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Using Route and Survey Information to Generate Cognitive Maps: Differences Between Normally Sighted and Visually Impaired Individuals

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SUMMARY

Visually impaired people (VIP) have to rely on different information to generate a cognitive map of their environment than normally sighted people. This study explored the extent to which a cognitive map could be generated by auditory information of route-type and survey-type descriptions of a fictitious environment. A total of 27 visually impaired and 28 normally sighted participants listened to either a survey-type or a route-type description of a fictitious zoo. They then answered both route-type and survey-type questions. This listening/question-and-answer sequence was repeated twice (total $n = 3$). The visually impaired participants showed no difference in error frequency between the two description types, while the normally sighted individuals performed better after listening to the survey-type description. In addition, the learning curve of the normally sighted individuals was steeper than that of the visually impaired and they made fewer errors. The error scores indicated two subgroups in both the normally sighted and the visually impaired groups. These two groups, the 'good' learners and the 'poor' learners, showed marked differences in generating a cognitive map from auditory descriptions of an environment. Copyright © 2008 John Wiley & Sons, Ltd.

Without the generation and use of some kind of a mental picture of our surrounding world, elementary tasks such as going to work or school, shopping, or moving about the house would be impossible. Gaining and using such a picture is termed 'cognitive mapping'. A cognitive map comprises "the internal representation of perceived environmental features or objects and the spatial relations among them" (Golledge, 1999, p. 6). The notion of a cognitive map was introduced by Tolman (1948) in his article on rats and maze learning. It has since proven very useful in studies on humans. The information included in a cognitive map may consist of landmark knowledge, route-based knowledge, or survey-based knowledge (e.g. Siegel & White, 1975). It is assumed that the latter two types of knowledge originate from the two possible ways an environment can be learned or viewed: that is moving around in an environment (route) versus looking down on it (assisted by a map or a high position; survey). Having a survey representation appears to benefit cognitive-mapping tasks because it provides a better knowledge base to solve occurring problems

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flexibly. Unexpected obstructions cannot be circumvented with route-based knowledge only, whereas an alternative route can be calculated using survey-based knowledge. The importance of landmarks in the Siegel & White paper was recently supported by studies in virtual environment learning (e.g. Stankiewicz & Kalia, 2007; Newman, Caplan, Kirschen, Korolev, Sekuler, & Kahana, 2007). In the present study the main focus is placed on route information and survey information, where no particular landmark-type information is given. If the Siegel & White stance is correct this would mean that participants would have difficulties learning the presented fictitious environment in the first place.

Visual information is generally used to generate a cognitive map and wayfinding aids are predominantly visual (signs with text and arrows). However, the ability to construct a cognitive map from verbal descriptions was recently demonstrated by Giudice, Bakdash, and Legge (2007). They trained blindfolded normally sighted participants with verbal descriptions of a ground plan of a corridor network during exploration, where the descriptions were adjusted to the participant's compass orientation during exploration. The test consisted of walking the shortest route between pairs of targets. It appeared that the participants used in more than half of the test trials routes they did not use in that particular order during the training phase. Their performance was not different from the performance during a visual control condition. This shows that normally sighted people are able to convert a non-visual verbal description into a cognitive map, that can be used to solve wayfinding issues.

Visually impaired people (VIPs), however, have to rely on vestibular, haptic, auditory and occasionally olfactory information. They also have to access their information in a more sequential way since they cannot 'look around' and gain a review 'at glance'. Their information, therefore, resembles route-based information more than survey-based information. Nonetheless, VIPs are able to perform cognitive-mapping tasks, that is they can learn mutual spatial relations between locations in the environment in order to reach destinations. Thus, it appears that VIPs are able to generate a cognitive map from non-visual sequential information sources.

The question arises whether there is a difference between normally sighted individuals and VIPs in their ability to form a cognitive map and to convert their general information type (more survey-like for the normally sighted versus more sequential, route-like for VIPs) into an abstract representation that, in turn, allows them to convert route-like information into survey-like information and vice versa if needed. Another question is whether this map generation is slower and less precise in VIPs than in normally sighted individuals (Thinus-Blanc & Gaunet, 1997).

