Drawing Maps and Remembering Landmarks after Driving in a Virtual Small Town Environment

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Abstract: Participants were designated active drivers or passive passengers according to whether or not they had control over the displacements of a virtual vehicle, while taking 5, 10 or 15 tours of a virtual small town environment. When tested later, passive passengers were able to remember more landmarks than the active drivers. However, with successive tours, participants in both groups were able to draw better survey maps of the environment, though this effect was greater in passive passengers. Landmark memory and map drawing ability were positively correlated. The results support models of spatial cognition that emphasise survey representations as the end product of spatial learning in new environments, but also emphasise that the acquisition of landmark information is continuous throughout this process.

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1. Introduction

For the psychologist, there are many exciting issues surrounding the use of maps – map production and interpretation, map alignment and orientation specificity, and gender and age differences in map use and interpretation (Aubrey et al, 1994; Foreman, 2006; Levine, 1982; Tlauka and Wilson, 1996). Maps can be regarded as supplementary forms of spatial information that can assist with the main goal of spatial cognition, namely to "avoid getting lost" (Lynch, 1960).

However, the type of map that is generated from personal navigation within an environment is usually not of the cartographic variety, but rather a "spatial cognitive map", generated from experience gained at eye level (not a survey perspective), and which enables expectations to be generated as successive parts of a familiar environment are encountered (cf. O'Keefe and Nadel, 1978). The benefits of acquiring such cognitive representations are obvious: in all species, they enable alternative routes and detours to be made for economy in time and effort, or in order to escape harm and predation – deducing alternative routes to exit a burning building, for example. How such cognitive representations are created and up-dated, what brain systems are responsible, and in what forms they are held, are issues that have engaged neuropsychologists and cognitive researchers over several decades (see reviews in Foreman and Gillett, 1997/8 and O'Keefe and Nadel, 1978).

Cognitive spatial mapping can be seen as an end product of a process of engagement with a new and unfamiliar environment. Siegel and White (1975) proposed that both ontogenetically (across childhood development) and in the course of adult spatial exploration of an unfamiliar environment, cognitive representations follow the same basic sequential course: first, landmarks are acquired, after which routes are learned that connect the landmarks, and finally, following repeated exposure, survey representations are acquired. Mental transformations may be required to translate between representations; for example, mental rotations of 2-D vistas must be made to infer object positions within the "mapped" space. Other theorists, such as Montello (1998), have argued against a strictly stage-based approach, and have proposed that spatial development is a more continuous process, involving the simultaneous acquisition of landmark and survey knowledge as environmental familiarity increases.

Emphasising the importance of environmental familiarity, Beck and Wood (1976) reported that "Long term residents of environments make better maps, both in content and veridicality, than recent arrivals" (see also Wapner et al, 1981). Ladd (1970) found that when black urban adolescents drew maps of their local neighbourhoods, these increased in richness and detail as a function of both familiarity and activity.

Having active choice and independent navigational experience, in a real environment, appears to enhance survey spatial knowledge. When Appleyard (1970) asked hundreds of people in a Venezuelan city to draw maps of their local areas and the city as a whole, those who drove around the city produced more accurate maps than those who generally travelled by bus or taxi (see also Hart and Berzok, 1982) and young adults who drive are better at drawing maps of their neighbourhoods than non-drivers (Andrews, 1973; Brown and Broadway, 1981). Drivers may benefit from having to attend carefully to directional information, but also from making spatial decisions in the planning of future actions (Gaunet et al, 2001). Child public transport passengers are also less knowledgeable about the geography and spatial layouts of their environments, such as the distance from home to school, than pedestrians (Hart, 1981; Joshi et al, 1999).

The present study was undertaken to determine whether, using a controlled environment created with virtual reality software, "levels" of development could be monitored, and whether the sequence of strategies proposed by Siegel and White (1975), i.e., landmark, route and then survey, could be verified. The study replicated a familiar situation in which an individual, newly resident in a small town, has to repeatedly navigate to targets such as a school, work, a shop, or babysitter. We wanted to know whether after 5, 10 or 15 tours, taken as a driver (in active control of the virtual vehicle), an individual would be better able than a passenger (passively observing while seated next to the driver) to remember landmarks, or routes, and to sketch survey maps of the environment. We expected landmarks to be remembered in early tours, but survey mapping skills to develop after greater exposure.

