The Effect of Goals on Memory for Human Mazes in Real and Virtual Space

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Abstract

Walking around one's environment is usually associated with a goal. However, little is known regarding the influence of goals on memory for distance and time in 'cognitive maps'. In two experiments we investigated the effect of goals of varying urgency on immediate memory for distance and time in real human mazes and virtual reality (VR) versions of the same mazes. Experiment 1 compared the effect of goals varying in urgency on memory for distance and time in a straight- line real space human maze and a VR maze. Experiment 2 examined the effect of goals on a real maze with multiple turns. Results show that goals effect distance estimation for straight line paths in both real space and VR space. However, evidence of the influence of goals is mediated by the number of right-angled turns in real space.

Keywords: Spatial Cognition; Real Space; Virtual Reality; Goals.

Introduction

When learning about where places are in the environment and how to get to those places, it is necessary to develop 'cognitive maps' of the world. Cognitive maps are mental representations of the environment (Tolman, 1946; Downs & Stea, 2005) that contain information about landmarks (objects), where they are placed, and the distance separating them. However, there are systematic distortions between metric distance and time and estimated distance and time that challenge the view that cognitive maps are topographic.

According to Montello (1997), memory for distance is distorted by a range of factors, including time and effort spent moving from place to place, and environmental structures and features such as the salience of landmarks in the environment (Jansen-Osmann & Wiedenbauer, 2006). For instance, there is evidence that distances in paths with several right angle turns are perceived to be longer than paths of the same length with fewer turns (Sadalla & Magell, 1980).

Golledge (1987) has noted that individual differences contribute to discrepancies between physical and perceived distance, and in particular individual differences in executive capacity, attention and choice of strategies. This provides support for Briggs' (1973) suggestion that cognitive distance is a combination of individual behaviour and environmental characteristics.

In spite of the vast literature relating to cognitive maps, there is a distinct paucity of research examining the effect of goals whilst travelling through an environment on distance perception. There is some evidence for enhanced recall of learned environments if the goal type and recall methods are congruent. For instance Taylor and Naylor (1999) found route goals enhanced performance on route perspective tasks and this was replicated with survey goals and survey perspective tasks, suggesting a context dependency on the development of cognitive maps. In contrast, Rossano and Reardon (1999) identified goal specificity as an inhibitory factor in the development of survey knowledge, claiming goals sacrifice schematic development, possibly by diverting attention from the environment and focusing more resources towards the goals. However, this research does not examine the more basic function that goals serve. Individuals very rarely walk through an environment without a purpose. Usually one travels somewhere for a reason, such as visiting a friend, buying groceries, or going to work. Moreover, often the goals vary in urgency and desirability.

Imagine that you are required to deliver medicine to a friend who is critically ill in hospital. Imagine instead that you have to deliver some bad news to a friend, such as the news that they have failed their exams. One could envisage that these differences in urgency may influence the perception of how far (and for how long) one has walked the same distance. Evaluating the influence of goals of varying urgency on distance and time estimation is the main goal of the present paper.

In light of testing the effect of goals on distance and time estimation, it is also of interest to establish whether the influence of goals may be mediated by the structural features the environment possesses and the nature of the media in which the environment is presented – this is the second goal of the paper.

There is growing interest in the similarities and differences between real and virtual worlds. Virtual Reality (VR) has been utilized in several areas such as the military, fire fighting and industrial training in hazardous conditions (Burdea & Coiffet, 2003). There has also been a recent trend in the employment of VR by the UK health services, not just for training purposes, but to familiarise patients with their potential environments. In addition, the US health service is currently investigating VR as a potential aid for patients suffering from post traumatic stress disorder (Moses, 2008).

In spite of the considerable interest in VR as a research tool, the evidence that VR is ecologically valid is somewhat mixed. For instance, with respect to perception, VR distances are reported as being shorter than equivalent distances in reality, and there are problems with 'perceptual-motor' coupling contributing to reported differences for speed perception (Witmer & Sadowski,1998, Banton *et. al*, 2005). In contrast, it has been claimed that VR augments real space research, such as distance knowledge, acquisition of route and survey knowledge (Jansen-Osmann & Berendt, 2002; Ruddle, Payne & Jones, 1997). But what of goals in virtual spaces?

Although VR may be classed as an economical and potentially safe alternative, there is still a basic expectation that goals will reveal differences between real and virtual tasks. The experiments below therefore compare performance in real human mazes and exact virtual analogs of those mazes when participants are asked to perform tasks varying in goal urgency.

Experiment 1

Real Space and Virtual Environment

This experiment examined the effect of goals varying in urgency on memory for distance (metres) and time taken to travel (seconds) a straight line route in real space (a human maze), and in an identical VR version of the maze.