Noordzij, Zuidhoek, Van Meggelen, Petersen, Prinsen, and Postma (2003) conducted a pilot study in which they gave participants either a survey-type or a route-type description of a fictitious zoo. In a reaction–time experiment, they asked their subjects to estimate whether the distance between one pair of animal cages was larger or smaller than between another pair, for example the distance between giraffe and rabbit compared to the distance between giraffe and hyena. The study was performed with normally sighted subjects and then repeated with VIPs. The results suggested that normally sighted individuals were faster using route descriptions than survey descriptions, but their accuracy was reversed. In contrast, VIPS were equally proficient in their use of route and survey descriptions. Noordzij and colleagues studied distance estimation, while the focus of the present study was on the rate of learning and the conversion of one type of applicable knowledge into another. The setup, therefore, was different from that of Noordzij et al. (2003), or Noordzij

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& Postma (2005), who also used route-type and survey-type information in a fictitious zoo or mall.

In the present study, participants were given a verbal description of a fictitious zoo. One half received a route-type description, the other a survey-type (overview) description. The route description comprised terms like 'on your left, on your right', whereas the survey (overview) description had terms like 'to the north, to the west'. After the description was repeated once the participants answered both route-type and survey-type questions. This listening/question-and-answer sequence was then repeated two more times. The repetitions allowed us to assess the (possible) accumulation of a particular kind of knowledge, a (possible) information-type conversion, and the learning rate.

The following hypotheses were tested:

(1) Normally sighted participants will perform better than VIPs when provided with survey-type information; this will be reversed when route-type information is provided.
(2) Normally sighted participants will perform better when provided with survey-type information than with route-type information; this difference will be reversed for VIPs.
(3) Normally sighted participants will generate a correct representation of the environment quicker than VIPs, especially during the first and second exposure to the information.
(4) Normally sighted participants will be able to use survey-type information better to answer route-type questions than vice versa.
(5) VIPs will be able to use route-type information better to answer survey-type questions than vice versa.

The results were also analyzed for other interesting effects. Performance was measured in terms of the proportion of correct answers.

METHOD

Participants

VIPs ($n = 27$) were recruited from the volunteer list of the Laboratory of Experimental Ophthalmology, of the University Medical Center Groningen (UMCG-LEO). Before the study commenced, notations were made of impairment type and severity, supplemented with some biographical data. A VIP was defined as someone who is unable to use the hospital's wayfinding signage system of normally sighted individuals. Table 1 presents the characteristics of the participating VIPs.

The normally sighted participants ($n = 28$) were recruited by asking for volunteers among the acquaintances of the experimenters. These individuals were matched as well as possible with a VIP with regard to age, gender and education. All participants were treated according to common ethical standards and all gave informed consent prior to the experiment. They also received travel expenses.

Materials

Two descriptions (route/survey) of a fictitious zoo were tape recorded on a cassette, read by a neutral male voice. Each description consisted of approximately 270 words and lasted

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Table 1. Characteristics of the visually impaired participants (Vips)

Part. nr.	Year of birth	Gender	Highest education	Travelling independent	Cause of impairment	Since
1	1975	Male	IVO	Often	Blind	1975
3	1915	Male	Primary school	Never	Macula degeneration	1984
4	1964	Male	LSGE	Often	Blind	1964
5	1946	Female	HVO	Often	Glaucoma	1980
6	1954	Female	HVO	Often	Different	1975
7	1949	Female	IVO	Regularly	Macula degeneration	1994
8	1945	Male	University	Hardly	Blind	1966
10	1964	Female	LSGE	Regularly	Macula degeneration	1964?
11	1941	Male	PUE	Regularly	Different	1989
12	1949	Female	HVO	Regularly	Different	1949
13	1931	Male	HVO	Regularly	Macula degeneration	1995
14	1939	Female	PUE	Often	Macula degeneration	1968
15	1947	Male	HVO	Often	Different	1947
16	1939	Male	HVO	Often	Glaucoma	1939?
17	1968	Male		Often	Different	1968
18	1952	Female	HVO	Often	Macula degeneration	1991
19	1940	Male	LSGE	Often	Cataract	1940
22	1943	Male	PUE	Often	Different	1965
23	1948	Female	Primary school	Regularly	Blind	1948
24	1964	Male	Primary school	Hardly	Blind	1964
25	1938	Female	Primary school	Often	Different	1938
26	1957	Male	PUE	Often	Blind	1957
27	1971	Male	Primary school	Often	Different	1971
28	1949	Female	LSGE	Regularly	Macula degeneration	1996
30	1959	Female	LSGE	Never	Different	1984
32	1952	Male	University	Often	Different	1952
33	1951	Female	IVO	Regularly	Different	1988

