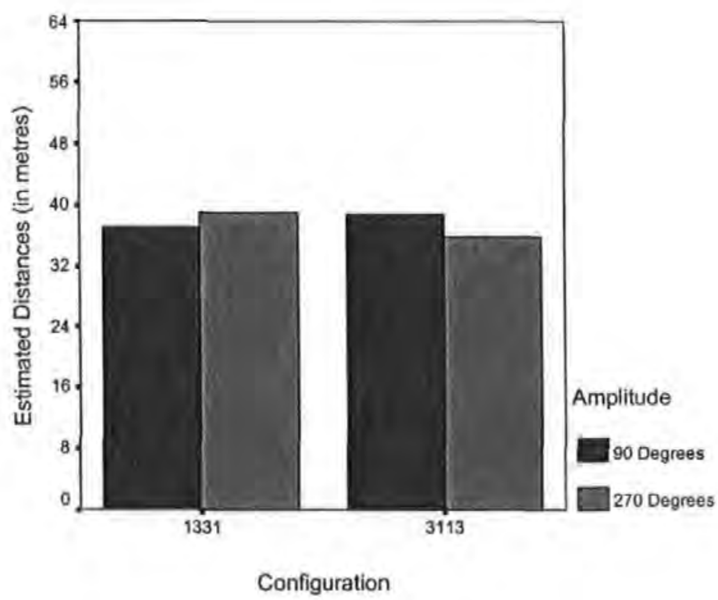
There was also a significant main effect of action on remembered path distances. As displayed in Figure 5.3.7, overall path distances were remembered significantly longer before action than after action. The difference amounts to about 7 metres on average. This effect was expected as the salience of the action has increased. During the recall process, the simulation of action may facilitate the retrieval of spatial representation from memory, thereby produced more accurate distance estimation, showing evidence that action is an important element in cognitive maps.

Figure 5.3.7: Main Effect of Action on Path Distance Estimated, in Experiment 7.



There was a significant 2-way interaction between configuration and amplitude of turn. As displayed in Figure 5.3.8, participants in the 1331 condition (who had learned Route A or Route C) remembered paths containing 90 degrees turns as being shorter than paths containing 270 degrees turns; whereas participants in the 3113 condition (those who learned Route B or Route D), paths containing 90 degrees turns were remembered as being longer than paths with 270 degrees turns.

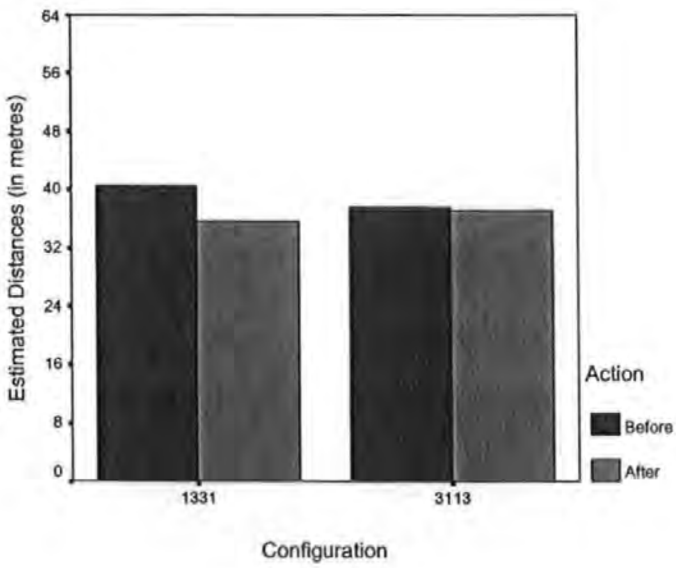
Figure 5.3.8: Two-Way Interaction between Configuration and Amplitude of Turn on Distance Estimated, in Experiment 7.



In other words, the sensitivity of distance with regard to amplitude of turn depends upon where the cluster of turns is located.

There was a significant 2-way interaction between configuration and action; participants in the 1331 configuration, remembered walking longer path distances before action than after the action; those in the 3113 configuration, remembered walking similar path distances before and after action (displayed in Figure 5.3.9).

Figure 5.3.9: Two-Way Interaction between Configuration and Action on Distance Estimated, in Experiment 7.

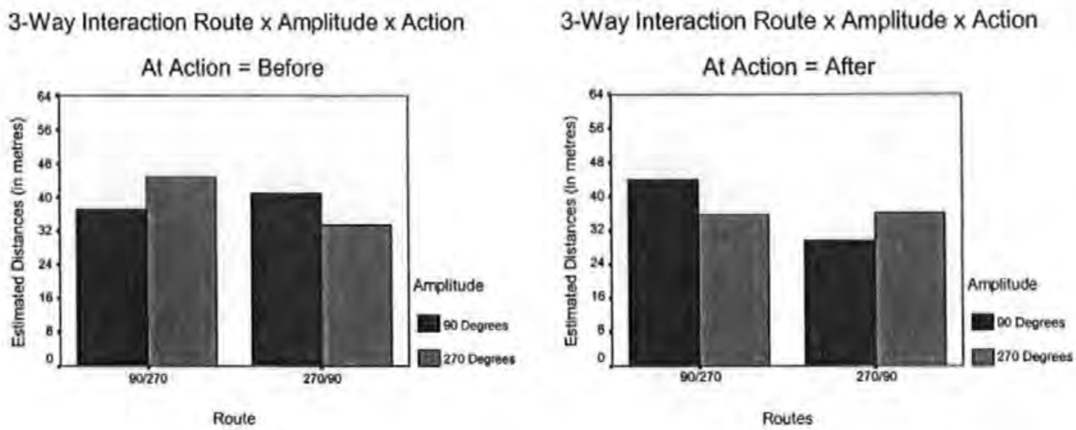


The sensitivity of distance to action depends on where the position of the cluster of turns is located.

The 3-way interaction between route, amplitude of turns, and action was also significant; we examine the combined influence of route and amplitude at each level of action on path distance estimations (displayed in Figures 5.3.10).

As Figure 5.3.10 shows before action the remembered distances were shorter or longer depending on which types of paths participants learned. When participants learned 90/270 routes (Route A or Route C) the remembered distances within the route were longer for paths containing 270 degree turns than for paths containing 90 degree turns, the difference amounts to about 7 metres. When they learned 270/90 routes (Route B or Route D), the remembered distances were longer in paths containing 90 degree turns than in path containing 270 degree turns, and the difference amounts to about 8 metres.

Figure 5.3.10: Three-Way Interaction between Route x Amplitude x Action, in Experiment 7.



After action, it is the reverse situation. When participants learned 90/270 routes (Route A or Route C) the remembered distances within the route were longer for paths containing 90 degree turns than for paths containing 270 degree turns, and the difference amounts to about 8 metres. When they learned 270/90 routes (Route B or Route D), the remembered distances within the route were shorter for paths containing 90 degree turns than for path containing 270 degree turns, and the difference amounts to about 6 metres. These results suggest that remembered distance was sensitive to action related factors such as turning and amplitude of turning.

There was also a significant 5-way interaction between all main factors (configuration, route, number of turns, amplitude of turns, and action), $\underline{F}_{(1, 57)} = 4.914$, $\underline{p} = 0.031$. Although it is difficult to interpret, it is clear that there are complex relationships between variables.

In order to examine this interaction further, we focus on remembered distances before the action and after the action overall. For this, we performed simple effect analyses for each group of participants (AB, BA, CD, and DC groups). Each analysis was done for each level of respectively configuration (C1: 1331 vs. C2: 3113), route presentation (R1: 90/270 vs. R2: 270/90), number of turns (T1: one turn vs. T2: three turns), amplitude of turns (A1: 90 degrees vs. A2: 270 degrees).

The full set of differences is displayed in Table 5.3.9. Note that in AB and CD groups, routes 90/270 were presented first, then follows routes 270/90; in BA and DC groups, routes 270/90 were presented first, follows by routes 90/270. (Appendix 7.2.6 displays graphs showing these relationships at each level of Configuration, Route, Turn, and Amplitude for before and after action).

Table 5.3.9: Details of the 5-Way Interaction 2 Configuration (C1 vs. C2) x 2 Route (R1 vs. R2) x 2 Number of Turns (T1 vs. T2) x 2 Amplitude of Turns (A1 vs. A2) x 2 Action (Before vs. After), in Experiment 7.

		T2 (3-Turns)		T1 (1-Turn)	
		A1 (90 degrees)	A2 (270 degrees)	A1 (90 degrees)	A2 (270 degrees)
		Before / After	Before / After	Before / After	Before / After
C1: 1331	R1 (AB)	<; ns	>; **	>; ns	>; ns
	R2 (BA)	>; **	<; ns	>; marginal	<; ns
C2: 3113	R1 (CD)	<; ns	>; ns	<; *	>; ns
	R2 (DC)	>; *	<; ns	>; ns	<; ns

Notes: <: before action the mean is smaller than after action;

>: before action the mean is larger than after action;

ns: $p > .05$; *: $p < .05$; **: $p < .01$.

