Rapid development of cognitive maps in people with visual impairments when exploring novel geographic spaces

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'Cognitive' map is a term that refers to a person's environmental knowledge. Anyone experiencing a new environment will, over time, develop a cognitive representation of that environment, including information derived from that environment (e.g., about places, routes and spatial relationships) and information about personal experiences (e.g. memories about events at locations and attitudes towards places). There is now a great deal of research into the cognitive maps of sighted people (see Golledge, 1999; Kitchin & Freundschuh, 2000; Kitchin & Blades, in press), but there is comparatively little research into the cognitive maps of people with visual impairments

The research into the cognitive maps of people with visual impairments can be considered under two headings. First, the research that has tested people in familiar environments. Such environments are usually large areas like the floor of a building (e.g.

Rieser, Lockman & Pick, 1980) a school campus (e.g. Ungar, Blades & Spencer, 1996), or the participants' own neighborhood (Byrne & Salter, 1983). These studies have shown that although there are differences in the way that visually impaired and sighted participants encode information, the cognitive maps of visually impaired people are effective representations of the environment (e.g. Rieser et al, 1980). Of course, the cognitive representations of familiar environments may have been constructed over many years of experience, and therefore studies in familiar environments cannot provide any insights into the first stages of cognitive map development.

The second focus of the research has been the investigation of how visually impaired people learn unfamiliar environments. This research has either been carried out in small environments, usually a small room or a layout designed in a laboratory (e.g. Passini, Proulx & Rainville, 1990; Rieser, Guth, & Hill, 1986) or less often the research has taken place in real world environments (see below). The advantage of small laboratory environments is that they permit a strong measure of control over the experimental conditions and they may be particularly appropriate when testing specific aspects of the cognitive maps of people with visual impairments (e.g. their orientation abilities). However, the results gained from studies in small environments may or may not be applicable to the performance of people in real world contexts. We will refer to studies in the real world as ones examining performance in geographic space. In geographic space there are a wealth of information that people with visual impairments can use (e.g. near and distant sounds, olfactory cues, wind direction, heat sources, tactile sensations from sidewalks, and the sense of walking on gradients or steps) and these cues are rarely present in laboratory studies. For this reason it has been difficult to extrapolate from laboratory environments to geographic ones.

In fact, very little research into the cognitive mapping of people with visual impairments has taken place geographic space. There are several reasons for this, but there are three reasons in particular. First, researchers have less control over real environments, because factors like pedestrian density, traffic flow, the weather, and cues like noise and heat are all likely to vary so that the environment is not exactly the same for all participants. The second reason is a practical one, because any realistic assessment of environmental learning means that people have to travel through an environment several times so that their increasing knowledge can be measured. Learning a large novel geographic space several times might therefore place onerous demands on experimental participants who are visually impaired.

The third reason why there has been so little research in geographic space stems from the results of some laboratory based studies. Some of those studies have shown that people with visual impairments, especially those who are totally blind, are poorer than sighted people at learning (small) unfamiliar environments (e.g. Passini et al, 1990; Rieser et al, 1986). If people with visual impairments are poorer than sighted people at learning new places, then there would be little reason for putting them through the stress of learning a large geographic space. This belief, coupled with the practical problems of organizing studies in real environments, has resulted in a lack of research in large spaces. However, as pointed out above, geographic spaces include many factors (auditory, olfactory, and tactile) that might contribute to the effective generation of a cognitive map, and it might well be the case that people with visual impairments can learn real environments successfully.

The studies summarized in this paper describe a series of experiments that compared the ability of visually impaired and sighted participants to learn unfamiliar large geographic spaces. The results of all these studies showed that people with visual impairments could learn large spaces very effectively, and this finding is novel. If people with visual impairments have the potential to learn complex environments quickly and successfully, it has important implications for the mobility training of people with visual impairments and these implications will be discussed below. The focus of this paper will be on the first experiment that we carried out, to explain the procedures and data analysis, and then we will briefly summarize the supporting findings from a subsequent study.

In the first experiment there were, ten totally blind, ten partially sighted, and ten sighted adults from Belfast (UK). They were asked to learn a 1.6 km route through a suburban part of the city that was unfamiliar to them. The route included 16 'choice' points (eight left turns, three right turns, three intersections, and the start and end points). Participants were asked to walk the route four consecutive times on the same day. The first time that they walked the route they were guided along it, but they were given no information about the route and they were not given any verbal directions. In other words, the guiding consisted of instructions like 'you need to cross the road you have been walking down' or 'you need to turn to face my voice'. For this reason all the learning was dependent on the participants themselves.

The route was divided into three sections and at the end of each section there was a salient landmark (A, B, and C). Participants were told, during the guided experience, that they would (on later trials) be asked to point from the start to A, from the start to B, from the start to C and from the start to the end of the route. They would also do the same series of pointing tasks from A, B, C and the end, making a total of 20 such judgements. After the guided experience participants were driven back to the start of the route by a different route (and sighted participants were blindfolded for this trip). Once the participants were back at the start of the route they were asked to walk it on their own, with an experimenter walking behind them for safety reasons. If a participant deviated from the route by more than a few meters they were stopped and led back to the point where they had left the route.