HVO, higher vocational education; IVO, intermediate vocational education; PUE, pre-university education; LSGE, lower secondary general education; ?, questionable date since these causes are not known to be congenital.

2′34″. The route-like description (original in Dutch) contained sentences like '... On your right is the petting zoo. Turn right and then left after passing the petting zoo. The aquarium is now on your right. The reptile house is on your left. Go straight ahead to the monkey rock. . . .'

A few sentences from the survey-type description are '. . . The area containing the indoor animal exhibits is north of the children's recreational area. It is divided into three sections. The aquarium is to the east and the insect house to the west. The reptile house is in the middle. . . .' A full translation of both descriptions can be found in Appendix A and a map of the fictitious zoo in Appendix B. There were three lists of questions that were given to each subject. Each list consisted of 20 questions, 10 route-type and 10 survey-type. List order was counterbalanced between subjects. The questions were read aloud by the experimenter. Examples of route-like questions are 'Standing on the path with your back to the petting zoo and facing the monkeys, which animals are on your left?' and 'You are walking between the reptile house and the aquarium, heading towards the petting zoo. Will you turn left or right to go to the insect house?'. Examples of survey-like questions include 'Which animals will you find east of the insect house?' and 'Which animals are west of the aquarium?' The questionnaire lists can be obtained from the first author.

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Design

The two groups of participants (VIPs and normally sighted individuals) were matched for age, gender and education. The matched couples were then assigned at random to an information type (survey-type or route-type information). The type and severity of the visual impairments were distributed between the information types as equally as possible. All four groups (normally sighted survey-type, normally sighted route-type, VIP survey-type, VIP route-type) were asked the same questions that is both survey-type and route-type. The answers were recorded after each listening/question-and-answer session ($n = 3$).

Procedure

After being welcomed, the participants were seated at a table, informed about the experiment and given the opportunity to ask questions. After agreeing to participate, they listened to the taped information. The subjects wore headphones and were told they could turn up the volume as loud as they preferred. Their first exposure to the information consisted of listening to the tape twice, followed by a question list. The answers were recorded on paper. The participants were then asked to listen to the information again. This was followed by another question list. This listening and question list was repeated one more time (total number of exposures $n = 3$). After filling in a few additional questionnaires for another study and undergoing debriefing, the participants were given travel expenses and dismissed.

RESULTS

The average number of correct answers to each type of question was calculated after each exposure and for each of the four (Visual condition × Information type) groups. These numbers were then recalculated as percentages and subjected to repeated measures ANOVAs (SPSS-GLM) using various post-hoc comparisons according to the hypotheses and design presented in the setup section. Figure 1 presents the averages in separate panels for each vision group. As can be seen, the normally sighted individuals answered more questions correctly than did the VIPs ($F_{(1,51)} = 5.89$; $p < 0.05$; $\eta^2 = 0.103$). In addition, the participants who received survey-type information answered more questions correctly than those who received route-type information ($F_{(1,51)} = 6.26$; $p < 0.05$; $\eta^2 = 0.106$).