As can be seen from the table, there were significant differences between before action distances and after action distances:

- In the AB group, before action distances were remembered as being longer than distances after action for paths containing three 270 degrees turns.
- In the BA group, there was a marginal effect; before action distances were remembered as being longer than distances after action for paths containing one 90 degrees turn.
- In the CD group, before action distances were remembered as being shorter than distances after action for paths with one 90 degrees turn.

- Finally, in the DC group, there were significant differences between before action and after action distances for paths containing three 90 degrees turns; distances were remembered as being longer before action than after action.

In summary, the distances remembered before versus after the action were not consistent across all levels of number of turns, amplitude of turns, configuration, and route.

5.4.4 Discussion

Seventy eight percent of participants' responses were correct. Although the rate of exclusion was still high (22 %), suggesting that in some participants memories for routes were imprecise, the majority of participants produced the landmarks in the correct order, and therefore distance estimates could be analysed.

During the experiment, none of the participants expressed any discomfort during or after the task, indicating that the methodology was appropriate.

The sensitivity of our methodology allows us to show that within a route, estimated distances were influenced by the number of turns contained in a path; paths containing three turns were remembered as being longer than paths with one turn. This result is in line with evidence from other studies (Sadalla & Magel, 1980). Moreover, we observed the effect of number of turns on the same route through mental walking and without vision, while Sadalla and Magel (1980)'s result was through actual walking with restricted visual information, and on separate routes. Most interestingly, we extended the findings of Experiments 5 and 6 with regard to the locations of turns within routes. We found the effect of number of turns at the outer paths (3113) as well as in the inner paths (1331). Taking together, our study and that of Sadalla and Magel indicate that the influence of turns is a robust effect.

In relation to the recall of landmark descriptions, the first landmarks (L1) were recalled better than the following ones (L2, L3, L4, and L5) across routes suggesting that there is a primacy effect as L1 was presented first to the participants during the tests.

The relationship between estimated and actual distances is consistent with previous studies. Remembered distances were sensitive to the variation in the actual distances: short distances were over-estimated whereas longer ones were under-estimated (e.g. Byrne, 1979; Decety, Jeannerod, & Prablanc, 1989; Philbeck, Klatzky & Behrmann, Loomis, & Goodridge, 2001; Radvansky, Carlson-Radvansky, & Irwin, 1995; Rieser, Pick, Ashmead, & Garing, 1995; Thompson, 1983; Thorndyke, & Hayes-Roth, 1982).

In relation to the influence of action, we found that as the body movements were more pronounced distances were remembered more accurately before the action than after the action. This result supports our hypothesis of the centrality of action on cognitive maps.

Most importantly, our study showed complex relationships between all variables (configuration, route, turn, amplitude, and action) on remembered distances. Although this interaction was difficult to interpret, one thing that was clear was that there were more complex effects than just the number of turns effect, or just amplitude of turns effect. The spatial layout contributed to differences in distance estimation. For instance, remembered distance was sensitive to the combined effect of the location of the cluster of turns (at the beginning or at the middle of the route), and how routes were presented (90/270 routes versus 270/90 routes). These complex and subtle relationships between variables that we considered in our study had not been examined in previous studies.

5.5 General Discussion

Given the problems that we outlined in Chapter 4 with past studies, we developed a new methodology with the aim of controlling confounding factors, such as visual cues and the bio-feedback of the actual walk, to allow us to adequately investigate whether action exerts an effect on distance estimation.

To begin with we found that during tests, in general participants claimed they felt comfortable and relaxed with the task, which indicated that our methodology developed an appropriate and sensitive procedure, especially given that participants had to wear a blindfold for the whole duration of the test that lasted about one hour. However, it must be noted that a large proportion of all the participants (45 % in Experiment 5) could not reproduce the correct route sequences. Participants may not have been paying enough attention to the task, or the task may have been too difficult. In any case, we decided to present the route twice to participants to reduce the drop out rate in subsequent experiments. This arrangement seemed partially successful as the drop rate decreased from 45 % (Experiment 5) to 22 % (Experiments 6 and 7). Despite the relatively high drop out rate, the data we collected across experiments indicated nevertheless that our methodology was successful. Future studies may present the environments a third time which might improve the inclusion rate further.

Now let us summarise the results of the three experiments we have undertaken using this new methodology to investigate more carefully the role of action in cognitive maps. The results found across experiments were consistent. It was shown that:

- In general the majority of participants correctly recalled the sequences of landmarks along the routes, especially when the environment descriptions were presented twice (Experiments 6 & 7);
- As compared to their respective actual lengths, short segment lengths tended to be overestimated, whereas longer ones tended to be underestimated;
- Within the same routes, paths containing several turns were remembered as being longer than paths containing fewer turns;
- The amplitude of turns had no effect on remembered distances (Experiment 7);
- The effect of action was observed in Experiment 7 (when the action was more pronounced), before the action distances were remembered as being longer than after the action;
- There were high degrees of interactions between variables (Experiment 7) indicating there were complex relationships between them.

Let us now consider how our data fit with current theories of environmental knowledge. Firstly, the sequence of landmarks in the environments was correctly remembered by participants showing that they had built up knowledge of the relationship between landmarks they encountered during imaginary navigation. Secondly, the relationship between remembered distance and actual distance was in line with previous studies (e.g., Decety, Jeannerod, & Prablanc, 1989; Rieser, Pick, Ashmead, & Garing, 1995). Thirdly, the influence of number of turns on remembered path lengths was congruent with previous studies (Sadalla &Magel, 1980). While Sadalla and Magel found the number of turns effect on separate paths, our data showed the same effect within the same route, suggesting that it is a robust effect on distance estimation.

Our results could be explained by the segmentation hypothesis. The segmentation hypothesis ascribed right angle turns to divide the pathway into segments, and the perceived length of segments were combined to produce an estimate of the total pathway length. Given two pathways of the same objective length but differing in the number of turns contained in each, the pathway with fewer turns will necessarily have longer segments. Given that shorter distances are overestimated and longer distances are underestimated, the path with more turns will be remembered as being longer than the path with fewer turns. Our results fit perfectly with the segmentation hypothesis with regard to the perception of the segment lengths and the influence of the number of turns on path distance estimates.

However, a more parsimonious explanation must be able to explain a range of effects. In the present study, we found the same effect of number of turns on remembered distances without actually traversing any distance. Our data actually point to an interpretation in terms of attention processes that signal memory for events and associated cognitive effort.

Participants heard the metronome clicks representing their footsteps during mental walks. It was clear that they had internalised distance and direction as well as turns information for use during recall that had enabled them to get from the starting landmark towards the final destination. This was supported by the fact that they correctly recalled the sequence of landmarks in the environment.

As participants were not walking any distance, they seemed to have been encoding the action of turning and the action of dispatching an object at mid-route landmark. In the absence of direct visual information, the memorisation was triggered by the body movement; i.e., the participants' attention would focus on memory for events (actual turning, and dispatching an object). However, this form of representation is available for limited periods only. Indeed, as time went on, memory faded and decayed (Thompson, 1983). The attention process then must be shifted in order to attend to the next event that came to mind. To proceed still further, the attention process had to be re-initialised. Given that when walking naturally the average footstep measures about 70 centimetres, and that there are two footsteps forward per second (i.e., 1.40 metre/sec), it will take 10 seconds to walk 14 metres. In terms of traversed distance, paths containing 3 turns were remembered longer (3 x 14 metres) than paths containing 1 turn (1 x 14 metres). It is not surprising in terms of the attentional process that people remember only a certain distance given that they can focus the attention only for the first 10 seconds during memorisation. The fact that participants remembered walking longer distances for paths containing several turns than for paths with fewer turns corresponded to the fact that they were actually moving (turning) more often in paths with several turns as well. Consequently, the more turns in a path the more attention shifts were required.

The direct result of the attention shifts was behaviourally demonstrated by the fact that, with regard to the amplitude of turn, no difference was observed whether the turn was 90 degrees or 270 degrees. This clearly suggested that the function of the body movement was to re-initialise the retrieval process.

In addition, the cognitive effort for the memorisation for the events that led up to the landmark at mid-route was more pronounced, whereas the cognitive effort lessens for the memorisation for subsequent events that led up to the landmark destination. Consequently, in term of cognitive effort, distance before the action was remembered as being longer and more accurate than distance after the action. This claim is corroborated by the results of previous studies which indicated that providing a theme activity that functionally linked landmarks within a route improved the accuracy of the cognitive representation (Cohen & Cohen, 1982).