Methodology

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

The 'role play' scenarios were selected from a pilot study where participants were asked to rate various scenarios in terms of urgency. Two scenarios were selected for this experiment as being of high and low urgency, also corresponding to differences in an individual's predicted speed of walk under such circumstances:-

- <u>High Urgency</u> – delivering medication to a friend critically ill in hospital.
- <u>Low Urgency</u> – delivering exam results to a friend, and opening the envelope so that you know that they have failed.
- <u>Control condition</u> – no scenario

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

Real Space Human Maze 1

The maze consisted of 26 polystyrene blocks, dimensions 1.2 x 2.1 x 0.3 metres. 11 polystyrene blocks were set up side by side, creating one wall 2.1 metres in height. A further 13 blocks were placed 1 metre opposite, creating a path 1 metre wide with additional blocks perpendicular to the longest wall at either end to ensure that the entrance to and exit from the maze were not visible to the participants. Finally, the maze was covered with clear tarpaulin. The total distance, using the central route of the maze, was 15.4 metres (Figure 1, Figure 2a). The beginning and end of the paths were distinguished with tape on the floor to provide the experimenter with the cue for timing the journey.

Virtual Human Maze

The computer model depicted an exact replica of the realn space maze 1 and was created using 3DStudioMax software (see Figure 1). The model was then transferred to VR4Max to establish immersion and navigation capability. The model was extremely realistic, replicating light and textures that gave the strong impression of the original maze. The Virtual Environment used for the Virtual Human Maze condition consisted of Intel Xeon X5450 CPU 2 x Quad (8 cores running at 3.00Ghz) GPU: Nvidia Quadro FX 5600, and StereoWorks DLP Passive Stereo Projection System that was based on a rigid rear projection screen with dimensions: 244x183cm, with images projected by two Christie Digital DS+25 high resolution projectors. The VR condition was passive and the pace pre-programmed according to the individual's natural walking speed. A 'head bob' of 1.5cm was used to enhance the perception of natural walking (Masaad, Lejeune & Detrembleur, 2007).

Figure 1: Still images showing real maze (left) and the VR maze (right).

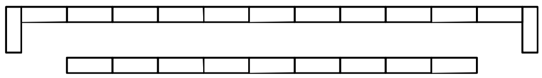

Figure 2a. Allocentric View – Straight Maze

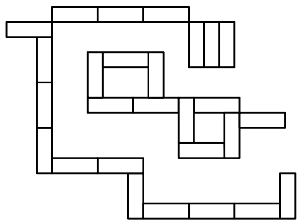

Figure 2b. Allocentric View – Maze with turns

Presentation

The study was presented to participants as a role play task. They were told that they were going to be transported to the experimenter's Polystyrene Block World (Maze), and that a scenario was going to be described to them where they would have to deliver an object whilst imagining themselves in that scenario. The importance of the role play scenario was emphasized so that participants would take the scenario seriously to make it as real as possible. At the end of the study they were advised that they would be required to answer questions about their role play experiences. The participants were not aware that they were being tested for their memory for distance or time during the task.

Experimental Design

To examine the influence of goals on distance and time estimation, the experiment employed a 2 (route: Real Space (RS) vs. Virtual Space (VS) x 3 (scenario: High Urgency vs. Low Urgency vs. Control) between-subjects design.

Participants

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

Procedure – Real Space

Participants' were tested individually in a session lasting about 30 minutes. Initially, participants were met in an area separate from the maze; they were then instructed to walk along a pre-designated reference path at their natural walking pace to establish step length & speed of walk. The speed of the metronome was then set to the speed of walk, and participants were again asked to walk along the path to the sound of the metronome to practice walking in time with the clicks. Next, participants were advised that they were going to be blindfolded and transported to the 'Polystyrene Block World'. Once the participant was blindfolded they were guided to the end of the 8 metre reference path, spun around three times and then guided to the beginning of the real or virtual maze.

At the beginning of the maze the experimenter then reminded the participants that they were to take part in a 'role play task'. When confirmation was received that they were ready to take part, the experimenter then instructed the participant to visualise the assigned scenario. After the visualisation the experimenter gave the participant a medicine bottle or a folded exam result manuscript to deliver at the end of the task. Participants in the control condition did not receive an object. When participants were confident of the importance and urgency of task, they were then asked to remove their blindfold and commence their journey. Participants were timed, discretely, during their duration in the maze and, on completion, were then asked a series of questions concerning distance estimation, time estimation, and levels of anxiety and urgency experienced.

Procedure - Virtual Space

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

Immediately after crossing the end line for the route, participants were asked a range of questions including how long (in metres) they thought the route was, how long they thought they had spent in the maze, and how urgent they perceived the task to be.