The interaction between Vision (Visual condition—see above) and Information type, suggested by Figure 1 was not significant ($F_{(1,51)} = 1.31$; n.s.; $\eta^2 = 0.025$). Based on reliability intervals using the Bonferroni correction for the number of tests, however, *post hoc* paired comparisons showed that the normally sighted individuals who received survey-type information did better than the VIPs receiving the same type of information. Since this was to be expected from hypothesis 1, the test was one-tailed (mean difference (md) = 21.9%; $p < 0.05$). The difference between Visual condition and route-type information was not significant ($md = 7.9\%$; n.s.), thus the reversal in hypothesis 1 was not supported.

Normally sighted individuals did better after receiving survey-type information than route-type information, as was predicted in hypothesis 2. As a result, this was tested one-sided ($md = 22.4$; $p < 0.05$). Because the difference in the VIP group between the two

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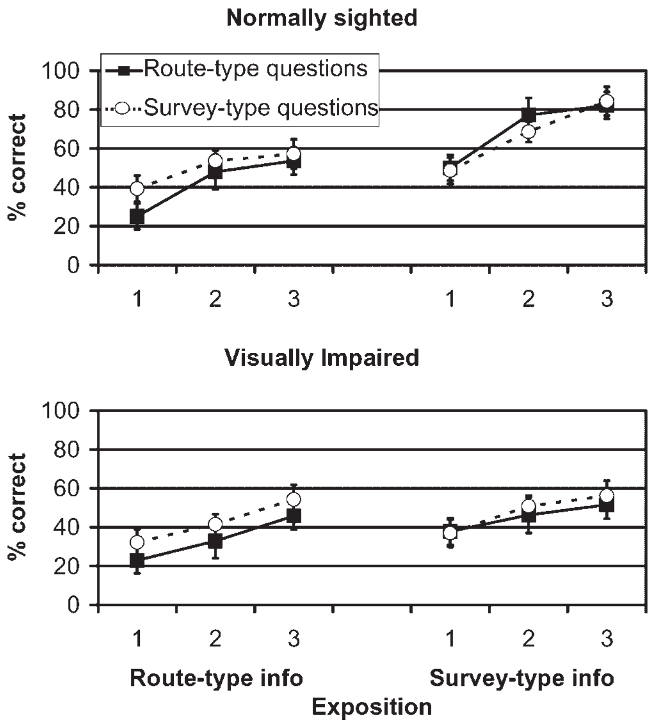

Figure 1. Average proportion of correct answers for each vision group, divided into Information type, Question type and Exposure. Note the better performance in the normally sighted group who had received survey information. Upper panel: normally sighted participants. Lower panel: visually impaired participants. Error bars represent the standard error of means

types of information' was not significant ($md = 8.3$, n.s.), the reversal for VIPs in hypothesis 2 was not supported.

Figure 1 shows a clear improvement with increasing information exposure ($F_{(2,102)} = 42.23$; $p < 0.001$; $\eta^2 = 0.628$). The normally sighted individuals improved (learned) faster than the VIPs. Since this supports hypothesis 3, a one-sided test could be performed $F_{(2,102)} = 2.90$; $p < 0.05$; $\eta^2 = 0.104$). Both the linear and the quadratic trends were significant for the interaction ($F_{(1,51)} = 2.91$; $p < 0.05$ one-sided and $F_{(1,51)} = 3.08$; $p < 0.05$ one-sided, respectively). The improvement in normally sighted people was greater between exposures 1 and 2 and leveled off between exposures 2 and 3. The improvement seen in the VIPs was less steep, but remained more or less equal throughout the three exposures. These findings support hypothesis 3. This hypothesis was also confirmed when the analysis was repeated for each vision group separately. In the ANOVA, both the linear and quadratic trends were significant ($F_{(1,26)} = 56.66$; $p < 0.001$ and $F_{(1,26)} = 8.08$; $p < 0.01$, respectively for the normally sighted individuals. For the VIPs, this was only true for the linear trend ($F_{(1,25)} = 27.74$; $p < 0.001$).