The cognitive mechanism we uncovered in the present study is different from that of the segmentation hypothesis. We attributed the fact that paths with more turns were remembered as being longer than paths with fewer turns to the attention shifts during the retrieval process, and suggested that the function of body movement was to re-initialise the retrieval process.

This finding supports and extends our previous results on the context effects on retrieval where we found that thinking about the importance of activity performed at a landmark lead to access of route based representation which subsequently influenced distance estimations and route descriptions. (Experiments 1-4). Our interpretation maintains that at least some distortions in distance estimation may originate from the perception of action.

The interaction between all variables (configuration, route, number of turns, amplitude of turns, and action) on remembered distances in Experiment 7 was difficult to interpret. However, our study showed clearly that there were more complex effects than just the number of turns effect, or the amplitude of turns effect. The spatial layout contributed to differences in distance estimation, for instance, remembered distances were sensitive to the combined effect of the location of the cluster of turns (at the beginning (3113) or at the middle of the routes (1331)), and how routes were presented (90/270 versus 270/90). This interplay between the main factors indicated empirically the importance of action in cognitive maps.

Although, our methodology provides exciting opportunities for more controlled experimentation, further validation work needs to be done. In order to ascertain the equivalence of the results, particularly as the focus has been to examine the role of action, future works should carry out a study comparing re-walk behaviour and actual walking behaviour.

Overall, our data suggest that a learning process had occurred after participants had been exposed to the environment through auditory simulated navigation. They were internalising distance information and were using this information to guide activity. When attempting to "walk" towards a landmark, participants claim they could "see" themselves moving toward the landmark. This tendency to "visualise" their approach to the landmarks may be due to the fact that information about the layout of the environment was being coded in a "visual" form. Therefore, route knowledge may be thought of in terms of a "network-map". According to the network-map theory (Byrne, 1979; Moar & Carleton, 1982), an environment encoded as a network-map can be viewed as a network of strings; each branch-point corresponds to a road junction. Landmarks are encoded as "nodes" along these strings. The metric distances between landmarks were not encoded; only the order of locations and branches were sufficient for navigation. As the spatial knowledge that we tested here was acquired through navigation, it is therefore plausible that the "strings" of the network-maps correspond to plans or motor programs that guide locomotion, which shows further evidence that motor representations are element of cognitive maps.

In the next chapter, we will discuss our study's contribution to the embodiment debate and will point out some weaknesses of our approach as well as outlining future studies.

6. CHAPTER 6: GENERAL DISCUSSION & CONCLUSION

6.1. General Discussion

The experimental work outlined in this thesis aimed to investigate the relative influence of context effects on retrieval and the importance of action performed on distance estimation from cognitive maps. This program of research was considered of particular interest for two key reasons.

Firstly, it has been well established that distance estimation from memory is biased. Research to date has been undertaken that systematically manipulated factors such as the structure of the environment (e.g., Sadalla & Magel, 1980; Sadalla & Staplin, 1980), the familiarity with the environment (e.g., Gale, Golledge, Halperin., & Couclelis, 1990; Thorndyke & Hayes-Roth, 1982;), the mode of acquisition (e.g., Taylor & Naylor, 2002; Taylor & Tversky, 1996), the retrieval processes (Holyoak & Mah, 1982; Huttenlocher, Duncan, & Hedges, 1992; McNamara & Diwadkar, 1997), and have demonstrated a number of effects. However it was unclear as to the origins of these effects.

Secondly, although bias in distance estimation could be partly explained by retrieval contexts, the representation of action must be emphasised as a range of literature in domains such as visual perception, language comprehension, and motor representation points to the central influence of action in cognition (Decety, 1991; Ellis & Tucker, 1998; Glenberg & Kaschak, 2002).

These two issues will be discussed in this section where we will consider the possibility that biases in distance estimation are a function of retrieval contexts that trigger action-based representations in memory during the estimation tasks, and that the action is implicitly part of cognitive maps. However, prior to discussing what the results of our study mean for the theory of cognitive maps and proposals for further research, we briefly summarise the results of the experiments.

The environment complexity, the mode of acquisition, categorisation, and the extent to which landmarks are considered as reference points, are factors that lead to systematic errors in distance estimation. These errors do not fit easily into the framework of perceptual and conceptual processing with respect to knowledge of the environments; they seem to be due to procedures invoked during judgement.

The implicit scaling model (Holyoak & Mah, 1982) suggested that in the process of judging the distance from A to B, the second object was treated as referent. Estimates from non landmarks to landmarks were smaller than estimates from landmarks to non landmarks. However, according to the contextual scaling model (McNamara & Diwadkar, 1997), the direction of the asymmetry can be determined by which element of the comparison served as the referent and established the context of the estimate. In a task in which participants were forced to retrieve the location of A before estimating the distance to B, the first object was treated as the referent; estimates from non landmarks to landmarks were larger than estimates from landmarks to non landmarks. In both models, landmarks and non landmarks differed in the contexts they evoked: more locations and more distant locations were retrieved in response to landmark cues than in response to non landmark cues. On the other hand, the retrieval bias model (Huttenlocher, Hedges, & Duncan, 1991) attributed asymmetries to bias in the retrieval of spatial locations. The model holds that stimuli are represented at 2 levels of detail: a fine-grain level and a category level. Given that memory is hierarchically organised and inexact, but people must report an exact value, in reporting, they combine information drawn from both levels, i.e., they based their report on estimation procedures that take account of prior (category) information.

Our study considered a new possibility that the contexts established at the time of retrieving spatial information from memory cued action related representations, which subsequently influenced distance estimation and route description. The methodology we used in our study (structured interviewed) has unveiled context effects which have been hitherto undocumented. People were primed by the dimensions or perspectives that were taken on the landmarks during the ratings, and the perspectives that they took influenced distance estimation and subsequent route description.

People learned about their environments probably through navigation aided by maps. It is likely therefore that the cognitive maps they have of their environments involve survey and route information (either complete representations or partial representations), and that priming on retrieval cues or selectively activates the relevant aspects of the representations. These representations are flexible in that they can be accessed in different ways dependent on contexts (Golledge & Spector, 1978). Indeed, the contexts evoked during the ratings for landmarks produce a particular conceptualisation of the relationship between landmarks. This view is in line with the evidence from the embodied cognition literature (e.g., Barsalou, 1999; Glenberg, 1997). In terms of the frequency of visitation, the processing of the relationship between landmarks involves thinking of how many times one has visited those places. This representation may tap the survey knowledge of that environment, and the use of survey representation produces short route distance estimates (Taylor & Naylor, 2001; Thorndyke & Hayes-Roth, 1982). On the other hand, the processing of the relationship between the same landmarks in terms of the importance of activity involves the simulation of the interaction at those landmarks, which cue action-based representation.

This representation may tap the route knowledge of that environment, and the use of route representation produces longer and more accurate route distances (Taylor & Naylor, 2001; Thorndyke & Hayes-Roth, 1982). Supporting evidence for this is that the importance group also produced a greater ratio of route style descriptions to route and survey style descriptions than the frequency group.

People also spontaneously produced procedural commands during spatial descriptions, suggesting that they mentally simulated the walk from one place to another and verbalised the instructions as route descriptions. This seems to suggest that they privilege procedural memory, which encodes motor skills and other kinds of automatic processing. It becomes clear from the present study that action or motor representation is implicated in the processing of distance and route description from memory.

Our study pushes into sharp focus the influence of the conceptualisation of landmarks that occurs prior to the retrieval of spatial information from cognitive maps. Thinking about the same landmarks in terms of actions performed at those places, or more abstractly in terms of the number of times the place has been visited, markedly affects judgements of distance and verbal description. These findings go beyond the implicit scaling hypothesis in that our data showed contextual effects on the same landmarks presented in the same order. It would appear that implicit scaling is one of a wider range of types of retrieval effects, which merit much closer attention.

However, it must be noted that the findings in Experiment 4 were not consistent with the findings from the first three experiments. It is still uncertain why these differences occurred. In Experiments 1, 2 and 3, participants were given landmarks in advance which led to smaller obtained differences in the estimations between groups; whereas in Experiment 4 participants were asked to generate their own landmarks which led to larger obtained differences in distance estimations between groups. The inconsistency between the two sets of results is likely a function of how landmarks were generated. Participants may evoke a range of criteria to generate their own landmarks, which may lead to individual differences in the criteria used for the generation of landmarks. A future study could investigate the generation process, and examine if it is indeed the case that there are individual differences in the criteria participants actually used to generate landmarks. Perhaps a stronger instantiation of the effect would result if participants were asked to list as many campus landmarks as possible using either the importance of activity or frequency of visitation criterion. This may lead to systematic relations between how landmarks are generated and the distance estimates that are subsequently produced.