Results

Preliminary Analyses

A series of between participants one-way ANOVAs were first run in order to check that participants across scenarios did not differ in their walking speeds and times spent in the maze. No significant differences were found for the pace of walk for the Real Space (RS), $F(2,39) = 0.05$, $p > 0.05$ or the Virtual Space (VS), $F(2,53) = 1.89$, $p > 0.05$ between scenarios. There were also no significant differences in the times spent in the maze between scenarios for the RS, $F(2,39) = 0.22$, $p > 0.05$or the VS, $F(2, 53) = 2.4$, $p > 0.05$.

Main Analyses

Responses from 3 participants (6.7%) in the RS and 4 (8.9%) from the VS were excluded, as their distance estimations were extreme. Therefore outliers, identified as exceeding a criterion of 2 standard deviations from the mean, were excluded. Responses from 42 participants in the RS and 56 from the VS were included in the following analyses.

Table 1 illustrates the mean distance estimates by scenario and environment type.

Table 1: Mean distance estimations (m) in Experiment 1

Scenario	Real Space	Virtual Space
Distance (15.4 metres)	$\bar{X}$ (σ)	$\bar{X}$ (σ)
Control	13.94 (11.45)	10.33 (7.39)
High Urgency	23.07 (22.50)	15.19 (13.72)
Low Urgency	10.42 (6.59)	10.97 (7.15)

Distance estimation

To examine the influence of urgency between RS and VS environments, a 2 condition x 3 scenario between subjects ANOVA was performed on distance estimations. There was no significant main effect of condition $F(2,92) = 2.07$, $p > 0.05$, and no reliable interaction between condition and scenario, $F(2,92) = 0.91$, $p > 0.05$. However there was a main effect of scenario, $F(2,92) = 4.22$, $p < 0.01$; the high urgency condition was associated with larger estimates than either the low urgency or control conditions (both $p<0.05$).

Time estimation

Time estimation was calculated as a ratio (= estimated time/actual time), in order to provide comparable reports across conditions.

There was no significant main effect of condition on time estimation, $F(2,92) = 2.46$, $p > 0.05$, or of scenario, $F(2,92) = 2.58$, $p = 0.08$. The interaction between condition and scenario was also non-significant, $F(2,92) = 2.25$, $p > 0.05$.

Urgency

The urgency reports were significant according to scenario $F(2,92) = 32.61$, $p < 0.001$, but not for condition, $F(2,92) = 0.31$, $p > 0.05$, and there was no interaction between condition and scenario, $F(2,92) = 0.16$, $p > 0.05$. A significant correlation was found between the level of urgency reported and the distances estimated, $r = 0.226$, $p < 0.05$. This analysis confirms that participants engaged with the role-play task.

Discussion

The results confirmed the expectation that goals distort distance estimation in real space and goals were also found to influence distance estimation in virtual space. This supports Jansen-Osmann and Berendt's (2002) claim that, despite the lack of proprioceptive information, VR is a valid methodological tool for the investigation of the mechanisms of spatial cognition.

Self-report urgency ratings after the experiment suggested that participants immersed themselves in the role-play appropriately. Additional self-report anxiety levels also supported this view.

The results provide evidence that goals affect the perception of distance in both real and virtual space. Moreover, the effect of scenario was very marked, with over double the mean distance estimate for the high urgency real scenario compared to the low urgency real scenario. However, these data pertain only to a single environment path type; a straight line path. Experiment 2 examines the effect of scenario on distance estimates for a path with many turns in real space.

Experiment 2

Real space – Route Angularity

This experiment employed a real maze with 8 turns in order to establish whether the effect of scenario is robust across environments with different spatial structures.

Real Space Human Maze 2

The maze was built from the same material as in Experiment 1 and consisted of 28 polystyrene blocks, dimensions 1.2 x 2.1 x 0.3 metres – more blocks were required to accommodate the variance in width at the right-angled turns. The maze consisted of 8 turns; 4 x right and 4 x left angled (Figure 2b). The maze was designed so that it exited directly into a lobby where the experimenter was waiting, out of the field of view of the participant. Again, the total distance, using the central route of the maze was 15.4 metres and floor markers provided the experimenter with the cue for timing the journey.

Method

The method used was exactly the same as in Experiment 1.

Participants

Sixty participants were recruited to take part from Newcastle city centre and were paid a nominal fee for their participation. Participants were aged between 18 and 53 years old (mean age = 25.75, SD= 9.3). Again, participants were randomly allocated and evenly distributed for age and gender across all conditions. No participant had any previous experience of the building in which the real space maze was constructed.

Procedure.

The procedure was exactly the same as in Experiment 1.