2. Method

Fifty-four undergraduate psychology students participated in self-selecting yoked pairs (45F, 9M), randomly allocated to driver and passenger conditions. The driver sat at a steering wheel, and a foot pedal controlling forward movement. They viewed a projected virtual image, 1 m high x 2 m wide on a screen 3.5 m in front of them, depicting a virtual town. This consisted of a figure of 8 roadway, plus buildings such as residential houses, blocks of flats, a supermarket, and a fast food outlet, plus trees, railings and a telephone box (the plan is shown in Figure 1). They had to follow road signs and markings that guided them on 5 journeys, which together took them on a full circuit around all parts of the VE. Each journey had a specific start and end point; road markings were colour-coded, so that, for example, the first was a red route (the start indicated by a red marker, the end by another red marker, and broken lines at the road centre also being red). Buildings were clearly marked with labels. Journeys took the drivers between specified buildings, thus between home, school, work, babysitter and so on. Groups of drivers made 3-minute tours 5 times (i.e., making 5 complete tours of the VE), 10 times, or 15 times. Passengers sat beside their paired driver, and simply observed the screen. Participants were not given any explicit instructions to attempt to commit to memory any aspect of the environment but were asked only to keep their attention focussed on it. This was done in order to negate the possible confound of passive participants paying unusually high attention to the learning task, identified by Wilson (1999) when the subsequent spatial tests are known prior to exploration. This meant that our comparison was of physical activity, in terms of control and action, with passivity in relative isolation from other possible cognitive confounds related to intentional learning.

Following this experience, every participant was tested for (1) landmark memory (via free recall of landmarks encountered), (2) route knowledge (via a forced choice questionnaire task with 10 items, e.g. indicating the direction of travel to a target from a described current position), and (3) survey map knowledge, assessed using 3 measures (via drawing a sketch map of the whole environment including roads and buildings, which was assessed by two raters; by pointing to unseen targets, assessed according to the angular errors between the actual and indicated directions; and also by placing 8 prominent and specified landmarks in their correct positions on an A4 outline map of the environment, assessed according to the distance of the placed objects from their true positions). Analysis of Variance (ANOVA) was used to compare between conditions (active driver/passive passenger) across the 3 lengths of exposure (5, 10 or 15 tours), on each measure. Effects were significant where $p<.05$. No gender effects were evident on any measure.

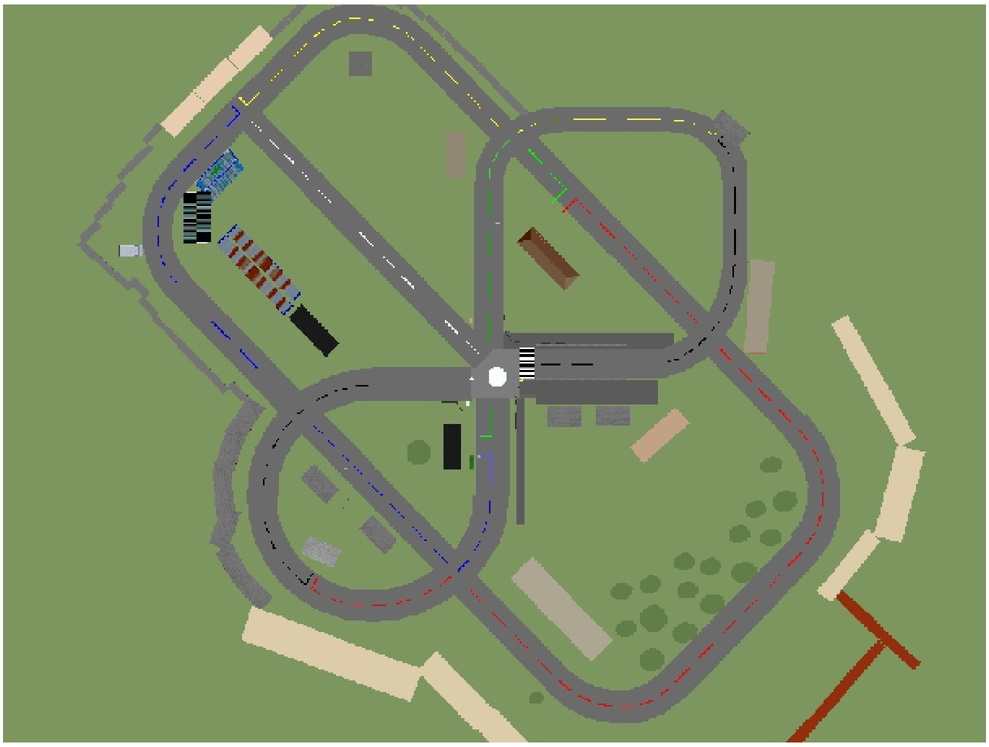

Figure 1 Bird's eye view of the layout of the virtual town, showing the positions of buildings and the colour-coded routes that participants had to follow. Due to the arbitrary units used in VEs it is not possible to provide an absolute scale for distances. The VE was designed to give explorers an authentic eye-level experience of driving a car through a small town centre.