What are the mechanisms underlying the contextual dependency effects?

The mechanisms or principles underlying contextual retrieval could be described as followed:

- thinking about an object or an event creates a context in working memory for subsequent mental processing;
- processing a stimulus in one context may be very different from processing the same stimulus in another context;
- the taken perspective selectively activates relevant spatial representations from long term memory;
- the retrieved information is transformed in the context in which the retrieval takes place.

Experiments 5, 6, and 7 were designed to examine the effects of action on remembered distance more directly. Given problems with previous studies in the literature reviewed in Chapter 4, we developed a new methodology to investigate the effect of action on distance estimation. The results of the experiments using this new methodology revealed complex relationships between variables that have been hitherto undocumented.

Our study also shows that although the segmentation hypothesis was adequate in explaining the mental mechanism that mediates why paths containing more turns were remembered as being longer than paths of equivalent length with fewer turns (Sadalla & Magel, 1980), a more parsimonious model would be able to explain a range of effects such as those we found in our study.

The segmentation hypothesis ascribed right angle turns to divide the pathway into segments, and the perceived length of segments were combined to produce an estimate of the total pathway length. Pathways with fewer turns necessarily have longer segments. Given that shorter distances are overestimated and longer distances are underestimated, when the path distance must be reported, the path with more turns will be reported as being longer than the path with fewer turns.

In the present study, we observed the same effect of number of turns on remembered distances without actually traversing any distance. We found body movements (turning on the spot) influenced distance estimation. Our data actually point to an interpretation in terms of attention processes that signal memory for events and associated cognitive effort, which fit the embodiment point of view.

Participants heard the metronome clicks representing their footsteps during mental walks, and were able to internalise distance and direction as well as turns information for use during recall. This enabled them to mentally get from the starting landmark towards the final destination as shown by the fact that they correctly recalled the sequence of landmarks in the environment they acquired knowledge of. However, as participants were not walking any distance, they seemed to have been encoding the action at turning on the spot and the action of dispatching an object at mid-route landmark. During recall, the memorisation process was triggered by body movements, i.e., participants' attention would focus on memory for events (actual turning, and dispatching an object). However, this form of representation is available for limited periods only. Indeed, as time went on, memory faded and decayed (Thompson, 1983). The attention process must then be shifted in order to attend to the next event that came to mind. To proceed still further, the attention process had to re-initialise, i.e., the function of the body movement was to re-initialise the retrieval process. It follows that when there were several turns in a path, there were also several attention shifts. The fact that participants remembered walking longer distances for paths containing several turns than for paths with fewer turns corresponded to the fact that they were actually moving (turning) more often in paths with several turns as well. Consequently, the more turns in a path the more attention shifts were required. Given that the average footstep measures about 70 centimetres when walking naturally, and that there are two footsteps forward per second (i.e., 1.40 metre/sec), it will take 10 seconds to walk 14 metres. In terms of traversed distance, paths containing 3 turns were remembered longer (3 x 14 metres) than paths containing 1 turn (1 x 14 metres).

In addition, the cognitive effort for the memorisation for the events that led up to the landmark at mid-route was more pronounced, whereas the cognitive effort lessens for the memorisation for subsequent events that led up to the landmark destination. Consequently, in term of cognitive effort, distance before the action was remembered as being longer and more accurate than distance after the action.

However, one can reasonably argue that the cognitive effort was due not to the effect of the body movement during the performance of action at mid-route but to the time involved in executing a longer sequence of movements. It would be appropriate to run a further experiment whereby participants would be asked to walk and stop several times within a landmark in order to control for time.

Nevertheless, it seems clear that action can distort or bias distance estimation when distance must be report from memory, which gives empirical evidence of embodied cognitive maps.

So what is the nature of cognitive maps?

Barsalou (1999) and Glenberg (1997) propose that cognitive structures are embodied; that they are shaped by how the body interacts with the environment. The implication of embodied cognition is that the body and the world in which it interacts, are directly linked. The importance of embodied knowledge was shown in the influence of action on distance estimation during imaginary navigation. The learned environment is coded in a visual form as a network-map. The traversed distance is coded not in terms of some set of abstract mathematical co-ordinates; a less abstract form of representation of distance is possible. When spatial information is internalised in a visual form, it allows activity to be controlled over a distance without the need to consult vision directly. It seems therefore reasonable to assume that cognitive maps are representations of navigable environments. It is difficult to imagine, for example, how one would model a world for navigation if one did not also encode actions. Since actions are implicitly a part of the representation, they will be naturally extracted as part of the retrieval process.

6.2. Conclusion

The research program undertaken in this thesis provided some evidence that there is some reason to maintain and pursue the idea that action representation is implicitly an element of cognitive maps, therefore it can be accessed during retrieval processes.

Following the embodied cognition framework, our study provides a new interpretation of why there is bias in distance estimation. We have shown that cognitive maps may be a mixture of survey and route information, which can be manipulated flexibly depending on contexts at retrieval. That is, bias in distance estimation is a function of the contexts at retrieval; whether the context evokes route based knowledge context or survey based knowledge context, or a mixture of both representations, it selectively activates relevant information to derive distance estimations. In other words, the context effects reflect the priming function of contextual cues. In particular, cognitive distance is stored in long-term memory along with contextual stimuli present during acquisition. Therefore, restoring the contextual cues at test signals or helps the retrieval of the relevant spatial representation from cognitive maps. In some other contexts, such as when visual information was absent during acquisition, and where the body movement was restricted to turning and performing action only, distances were remembered as a function of the attention shift and associated cognitive effort for signalling memory for events.

Many theorists have argued that separate anatomical systems handle object recognition and classification (the "what" system) and object localisation (the "where" system) (e.g., Landau & Jackendoff, 1995; O'Keefe & Nadel 1978). This idea has received a good deal of empirical support. Lesion studies with primates indicate that the inferior temporal cortex is involved in pattern and object recognition but not spatial localisation (Ungerleider & Mishkin, 1982). However, "what" and "where" representations seem inadequate to explain the empirical data on biases in distance estimation, and why context effects exist.

Recently, Goodale (1997) and Jeannerod (1997) argued that the "what" system is associated with the ventral pathway and extracts information sufficient to establish the identity of objects in terms of their colour and form. The "where" system (or the "where" and "how" systems, see Goodale, 1997; Cream & Profitt, 2001) is associated with the dorsal pathway, and is assumed to extract visuo-motor information that specifies the size, location and orientation of objects to inform grasping movements and action performed in the environment. There might be a tight coupling between the "what" and the "where" and "how" systems, and if this was the case, it opens up the possibility that the "where" and "how" systems represent the action. It seems therefore reasonable to suggest that the influence of action we highlighted in this thesis is important for cognitive maps.

Our results have wide ranging implications for investigation into cognitive maps. Not only does retrieval cueing need to be investigated more, but studies need to be careful to separate out encoding and retrieval as possible explanations for effects under investigation. For example, tasks which set out to test acquisition of spatial knowledge need to ensure that the task used for retrieval does not bias towards survey or navigation responding. Just as retrieval is a central part of mainstream theories of memory, the neglect of retrieval in relation to cognitive maps may have narrowed the perspective of what is represented.

Subject to the important fact that context seems to play a major role in influencing estimates of distance, there is one important generalisation to be made. It seems clear that the effects found in the present study lead us to reject any simple notion of cognitive maps as equivalent to cartographic representations. Rather cognitive maps are "functionally" equivalent to cartographic maps as opposed to structurally equivalent in terms of a complete reproduction at different scales.

To the extent that behaviour is linked to cognitive maps, the tendency to treat distance as something separate from the activities that people might undertake is questionable. Consequently, to expect a simple functional relationship between cognitive and physical distance that is independent of any behavioural context is not relevant. The implication is that we might expect people to provide different estimates in different situations, for example, if they were to go to a place and accomplish a task as opposed to go to a place without accomplishing any task.

Although, the development of the new methodology presented in this thesis provides exciting opportunities for more controlled experimentation, it could be argued that it is artificial as there was any actual walking involved during the acquisition of spatial knowledge. We must reiterate that further validation work needs to be done, before we can be absolutely certain that the methodology provides equivalent results to actual walking in the environment. Future work should carry out a study to compare re-walk behaviour and actual walking behaviour.

Further validity is needed for our results on priming effects before we can ascertain of its lasting effects on distance estimations and route descriptions. For instance, we could delay the rating phase from the distance estimation and route description tasks for a period of time (e.g., 2, 5, 10 minutes) by providing participants with tasks such as reading out loud or reading (mentally) non-sense words slowly or counting backwards. Further validity may focus on the criteria used for the ratings of landmarks, for instance the historical and cultural importance criteria or the architectural style criteria could be used.