A major effect was noted with regard to Question type: survey-type questions were generally answered better than route-type questions ($F_{(1,51)} = 5.31$; $p < 0.05$; $\eta^2 = 0.094$). Figure 1 shows the interaction between Information type and Question type ($F_{(1,51)} = 5.06$;

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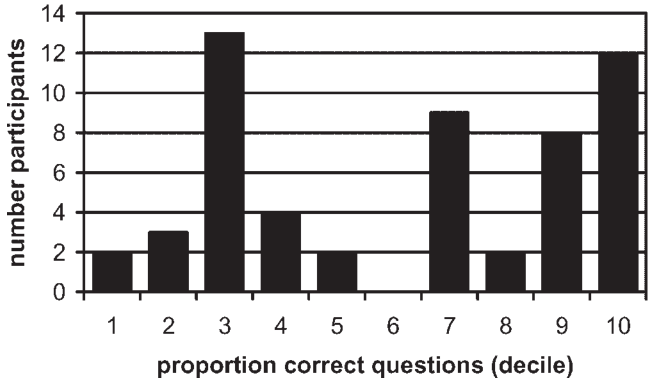

Figure 2. Frequency distribution of the proportion of correct answers after having undergone three listening/question-and-answer sessions.. Note the clear separation between 'good' performers ($\geq$60% correct answers) and 'poor' performers ($\leq$50% correct answers)

$p < 0.05$; $\eta^2 = 0.090$). When route-type information was given, the route-type questions were answered better than the survey-type questions. In contrast, there was no difference between the answers to the two types of questions when survey-type information was given. Higher order interactions were not significant and hence hypotheses 4 and 5 were not supported.

An additional analysis was made, restricted to the VIP-group, to explore the influence of early versus late onset of the visual impairment. The participants of the VIP-group were divided into an early- and a late-impairment group. A participant was allotted to the late-impairment group if there were four or more years between birth and impairment onset. Otherwise a participant was assigned to the early-impairment group. No difference in performance was found between these groups ($F_{(1,23)} = 0.05$; n.s. $\eta^2 = 0.002$).

On inspection of the data, a division appeared between those participants who were able to learn the relative positions of objects in the fictitious zoo ('good' performers) and those who did not improve after three exposures ('poor' performers). Figure 2 shows the distribution of the participants' correct answers after exposure 3, that is 'final performance'.

In order to explore the influence of being a 'good' or a 'poor' final performer, we found it justified to divide the participants' groups into two subgroups: those having correctly answered more and those having correctly answered less than 60% of the final set of 20 questions (see Figure 2: $\geq$60% and $\leq$50%). The GLM analysis of the complete design was then repeated with this additional factor: Performance group. It resulted in the following design: Performance group (good, poor: between subjects) $\times$ Visual condition (normal, VIP: between subjects) $\times$ Information type (route, survey: between subjects) $\times$ Question type (route, survey: within subject) $\times$ Exposure (1, 2, 3: within subject).

Of course, the main effect of performance group was highly significant ($F_{(1,47)} = 121.93$; $p < 0.001$; $\eta^2 = 0.722$.). The first-order interactions between performance group and the other independent variables were especially interesting. We found that the difference between 'good' and 'poor' final performers in each vision group was the same ($F_{(1,47)} = 1.60$; n.s.; $\eta^2 = 0.033$). The interactions between Performance group and Question type ($F_{(1,47)} = 8.56$; $p < 0.01$; $\eta^2 = 0.154$), Performance group and Information

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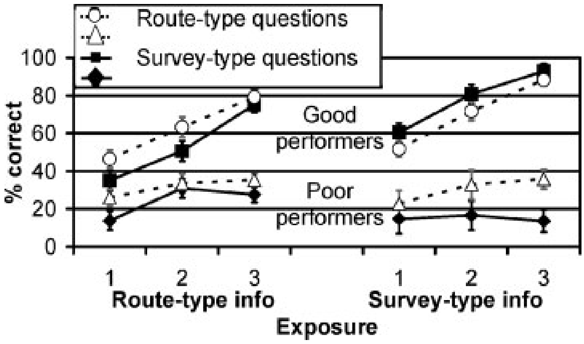