3. Results

Landmarks: Passive passengers remembered significantly more landmarks than active drivers ($F[1,53]=6.39$), and across all exposure conditions, but in both active and passive conditions more landmarks were remembered after 15 tours than after 5 ($F[2,53]=8.08$).

Route knowledge: No significant effects appeared on the questionnaire responses, though route selection was not tested per se.

Survey mapping: Pointing errors (to unseen targets) and map placement error scores reduced significantly between 5 and 15 tours in both conditions.

High inter-rater reliabilities (around $r = .78$) were obtained for map-drawing measures. Map raters' scores were averaged per participant. Raters were asked to score maps on a 1-4 scale, based on how "useful" the map would be, should it be used as a navigation aid. Some 76% of maps showed a circuitous map, reminiscent of the actual layout, 14 correctly showing a figure-of-eight arrangement (drawn by 9 active driver participants and by 5 passive passengers). Only 8 road layout sketches did not feature a circuit. There was a significant exposure effect ($F[2,48]=3.70$), maps drawn by people in the 15 tour condition being significantly better that those in the 5 tour condition, though the 10 tour participants were intermediately placed and did not differ significantly from either of the other groups. However, a significant interaction between condition and exposure ($F[2,48]=3.53$) reflected the limitation of the exposure effect to passive participants; it was not significant for active drivers. Figures 2 and 3 show maps drawn by participants in the passive group who had toured the environment on 15 and 5 occasions respectively.

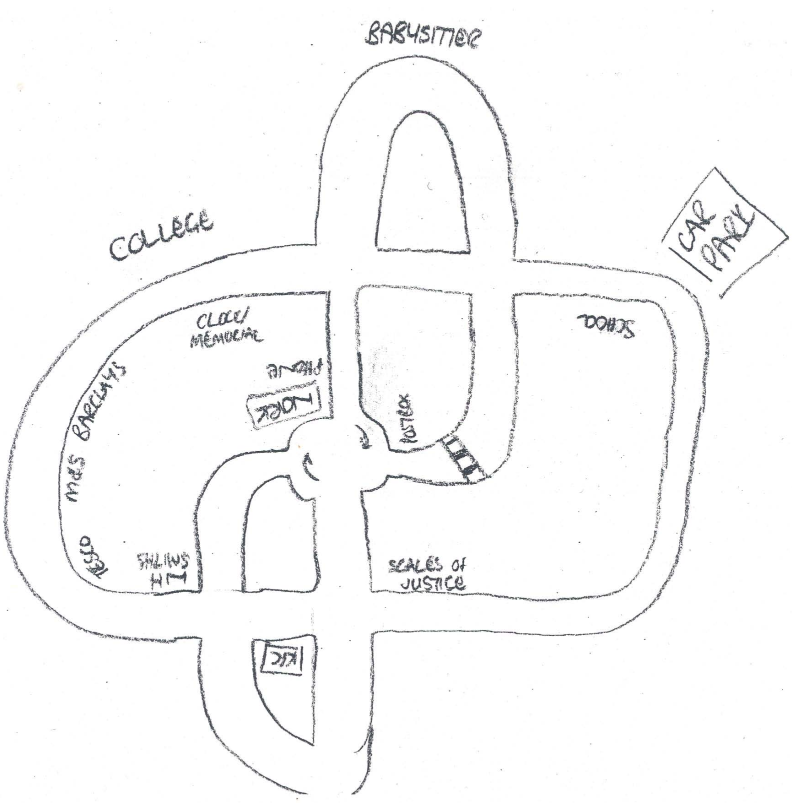

Figure 2 This sketch map, drawn by a passive passenger participant who experienced 15 tours the VE, bares a good resemblance to the actual VE road layout being both continuous and circuitous (see figure 1).