Other contextual factors might also influence the memory for distance. It would be interesting to examine the influence of emotions associated with places. Emotions drive attention, index events, set priorities, and create meaning. It could be hypothesised that affective cues influence the retrieval of cognitive distance when those cues represent information about the value of the landmarks. Positive affective cues may be experienced as feelings of efficacy, which enhance memory and lead to short distance estimation. In contrast, negative affect cues should inhibit the retrieval process and lead to exaggeration of distance estimation.

The research reported in this thesis has demonstrated the potential importance of the embodiment perspective for the understanding of cognitive maps. Future studies would benefit from examining cognitive maps within the embodied spatial cognition framework.

7. APPENDICES

7.1. Context Effects on Retrieval

7.1.1. Sample of Landmarks Ratings in Experiments 1, 2, & 3.

7.1.1.1. Frequency Condition

How often do you go to each place during term time?
Please rate only places you know using a 10-point scale.

1 - - - 2 - - - 3 - - - 4 - - - 5 - - - 6 - - - 7 - - - 8 - - - 9 - - - 10
Never go — Very frequently

Locations	Rating Point
Fitzroy Building	5
Link Building	10
Brunel Laboratories	5
Sherwell Centre	3
Pitts Hall	....
Library	7
Squash Courts	....
Gilwell Hall of Residence	1
Davy Building	3
Isaac Foot Building	2
Scott Building	4
Security Lodge	1
Robbins Lecture Theatre	10
Mary Newmann Hall	2
Students Union	6
Smeaton Building	1
Moneycentre	....
Cookworthy Building	....
Main Hall	10
Babbage Building	3
Planetarium	....
Reynolds Building	....

How important is the activity of each place to you?
Please rate only places you know using a 10-point scale.

1 - - - 2 - - - 3 - - - 4 - - - 5 - - - 6 - - - 7 - - - 8 - - - 9 - - - 10
Not at all — Very important

Locations	Rating Point
Isaac Foot Building	2
Security Lodge	....
Main Hall	9
Brunel Laboratories	....
Fitzroy Building	....
Library	8
Babbage Buidling	8
Davy Building	6
Pitts Hall	....
Sherwell Centre	2
Planetarium	....
Robbins Halls	10
Moneycentre	....
Squash Courts	....
Smeaton Building	....
Gilwell Hall of Residence	....
Students Union	4
Cookworthy Building	....
Reynolds Building	....
Link Building	10
Mary Newmann Hall	....
Scott Building	4

7.1.1.2. Importance Condition

How important is the activity at each place to you?

Please rate only places you know using a 10-point scale.

1---2---3---4---5---6---7---8---9---10

Not at all important — Very important

Locations	Rating Point
Fitzroy Building	----
Link Building	9
Brunel Laboratories	1
Sherwell Centre	9
Pitts Hall	1
Library	10
Squash Courts	----
Gilwell Hall of Residence	----
Davy Building	5
Isaac Foot Building	7
Scott Building	5
Security Lodge	1
Robbins Lecture Theatre	10
Mary Newmann Hall	2
Students Union	4
Smeaton Building	----
Moneycentre	1
Cookworthy Building	----
Main Hall	10
Babbage Building	9
Planetarium	1
Reynolds Building	----

How often do you go to each place during term time?

Please rate only places you know using a 10-point scale.

1---2---3---4---5---6---7---8---9---10

Never go — Very frequently

Locations	Rating Point
Isaac Foot Building	2
Security Lodge	----
Main Hall	5
Brunel Laboratories	1
Fitzroy Building	----
Library	8
Babbage Building	3
Davy Building	3
Pitts Hall	----
Sherwell Centre	4
Planetarium	1
Robbins Halls	10
Moneycentre	1
Squash Courts	----
Smeaton Building	----
Gilwell Hall of Residence	----
Students Union	5
Cookworthy Building	----
Reynolds Building	----
Link Building	5
Mary Newmann Hall	2
Scott Building	3

7.1.2. Sample of Landmarks Generated by Participants & Subsequent Ratings in Experiment 4.

5	Student Union	6
7	Library	5
2	Babbage building	2
9	Pitts Memorial Hall	9
10	Robbins Halls	10
2	Gilwel Halls	2
2	Mary Newman	2
1	Isacc Foot	1
8	Davy building	8
8	Link building	9
2	Cookworthy building	1
5		

7.1.3. Classification Scheme for Route Descriptions.

Classes	Sub-classes	Codes	Examples of Utterances
1: Start position		**C1**	Come out of X; Leave X
2: Action prescriptions without mention of landmarks			
	1: Proceed straight ahead	**C21**	Go forward; Go straight ahead
	2: Proceed pseudo distance	**C22**	Go a bit further
	3: Change of direction	**C23**	Turn left/right
	4: Maintain progress	**C24**	Keep going
	5: Change the current path	**C25**	Cross over
3: Action prescriptions with mention of landmarks			
	1: Aim at a specific landmark	**C31**	Go towards X;
	2: Use of a specific landmark	**C32**	Follow X; Take X; Go through X
	3: Maintain progress on a specific landmark	**C33**	Keep going on the corridor
	4: Change the current path	**C34**	Cross over the road
	5: Proceed past a landmark	**C35**	Go past X
	6: Reorientation at a specific landmark	**C36**	Turn left/right at X
4: Introduction of new landmarks			
	1: Use of "There is"	**C41**	There is a pub
	2: Description of visual scene	**C42**	You find X; You see X;
	3: Egocentric point of view	**C43**	X is on my left/right/in front/behind
	4: Landmark's point of view; Allocentric co-ordinates	**C44**	X is between two buildings; X is opposite a building; X is south of a building
5: Description of landmarks			
	1: Landmark identity	**C51**	A pub called The Duchess
	2: Landmark Physical Features	**C52**	A tall building; The red doors
	3: Landmark's Function	**C53**	The main entrance
6: Destination / Goal		**C6**	It's there

Note: X = environmental features (buildings, streets, signposts, etc.)

7.1.4. Samples of Route Descriptions and Their Categorisations.

7.1.4.1. Importance Condition / Direction High - Low

You are outside the main doors of link,	Cl	**C44**	C51	C53
you go forward a couple of meters,	C22			
turn that way which is NW,	C23	C52	**C44**	
on a clock it is 11,	C53	**C44**		
turn left,	C23			
go forward	C21			
and the bus stop is in front of you	**C43**	C53		
walk toward that	C31			
and you are on like a pavement,	C33			
if you face the bus stop	**C43**	C53		
you turn left	C23			
and you go up until the crossing,	C32			
you cross the road at the traffic lights	C35	**C44**		
and you walk past the scholar pub	C37	C51		
walk past that	C37			
across another bid of road with a little bit island	C35	C53		
go cross that,	C35			
cross the traffic lights	C35			
then go right	C23			
and then left,	C23			
go straight forward	C21			
and under an archway	C32			
and go right	C23			
and you are there.	C6			

7.1.4.2. Importance Condition / Direction Low - High

I'd come out of the front of the Davy building	C1	C52	C51
facing up towards the road,	**C43**		
I'd get out onto the public pavement,	C32	C53	
then I'd turn right	C23		
and I'd go underneath the pedestrian subway,	C32	C53	
and come up through the other side,	C32	C53	
then I'd go round past the BSM on my left,	C37	**C43**	C51
then there I'd have to bear right,	C23		
carry on a little way	C24		
past a little food bar,	C37	C52	
and then you get to the ... car park on the left,	C32	**C43**	
and road up to Robbins is on left,	C32	**C43**	C51
and it's just up there on the left.	C6	**C43**	

7.1.4.3. Frequency Condition / Direction High - Low

I come out of Sherwell	C1	C51
and I turn left,	C23	
I'd go down the road	C32	
and turn left	C23	
and go up past the road	C21	C37
that past the University wines	C37	C51
and walk through Robbins,	C32	C51
and I'd go to Gibbon Street.	C31	C51

7.1.4.4. Frequency Condition / Direction Low - High

I am outside isaac foot building	C1	C51
turn right	C23	
walk between mary newmann and isaac foot	C32	**C44**
walk between the two building	C32	**C44**
turn left	C23	
walk down past the SU	C37	C51
where the building site area is	**C44**	
walk down the gap	C32	
between the building site and SU	**C44**	C51
and go down the steps	C32	
toward the main hall	C31	C51
and you go up some stairs of the main hall	C32	C51
through a set of double doors	C32	C52
go along the corridor	C32	
keep going along the corridor of davy building	C32	C51
keep going to another set of double doors	C32	C52
toward the lift	C31	
at the end of the building	**C44**	
and you go to another set of double doors in link.	C32	C52