Figure 3. Average proportion of correct answers for each type of information (separate panels), according to Learner's group, Question type and Exposure. The 'good' performers showed a significant increase in performance from Exposure 1 to 3, while the 'poor' performers did not. Error bars represent standard error of means

type ($F_{(1,47)} = 8.09$; $p < 0.01$; $\eta^2 = 0.147$), Performance group and Exposure ($F_{(2,94)} = 17.89$; $p < 0.001$; $\eta^2 = 0.276$) and Performance group, Question type, and Information type ($F_{(1,47)} = 11.63$; $p < 0.001$; $\eta^2 = 0.198$), however, were significant (Figure 3).

As can be seen in the 'good'-performance group, the use of route-type information led to a better performance with the route-type questions and the use of survey-type information to better answers to survey-type questions. These participants also gave better answers to all of the questions after receiving survey-type information and they continued to improve after the third exposure. In contrast, the 'poor' performers correctly answered more route-type questions irrespective of the type of information they received. In addition, there was no difference in performance with regard to the type of information (route or survey) received. Finally, 'poor' performers did not improve as a result of exposure.

Table 2 shows the frequency distribution of 'good' and 'poor' performers across the four categories of participants. The difference between normally sighted individuals and VIPs was marginally significant ($\chi^2 = 3.06$, df $= 1$, $p = 0.080$) and did not differ between Information type ($\chi^2 = 2.29$, df $= 1$, $p = 0.130$).

Additionally, the distribution between 'good' and 'poor' performers was counted for the VIPs, divided between early- and late-impairment onset. This distribution is presented in Table 3. It was not different between those two VIP-groups ($\chi^2 = 2.30$, df $= 1$, n.s.).

Table 2. Frequency distribution of 'good' and 'poor' learners across groups

Group	Type of information	'Good' learners	'Poor' learners
Normally	Route	7	7
Sighted	Survey	12	2
Visually	Route	6	8
Impaired	Survey	6	7

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Table 3. Frequency distribution of 'good' and 'poor' learners for early-impairment onset and late-impairment onset in the VIP-group

	Group	'Good' learners	'Poor' learners
Visually	Early-onset	5	7
Impaired	Late-onset	9	6

DISCUSSION

The present study investigated the generation of a cognitive map of a fictitious environment (a zoo) by normally sighted individuals and VIPs. Information about the zoo was presented auditory by means of either a route-type or a survey-type description. This information was repeated twice. After each information exposure, the participants were asked both route-type and survey-type questions about the relative locations of elements in the zoo.

When survey-type information was given, the normally sighted individuals answered the questions better than the VIPs. There was no difference between the participants, however, when route-type information was given. This partially supports the first hypothesis. We also found that normally sighted individuals who received survey-type information performed better than those who received route-type information. No such difference was found in the VIP group. This partially supports the second hypothesis. These results mean that VIPs are using route-type information as good as survey-type information, whereas normally sighted people do better with survey-type information. Since VIPs receive much, if not all, of their information in ways other than through sight, they must rely more on senses that are much more sequential and egocentric in nature. This appears to result in the relative equality of sequential, route-type information compared to survey-type information in the development of a cognitive map by VIPs. In contrast, normally sighted individuals are used to surveying an area literally 'in one glance' and benefit from survey-type information. The fact that people are able to transform one type of information into another is a replication of older results (e.g. Tversky, 2000). Recently, Noordzij, Zuidhoek, and Postma (2006) showed similar findings in a study using route and survey descriptions for a distance-comparison task. They did not, however, present data on the gradual generation of a cognitive map. Also the results of the VIPs are in line with the findings of Giudice, Bakdash, and Legge (2007) in that they are able to form a cognitive map from a verbal description and that they are able to solve wayfinding issues using this map.