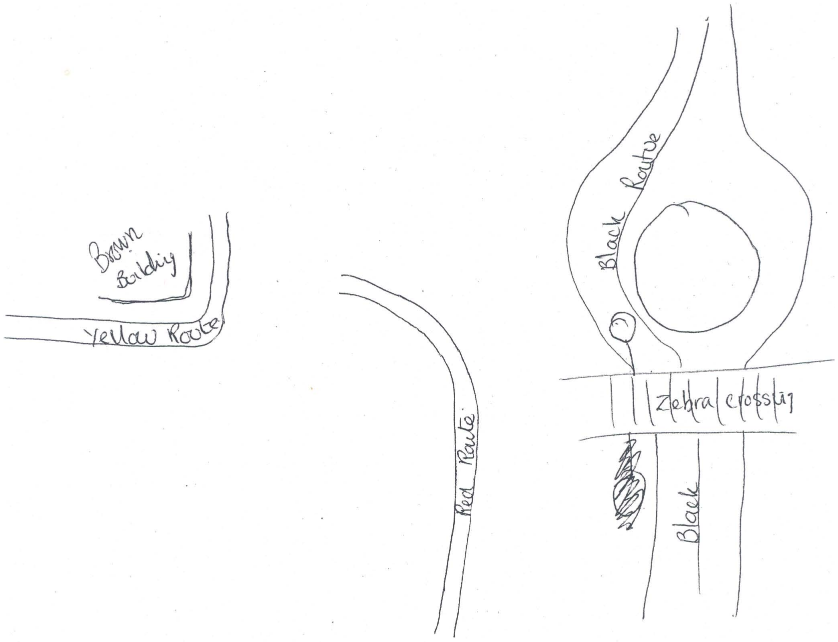

Figure 3 The sketch map drawn by this passive passenger participant, who experienced only 5 tours of the VE, is fragmented and shows only a few features of the VE in an apparently random fashion. It is interesting to note, however, the prominence of the roundabout, a central feature of the VE.

As VE exposure increased between 5 and 15 tours, landmark memory improved from around 8 prominent items recalled to over 15. Correlational analysis indicated that map drawing score was significantly correlated with the number of landmarks recalled ($r[52] = 0.34$).

4. Discussion

The study showed that the development of survey mapping skills does appear to follow the course suggested by Siegel and White (1975), insofar as greater exposure to an environment (as might occur for a newcomer to a town, over a test period that was equivalent in time to 2 weeks of making journeys between prominent buildings) leads to a significantly increased ability to depict the environment in survey mapping form. However, the acquisition and use of landmarks is arguably related to the process of survey mapping as it evolves; landmarks are progressively acquired over the period of time in which survey mapping is developing, so that their correct acquisition and retention is an important factor in generating better survey representations. In that sense our data support Montello (1998), who criticised the idea (Siegel and White, 1975) that in the early stages of familiarity with an environment, landmark knowledge is qualitatively non-metric: "Metric configurational knowledge begins to be acquired on first exposure to a novel place" (Montello, 1998, p.146). However, there can be no doubt that effective survey representations represent an"end product", taking over progressively from landmark use as strategies of choice; they are adaptive and sophisticated, differentiated from landmark-based orientation via their greater flexibility, especially in circumstances requiring escape, e.g., when it is necessary to adopt a novel route to circumnavigate a danger.

A surprising result of this study, though consistent with the results of some earlier studies using VEs (cf. Attree et al, 1996), is that passive participants acquired landmark information more rapidly (and sketched superior survey maps) than active drivers, perhaps because the latter group's spatial working memory capacity is compromised in a VE by their having to operate input devices (Sandamas, 2007). Added to which whilst the active drivers had control over decisions to move or not to move and the sensori-motor experience of manipulating the input device, their activity was not practical, i.e. it had no known purpose or outcome as it would in reality. According to Cohen and Cohen (1985) activity in space is generally linked with other cognitive and social concerns providing purpose to the activity and use of spatial information. Therefore, it could be argued that, when other factors such as attention are equated there is no benefit of being active per se. Sandamas (2007) has also suggested that the findings of previous urban / ecological studies, such as Appleyard (1970), that car drivers demonstrate better spatial understanding of a city layout than do bus passengers, may not be demonstrative of the benefits of activity. Rather they may demonstrate the benefits of the competencies and attentional requirements associated with driving and the lack of attention generally paid by passengers to the environment through which they are being transported.

Our results are also important because they indicate the importance of acquiring and using landmarks, in the course of developing a spatial cognitive representation of a new environment. It is possible that, strategically, the types of map used by a newcomer to an area might be designed differently from those used by people having long-standing local knowledge. For example, newcomer's cartographic maps might be designed to emphasise the most important landmarks, on a hierarchical basis, and the shortest routes that link them. Moreover, virtual and SATNAV representations might be developed which augment reality, to encourage the acquisition of especially useful local landmarks and thus speed the process whereby newcomers become as spatially competent as locals. Obviously the future design and efficacy of such maps and digital navigation devices need to be researched.

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