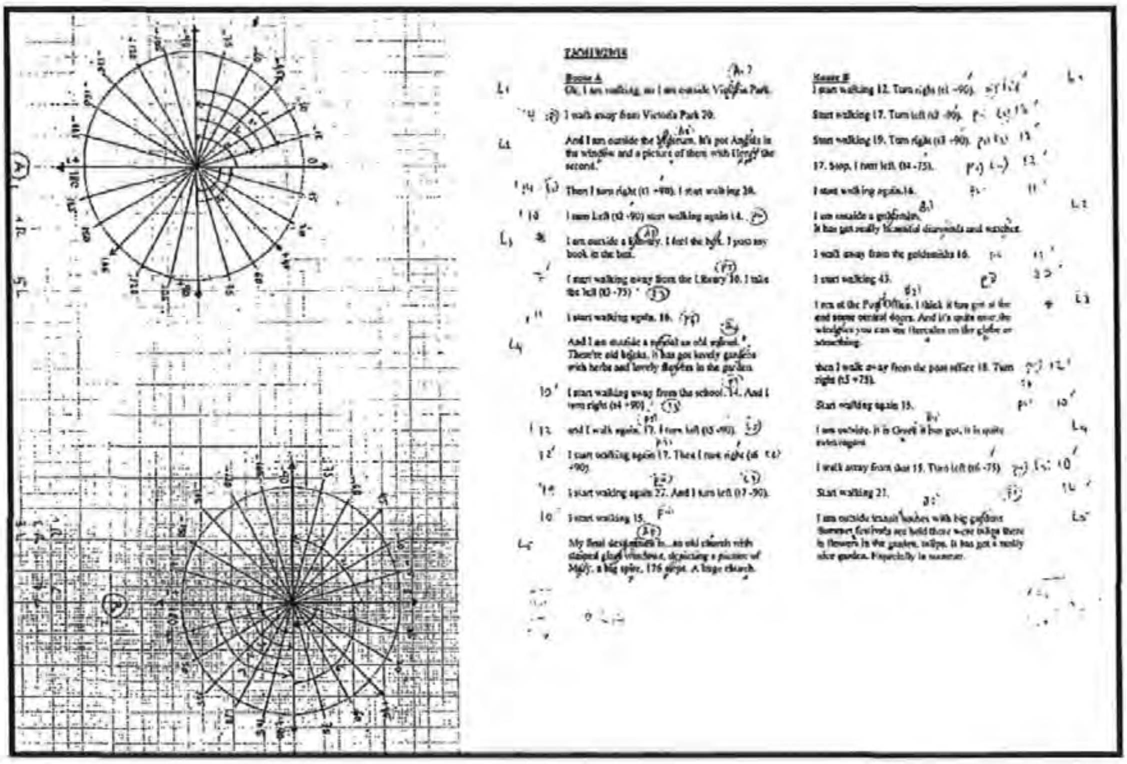
7.2. Importance of Action

7.2.1. Sample of Steps Chart

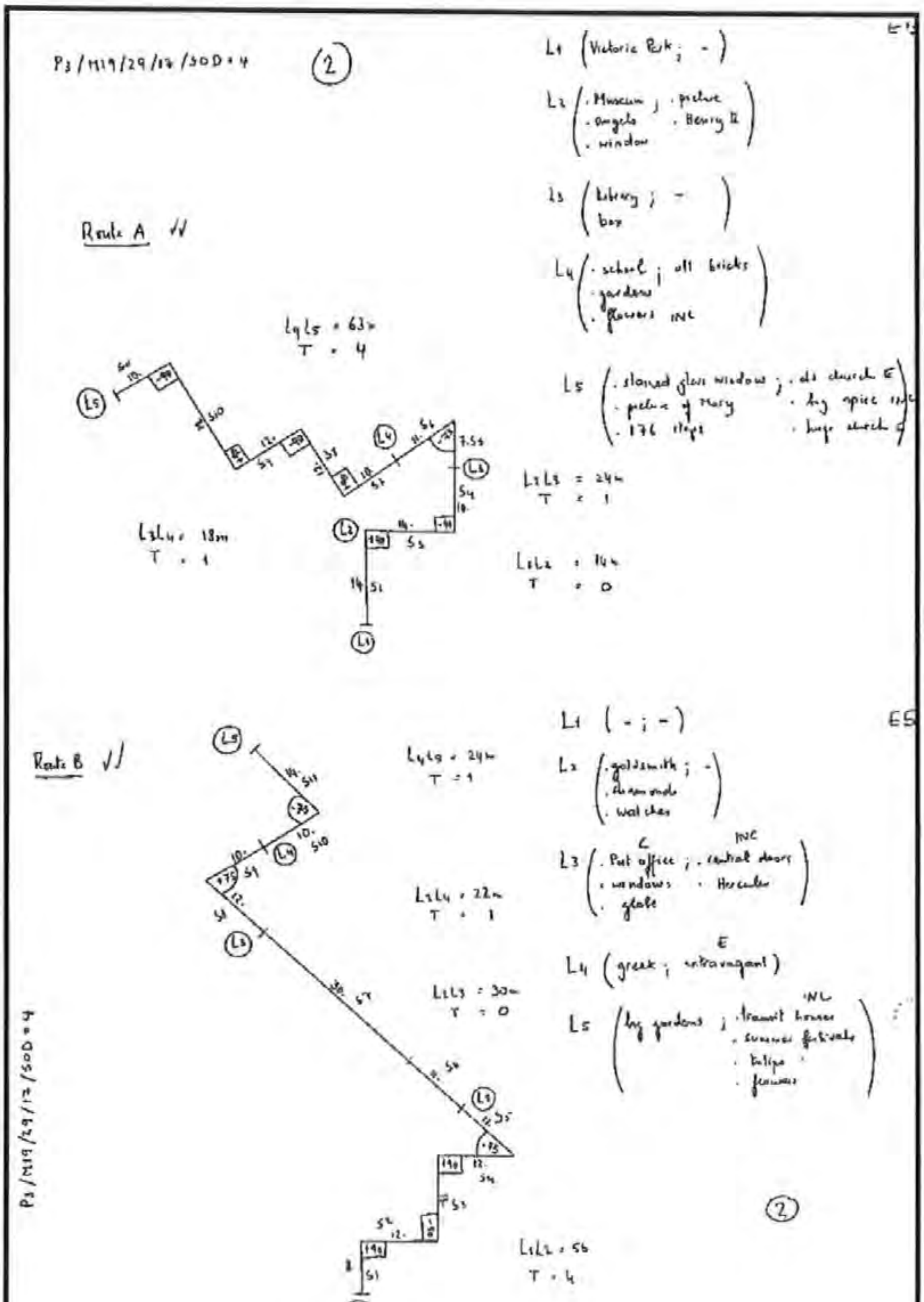
		27
Route A	Length	
Silver	24	32
Beacon	40	54
Beacon	18	24
South	6	8
Maple	28	38
Hill	12	16
Hill	12	16
Summer	28	38
Park	6	8
Ford	18	24
Ford	40	54
Cedar	24	32
Route B		
Mount	18	24
Princess	6	8
Alma	28	38
North	12	16
North	24	32
Castle	40	54
Castle	40	54
Baker	24	32
Baker	12	16
Scott	28	38
Kings	6	8
Union	18	24

			32
Route A	Lengths	Route B	
Silver	24	Mount	38
Beacon	40	Princess	64
Beacon	18	Princess	29
South	6	Alma	10
Maple	28	Castle	45
Hill	12	North	19
Hill	12	North	19
Summer	28	Kings	45
Park	6	Union	10
Ford	18	Baker	29
Ford	40	Baker	64
Cedar	24	Scott	38
Route C		Route D	
Mount	18	Silver	29
Princess	6	Beacon	10
Alma	28	South	45
Castle	12	Maple	19
Castle	24	Maple	38
North	40	Hill	64
North	40	Hill	64
Kings	24	Summer	38
Kings	12	Summer	19
Union	28	Park	45
Baker	6	Ford	10
Scott	18	Cedar	29

7.2.2. Sample of Data Record



7.2.3. Sample of Data Treatment



7.2.4. Route B Description (1331)

You are in a place called Louistown. Your starting place is the Park School.
I am going to take you on a walk from the Park School to the Visitor Centre.

I am going to start you at a place called **Park School**. It was used as a grammar school until it was closed. Park School is a two-storey building. There is a Victorian style clock tower at the entrance. In front of the entrance, there is a mature oak tree.

I am to get you to walk away from Park School along a road called Mount Road.
Start walking. Stop. Now you turn onto Princess road. Start walking. Stop.