The improvement seen in the normally sighted individuals with regard to learning was much steeper in the first part of the curve. In contrast, the slope of the curve remained the same for the VIPs. VIPs also learned slower than the normally sighted subjects. This supported the third hypothesis. A ceiling effect may have caused the learning curve to level off after the second exposure in normally sighted individuals. The VIPs, in contrast, still showed possibilities for improvement.

One important issue in this study was the difference in performance between Question type with respect to Information type. The route-type information group answered route-type questions better than survey-type questions. This was not the case for the survey-type information group: both types of questions were answered equally well. In addition, there was no clear difference between normally sighted individuals and VIPs with

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respect to correctly answered questions across information type. Therefore, the differentiating hypotheses four and five were not supported.

Closer inspection of the data, however, showed that the group of participants was far from homogenous with regard to performance. It appeared that one subgroup of participants showed marked improvements, while another showed virtually no improvement at all. When these two groups were separated (i.e. a group with a 'good' final performance and a group with a 'poor' final performance), the effects of Information type and Question type were strikingly different. Route-type questions were answered better than survey-type questions in the 'poor'-performance group, irrespective of Information type. Performance, however, did not differ between the two information types nor did it hardly improve from the first to the third exposure. This pattern was completely different in the 'good'-performance group. Route-type questions were answered better when given route-type information and survey-type questions when given survey-type information. Furthermore, survey-type information resulted in a generally better performance than route-type information and performance continued to improve from the first to the third exposure. There were no differences between normally sighted individuals and VIPs.

This means that the differentiating effects of Information type on Question type in hypotheses four and five were only found in those participants who were able to use the information and learn from it. It is, therefore, legitimate to call these groups 'good' learners and 'poor' learners. This finding of 'good' and 'poor' learners may be a peculiarity of the present study. However, recent findings by Noordzij et al. (2006; their Table 2) showed a similar bimodal distribution of errors. Thus, it is more likely that there are 'good' and 'poor' performers/learners with regard to spatial-cognition tasks or even spatial-cognitive abilities. One may speculate what was missing for the 'poor' performers. Perhaps the explicit use of landmarks was the key aspect here, in line with the Siegel & White stance. The participants had to use the mentioned contents of the various areas in the zoo as landmarks (e.g. monkey rock, aquarium, petting zoo, etc.). It may be that the 'good' performers could do this already, but the 'poor' performers were lacking the ability to use these descriptions as landmarks and learn the spatial relations between them. Within the group of VIPs no difference in performance was found for the early- versus the late-impairment onset group. More systematic inquiries are needed.

In general, the aforementioned results are in line with ideas of Millar (1995; see also Taylor & Tversky, 1992, 1996). She proposed that spatial knowledge is composed of multimodal information, which can be retrieved to address both survey-type and route-type issues. Although VIPs may be as adept as normally sighted individuals in forming and using such coding and retrieval, the present study found that VIPs were not as efficient as normally sighted individuals (Ungar, 2000). Efficiency in VIPs may be improved if they are engaged in active and locomotive exploration of the spatial relations between objects and the pathways between them in real environments (Klatzky, Loomis, Beall, Chance, & Golledge, 1998). Another possibility may be to provide them with tactile maps to study environments in advance (Ungar & Blades, 1994, 1996, 1997).

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APPENDIX A

Descriptions of the fictitious Groningen Zoo. Translations are as literal as possible.

Route-type information

You are visiting the zoo in Groningen. The entrance is at the southern end. Go through the gates. The ticket booth is on your right, the restaurant on your left. Walk straight ahead. Coming up on your left is the children's playground. On your right is the petting zoo. Turn right just past the petting zoo. Then, take the first left. You are now on a path with the aquarium on your right and the reptile house on your left. Walk straight ahead to the monkey rock. In front of the monkey rock, turn right and then left. The mountain animals are now on your right. Walk between the mountain animals and the monkey rock. In front of you are the bears. You are now at the far end of the zoo. Turn left in front of the bears. You are now walking around the monkey rock, keeping the bears on your right. Keep following the path. After the bears, the cat-like predators will be on your right. They are also at the far end of the zoo. Birds are now on your left. Turn left and walk around the aviary, keeping it on your left. On your right are the African animals. Keep walking straight ahead. After a while, the reptile house will be on your left and the insect house on your right. In front of you is the children's playground. Turn left and then take the first right. The playground is now on your right. Again, continue to walk straight ahead. The restaurant will be on your right and the ticket booth on your left. You leave the zoo though the entrance/exit.