Results

Preliminary Analyses

One-way between participants ANOVAs found no significant difference across scenarios for participants' walking pace for the real space $F(2,53) = 0.47$, $p > 0.05$. There was also no significant difference in the time spent in the maze between scenarios, $F(2,53) = 0.11$, $p > 0.05$

Main Analyses

Responses from 4 participants (7%) were excluded, using the same criteria as Experiment 1.

Table 2 shows the mean distance estimates by scenario.

Table 2: Mean distance estimations by scenario in Experiment 2

Scenario	Straight Path		Turns	
Distance (15.4 metres)	$\overline{X}$	(σ)	$\overline{X}$	(σ)
Control	13.94 (11.45)		18.12 (6.37)	
High Urgency	23.07 (22.50)		13.16 (7.15)	
Low Urgency	10.42 (6.59)		15.8 (7.85)	

Distance estimation

The influence of urgency was investigated between the straight path and the path with 8 right-angled turns (i.e., running a combined analysis for the real maze data in Experiments 1 and 2). A 2 path type x 3 scenario between subjects ANOVA revealed no significant main effect of path type, $F(2, 92) = 0.003$, $p > 0.05$, or of scenario, $F(2,92) = 1.59$, $p > 0.05$. However there was a significant interaction between path type and scenario, $F(2,92) = 4.56$, $p < 0.01$. An effect of scenario was found for the real maze with straight lines, as established before, but no such effect was present for the real maze with multiple turns.

Time estimation

Several participants claimed that they found it difficult to keep in step with the metronome whilst turning corners, resulting in participants spending less time in the maze with turns (Mean = 13.8 seconds) than in the straight line maze (mean = 11.8 seconds), $p< 0.001$. Therefore time estimations were converted to ratios: estimated time/actual time. There was a significant main effect of path type on time estimation $F(2,92) = 12.32$, $p < 0.001$. Participants reported spending more time in the environment with turns than in the straight-line environment. However, there was no significant main effect of scenario for time estimation $F(2,92) = 2.75$, $p > 0.05$, and no interaction between path type and scenario $F(2,92)$, 0.88, $p > 0.05$.

Urgency

The urgency reports were significantly different across scenarios, $F(2,92) = 17.64$, $p < 0.001$, but not across path types, $F(2,92) = 1.54$, $p > 0.05$. Also, there was no interaction between path type and scenario, $F(2,92) = 1.00$, $p > 0.05$. There was also no significant correlation between the level of urgency reported and the distance estimated, $r = 0.34$, $p > 0.05$.

Discussion

The more complex environmental structure with multiple turns did not produce the same findings with regard to scenario as those found for the straight-line path in a real human maze. However, this difference cannot be explained as a function of differences in perception of urgency across conditions; urgency ratings were reliably different between scenarios for the path with many turns just as they were for the straight-line path.

The absence of the distortion of distance estimation for the role-play task in the complex environment may be a result of environmental complexity; participants reported difficulty in keeping to the sound of the metronome at the turns. This may also explain the failure to find the established effect of number of turns on distance estimation found in past studies (e.g., Sadalla & Magel, 1980; Bugmann & Coventry, 2008).

General Discussion

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

The results for the straight line path (Experiment 1) show the powerful influence goals exert on immediate memory for distance travelled. Greater urgency is associated with greater distance estimates in both real and virtual space. Moreover, there was a reliable correlation between urgency ratings and distance estimates, suggesting that individual differences in perceptions of urgency may also play a role in perception of distance (consistent with Golledge, 1987, 1999). This effect cannot be explained by the amount of time spent traversing the path given that time and speed of walk were strictly controlled. In addition the absence of differences in scenario effects as a function of media supports the robustness of VR as a methodology despite acknowledged limitations with regard to simulating real life experience (Campos *et. al*, 2007).

Surprisingly an effect of scenario was not found for the real human maze containing many turns. This may indicate that environment structure mediates the goals involved in a task. However, an alternative explanation seems more likely; participants walking in the human maze with many turns found it difficult to walk in time with the metronome clicks on turns, distracting them from the role play task at hand. If this is the case, then running the VR version of the task with many turns will be necessary to arbitrate between these explanations; an effect of scenario should be present in VR if the second explanation holds given that no problems at turns occur in VR. We are currently exploring this possibility.

Theoretically, one can ask why urgency of goals influences distance estimation. Bugmann and Coventry (2008) have suggested that the extent to which attention is engaged during a task affects memory for distance. So urgency may lead participants to consciously engage with the task more, consistent with Bugmann and Coventry's 'attentional shift' hypothesis. One way of testing this hypothesis is to get participants to 'think aloud' while they are performing a task; longer protocols should also lead to increased distance estimates.

In summary, the present data suggest that goals may well influence immediate memory for route distance. A further series of studies in progress aims to identify the precise mechanisms involved.

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