You are now in front of a place called **Crystal Bank**. It is one of the most modern buildings in town. Crystal bank has a glass façade. There is an artistic feature flowers bed at the entrance. In front of the entrance, there is a large cash point machine.

Leaving Crystal Bank behind, you continue walking straight ahead along Princess road. Start walking. Stop. You turn onto Alma Road. Start walking. Stop. You turn onto Castle Road. Start walking. Stop. You turn onto North Road. Start walking. Stop.

You are now in front of a place called the **Post Office**. It is one of the most characterful buildings in Louistown. The Post office has a double entry door. There is a sculpture representing Hermes at the entrance. In front of the entrance, there is a large post box.

OK. Now you walk into the Post Office. Start walking. Stop.

Now you bend over to put down the umbrella on the floor. OK.
Now you take the parcel out of the bag. OK.
You are now standing directly in front of the letter box.
You feel the letter box in front of you.
Now you post the parcel into the letter box. OK.
Now you bend over to pick up the umbrella.

Now you walk out of the post office. Start walking. Stop.

You find yourself on North Road again. Now you continue walking straight ahead leaving the post office behind you. Start walking now. Stop.You turn onto Kings Road. Start walking. Stop. You turn onto Union Road. Start walking. Stop. You turn onto Baker Road. Start walking. Stop.

You are now in front of a place called the **Town Hall**. It is the most picturesque town houses in Louisville. The Town hall has a patterned red brick external wall. There is a diminutive gate lodge at the entrance. In front of the entrance, there is an ornamental plaque.

You leave the town hall behind and continue walking straight ahead along Baker Road. Start walking. Stop. Now you turn onto Scott Road. Start walking. Stop.

You are now in front of a place called the **Visitor Centre** which is your final destination.
It regularly exhibits works of local as well as international artists. The Visitor centre has a marble colonnade at the front. The Centre's flag is displayed at the entrance. In front of the entrance, there is a signpost".

7.2.5. Route D Description (3113)

"You are in a place called Charles-town. Your starting place is the Merchant House.
I am going to take you on a walk from the Merchant House to St John's Church.

I am going to start you at a place called **Merchant House**. It is a medieval house well preserved to this very day. The house has a very ornamental bay window. There is a beautiful shrubbery at the entrance. In front of the entrance, there is a decorative stone gatepost.

I am going to get you to walk away from the Merchant House along a road called Silver Road. Start walking now. Stop. Now you turn onto Beacon Road. Start walking now. Stop. You turn now onto South Road. Start walking. Stop. You turn now onto Maple Road. Start walking. Stop.

You are now in front of a place called the **Museum**. It is one of the most interesting museums in town. The museum has an antic style wooden door. There is a fossil's plaque at the entrance. In front of the entrance there is a sculpture on the ground.

Leaving the Museum behind, you continue walking straight ahead along Maple Road. Start walking. Stop. You turn now onto Hill Road. Start walking. Stop.

You are now in front of a place called the **Library**. It is very popular among people living in Charles-town. The library has a marble staircase at the front. There is a stone table carved with flowers at the entrance. In front of the entrance, there is a sundial.

OK. Now you go into the library towards a counter. Start walking. Stop.

Now you bend over to put down the umbrella on the floor. OK.
Now you take the book out of the bag. OK.
You are now standing directly in front of the book return box.
You feel the return box in front of you.
Now you post the book into the return box. OK.
Now you bend over to pick up the umbrella.

Now you walk out of the library. Start walking. Stop.

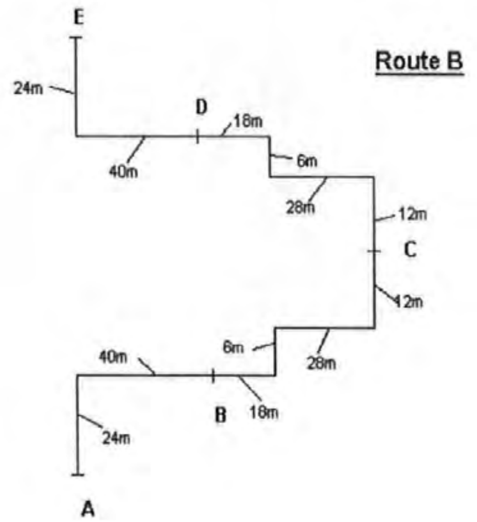
You find yourself on Hill Road again. Now you continue walking straight ahead leaving the library behind you. Start walking now. Stop. Now you turn onto Summer Road. Start walking. Stop.

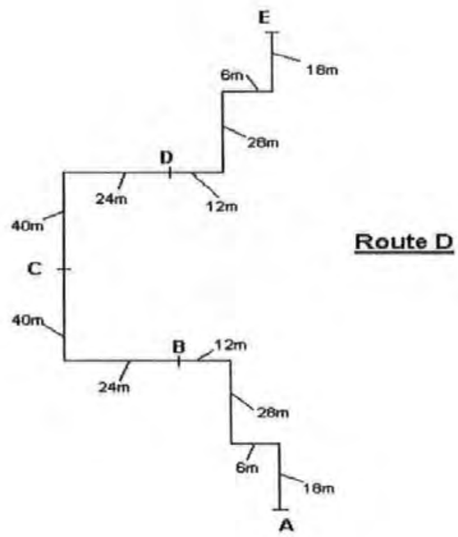
Now you are in front of a place called the **Concert Hall**. It is the home of the Charles-town Symphony Orchestra. The concert hall has a golden dome shaped roof.
There is a water feature at the entrance. In front of the entrance there is a beautiful cast iron gate.

Leaving the concert hall behind, you continue walking along Summer Road.
Start walking. Stop. You turn now onto Park Road. Start walking. Stop. You turn onto Ford Road. Start walking. Stop. You turn onto Cedar Road. Start walking. Stop.

Now you now in front of a place called **St John's Church** which is your final destination. Its Gothic architecture stands out against its surrounding.
The Church has an imposing tower. There is a life-size figure of St John at the entrance.
In front of the entrance, there is an intricately carved holly cross".

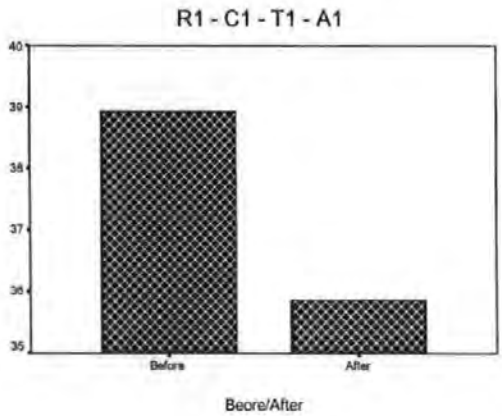
Schemas of Route B and Route D, used in Experiment 7





7.2.6. Five-Way Interaction between Route presentation, Configuration, Turn, Amplitude, and Action, in Experiment 7.

7.2.6.1. The AB Group



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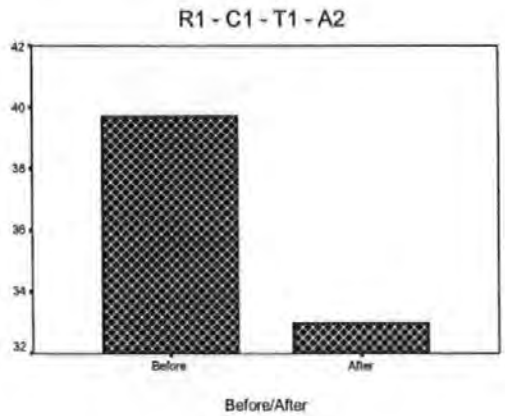

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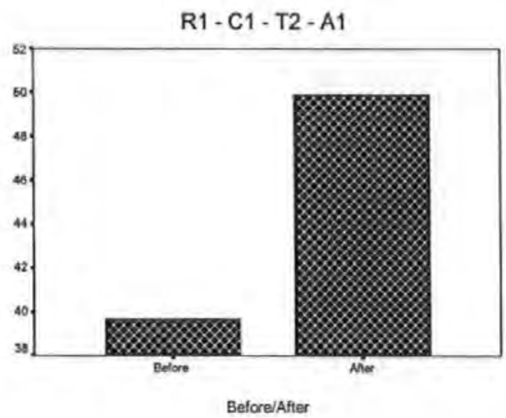

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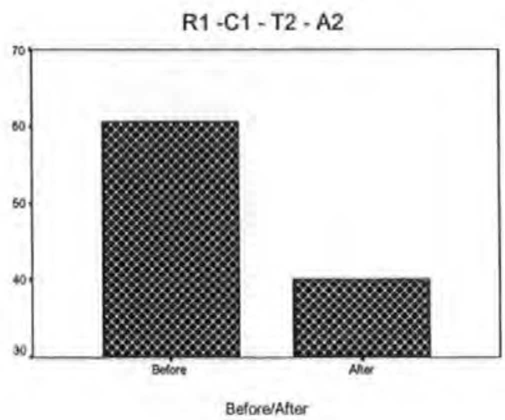