Survey-type information

The Groningen Zoo is rectangular in shape, divided into four main areas that are lined up after each. From south to north are the facilities area, the children's recreation area, the area with the indoor animal exhibits and the area with the outdoor animal exhibits. Each of these areas is subdivided into smaller parts by footpaths. The zoo's entrance is in the middle at the southern end. The facilities, that is the ticket booth and restaurant, are just inside the gate. The ticket booth is to the east and the restaurant to the west. North of the facilities is the children's recreation area with a petting zoo and a playground. The petting zoo is to the east and the playground to the west. The area containing the indoor animal exhibits is north of the children's recreation area. This area is divided into three parts. To the east is the aquarium and to the west the insect house. The reptile house is in the middle. The area containing the outdoor animal exhibits is in the northern most part of the zoo. It is divided into two rows, the first with four exhibits and the second with two. From east to west in the first row are the mountain animals, the monkey rock, the birds, and finally the African animals. All the way to the north in the upper row, you will find the bears and the cat-like predators. The bears are in the eastern part and the cat-like predators in the western part.

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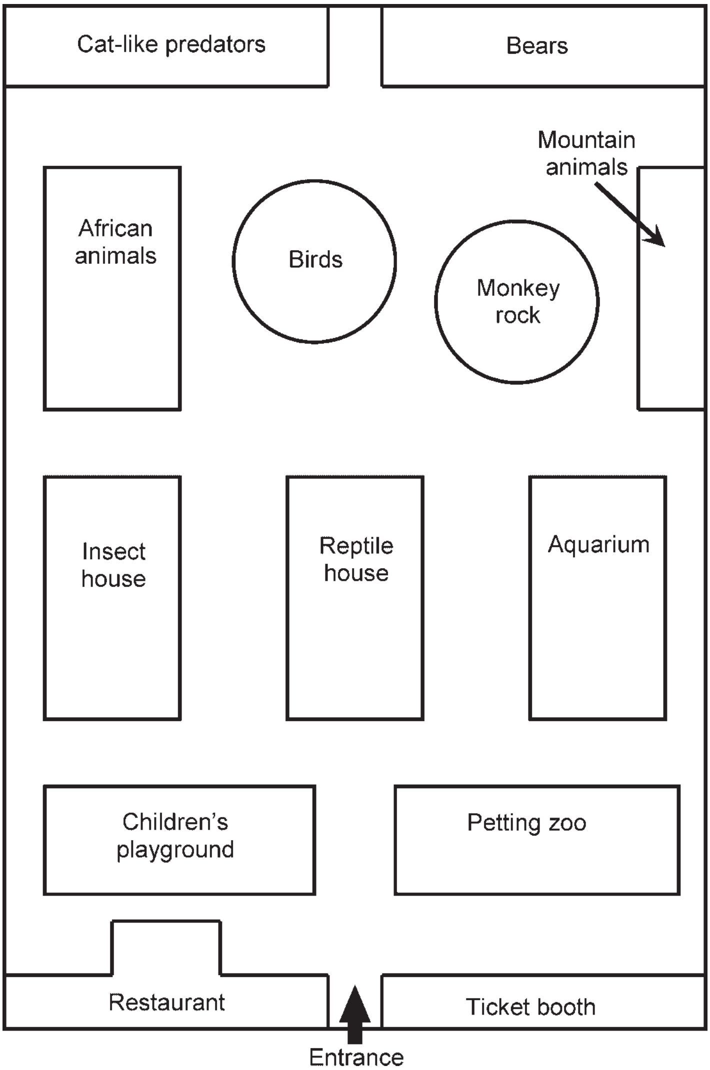
APPENDIX B

Map of the Groningen Zoo.



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