Participants walked the route three times on their own. Each time they walked the route they performed the pointing task and at the end of each trial they also carried out three tasks. They were asked to verbally describe the route, to estimate distances between places along the route, and to construct a map of the route. The map was made out of magnetic pieces that the participant could place on a metal board.

In summary, participants walked the route themselves three times. Each time their accuracy at choice points along the route was recorded, and each time the participants carried out four tasks: pointing between landmarks, giving a verbal description, estimating distances and making a map. Three of these tasks (route walking, verbal description, and estimating distances) refer mainly to one aspect of cognitive maps - i.e. route knowledge (Siegel & White, 1975). Two of the tasks (pointing and map making) depend more on participants ability to form a cognitive map of the whole area because successful performance on these tasks requires an appreciation of the spatial relationships between different places along the route (Siegel & White, 1975).

The route knowledge of all three groups was very good. All the participants were able to estimate distances along the route quite accurately after their first experience of walking it for themselves and there was no difference between the visually impaired, blind or sighted groups. As for the verbal descriptions there were slight differences in the way that visually impaired and sighted participants described the route, because the sighted participants used more spatial references and the visually impaired groups used more reference points. Nonetheless all three groups gave equally accurate descriptions of the route (e.g. by reporting left and right turns correctly). For the walking itself there were some differences between the groups because the first time that participants walked the route on their own the visually impaired and blind groups were poorer than the sighted group and deviated from the route more often. However, the second and third times that participants walked the route themselves, there was no difference between the groups. In other words, by the time that the participants had experienced the route twice (once as they were guided along it and once when they walked it for themselves the first time) they all had a good knowledge of the route irrespective of their degree of vision.

Not only was participants' specific route knowledge very good, but their appreciation of the overall layout of the route was also good. Participants' ability to point between places improved from the first to the third time that they walked the route, but there was no difference between the three groups on each trial. The same pattern of results also applied to the map-making task. There was an improvement in the accuracy of maps over the three trials, but there were no differences between the groups.

Taken together these results show that one aspect of cognitive map knowledge (i.e. route recall) was achieved quickly and that there were only small differences between the two visually impaired groups and the sighted group. Developing a cognitive map representation of the whole environment took all the participants longer as there was a general improvement with greater experience, but most importantly, there were no differences between the visually impaired and the sighted participants.

We carried out a similar study in the United States, with visually impaired and sighted participants who were asked to walk a novel route through a suburb of Santa Barbara, California. The procedure and measures were the same as in the Belfast study described above. As in that study, we found that there were few differences between the cognitive mapping abilities of the participants who were visually impaired and those who were sighted. We suggest, on the basis of these two studies that people with visual impairments may have little difficulty learning novel areas. The assumptions that have been made previously about their limited or much delayed ability to form cognitive representations of new environments may have underestimated their potential ability.

The successful performance of visually impaired people in these studies contrasts with the limitations that have sometimes been reported in earlier laboratory based studies that took place in small and limited environments. There could be at least two reasons why the performance of the visually impaired was unexpectedly good. The first reason has already been mentioned: geographic space includes much richer environmental information (auditory, olfactory and tactile) than the spaces typically used in previous studies.

However, before assuming that the cues present in a real world environment may be the reason for the visually impaired people's success, we had to consider a second possible reason for the good performance of the participants in our experiment. This second reason relates to the experimental procedure that we used. In our studies the participants were required, during each trial, to estimate distances and directions, describe and map the route, and these measures were necessary to measure the development of participants' knowledge. However, the repeated emphasis on recalling aspects of the space that tapped into participants' cognitive map knowledge may in itself have been a factor in successful learning. Indeed, several of the participants spontaneously said that one or more of the tests they carried out had made them think about the space in ways that had helped them to learn it.

We therefore considered whether the measures themselves could have had any effect on learning in a follow up study. After the study in Santa Barbara, we asked a further group of participants with visual impairments to walk the route three times, but they did so without carrying out any of the test measures. If performing the tests had contributed to the cognitive maps of the original participants we predicted that the performance of the original participants should have been better than the performance of the participants in the follow up study who only walked the route without being tested. Because the participants in the follow up study did not carry out any of the tests we could not, of course, measure their knowledge of the overall layout of the route. However, we could compare their knowledge of the route (assessed by the number of correct decisions at choice points) with the route knowledge of the participants who had taken part in the original study. In fact there was no difference because both groups learnt the route equally well. In other words, route knowledge was not affected by the amount of testing that participants experienced while they were experiencing the route. The latter result reinforced the original finding that people with visual impairments can learn large geographical spaces quickly and effectively, and showed that successful learning was not an artifact of our experimental procedures.

In summary, people with visual impairments have the potential learn complex geographic spaces. In both the Belfast and Santa Barbara studies the visually impaired participants were able to both learn the way along a route and form an accurate cognitive representation of the environment after only limited experience. There were no differences between the performance of partially sighted and blind participants, and both groups only required a small amount of additional experience compared to sighted participants to achieve the same level of competence as the sighted group. We suggest that many visually impaired people are capable of learning geographical spaces without major difficulty and without significant delay compared to sighted people. This conclusion has major implications for mobility training, because we would argue that many visually impaired adults can be expected to learn complex new environments successfully if they are given the opportunity to do so.

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