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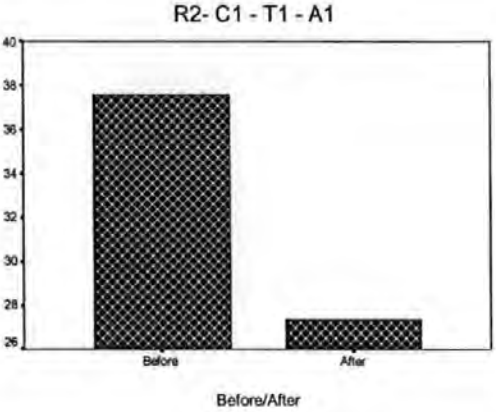
7.2.6.2. The BA Group



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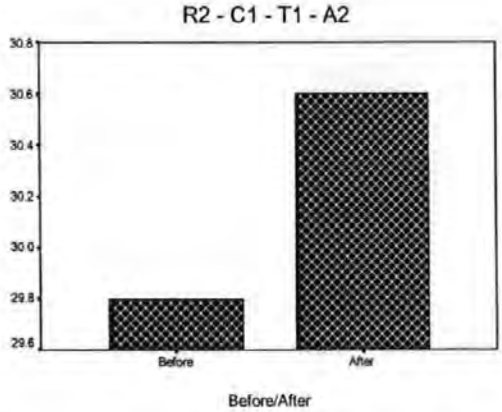

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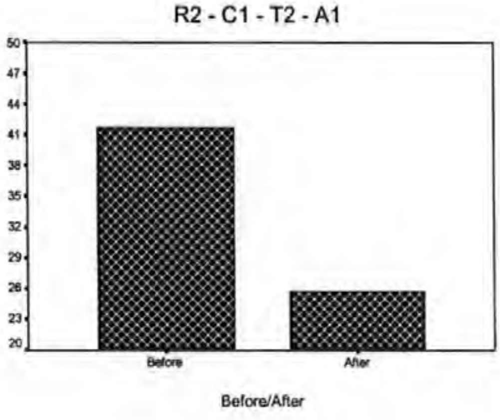

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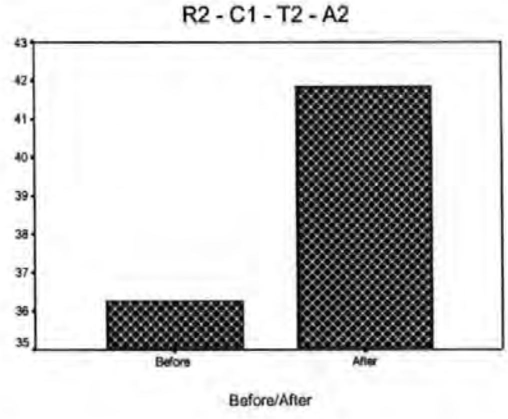

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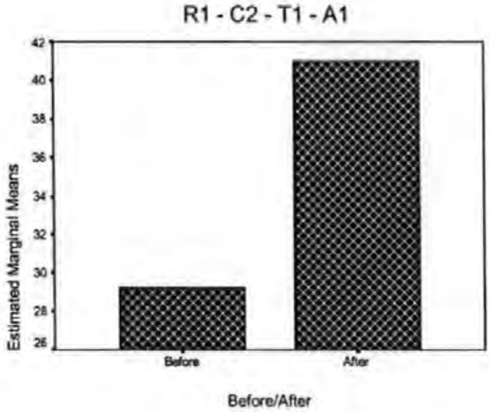
7.2.6.3. The CD Group



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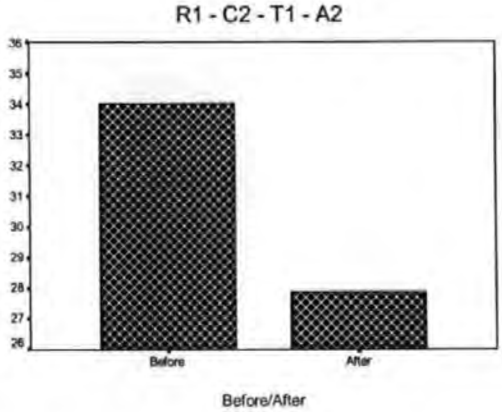

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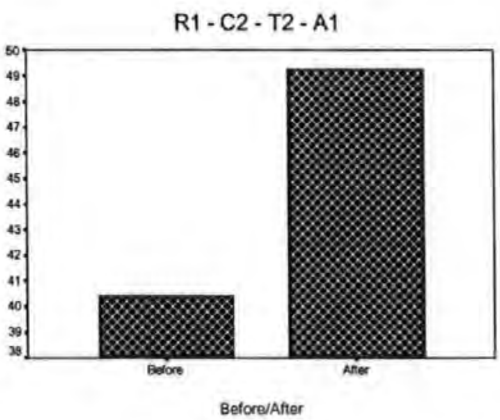

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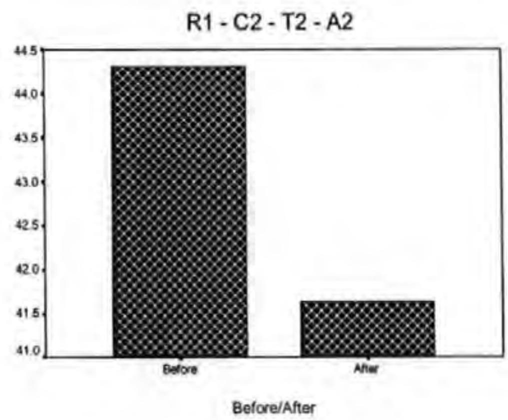

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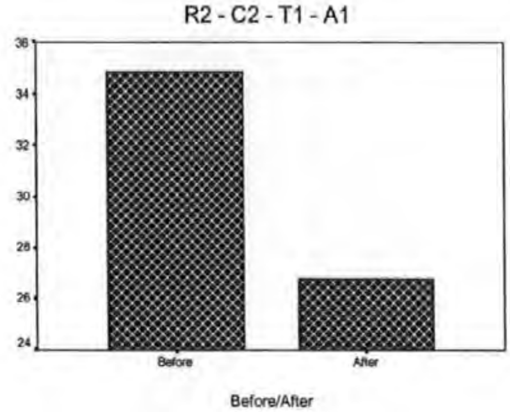
7.2.6.4. The DC Group



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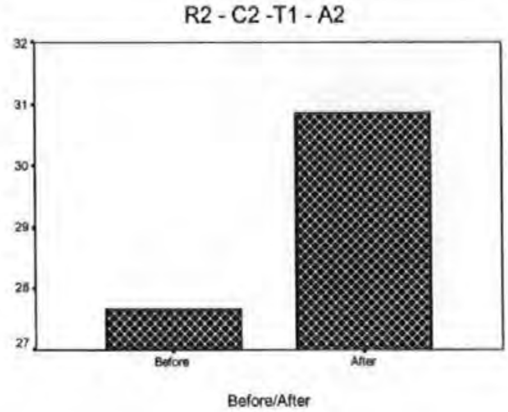

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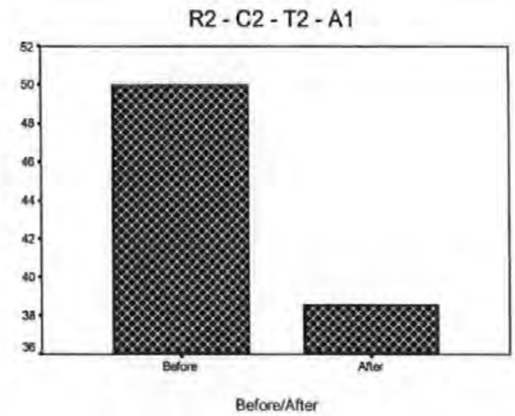

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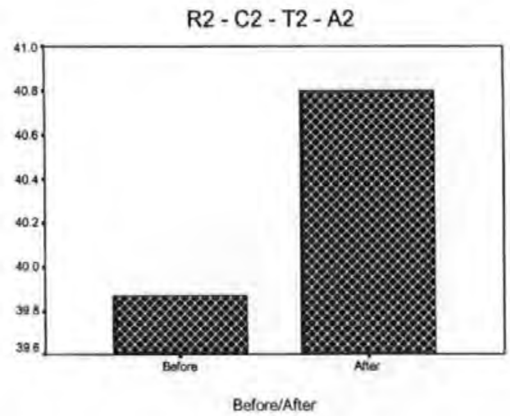

(16)

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