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The Influence of Landmarks and Pre-exposure to a Structural Map During the Process of Spatial Knowledge Acquisition: A Study with Children and Adults in a Virtual Environment

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ABSTRACT

This study investigated the effects of featural information (landmarks) and geometric information (pre-exposure to a structural map) and their possible interaction during the process of spatial knowledge acquisition of 8- and 11-year-old children and adults in a virtual environment. The study confirmed the well-known result of a developmental achievement in spatial cognition from childhood to adulthood. Although landmarks and the pre-exposure to a structural map did not affect the time to learn a specific route, they influenced the use of behavior in spatial learning and eased the acquisition of spatial knowledge measured by a route reversal and map-drawing tasks. Children and adults are able to integrate featural and geometric information in the spatial knowledge acquisition process in an environmental space, but their integration depends on the spatial processing stages that are investigated. Moreover, it was successfully demonstrated that the use of desktop virtual environments seems to be appropriate to investigate the development of spatial cognition.

Keywords: wayfinding performance, wayfinding behavior, spatial knowledge, virtual environments, children

INTRODUCTION

It is the main goal of this study to investigate the influence of landmarks and the pre-exposure to a structural map (a schematic map without objects in it) during the process of spatial knowledge acquisition for adults as well as for

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children in a large-scale or environmental space, i.e., a space which is not perceivable from one single vantage point (see e.g., Canter & Craig, 1981). Both factors should be investigated regarding the different processing stages during spatial knowledge acquisition, from exploring and learning a way in an unknown environment up to the acquisition of spatial knowledge of the respective environment. The existence of these different processing stages is evident from a theoretical (Creem & Proffitt, 1998, 2001; Liben, 1988; 1999) as well as from an experimental point of view (i.e., Jansen-Osmann & Fuchs, 2006; Jansen-Osmann & Wiedenbauer, 2004b).

A quite interesting, but not well-investigated, question is which factors influence which processing stages during spatial knowledge acquisition in children. One reason for this might be the lack of appropriate environments that can be manipulated with relatively little effort (Blades, 1997). This lack was overcome recently with the use of virtual environments in spatial cognition research, which simplifies the investigation of spatial behavior and spatial knowledge due to the possibility to create environments of varying complexity, to measure navigation behavior online, and to control spatial learning parameters (Péruch, Belingrad, & Thinus-Blanc, 2000). In the context of developmental research, virtual environments have been used almost exclusively to *train* children's spatial abilities (Foreman, Stirk, Pohl, Mandelkow, Lehnung, Herzog, & Leplow, 2000). Research investigating more basic developmental aspects of spatial cognition in virtual environments, in fact, was almost absent until very recently (but see Jansen-Osmann & Wiedenbauer, 2004a, 2004b, 2004c; Jansen-Osmann, Schmid, & Heil, 2007b, for exceptions).

Developmental Research on the Influence of Landmarks and Structural Maps

The definitions of "landmarks" itself range from landmarks as reference points that determine the localization of other points in the environment (Sadalla, Burroughs, & Staplin, 1980) to landmarks as prototype locations (Newcombe & Huttenlocher, 2000) to landmarks as visual objects that are perceived and remembered (Presson & Montello, 1988, for an overview, c.f. Sorrows & Hirtle, 1999). During navigation, landmarks are experienced sequentially in space and time and help people to get around (Golledge, 1991). Developmental research has shown that when finding their way in an unfamiliar environment, school aged children rely on the presence of landmarks more than adults do.

Moreover, second graders had even more difficulties than sixth graders when the landmarks were removed (Cohen & Schuepfer, 1980). Advising 6- and 12-year-old children to pay attention to landmarks near the route helps both age groups to retrace the route successfully, but only the older children profited from being told to notice distant landmarks (Cornell, Heth, & Broda, 1989). Concerning the development of spatial knowledge of landmarks, there is ample evidence that children's acquisition of spatial knowledge of large-scale environments becomes more and more accurate over the course of childhood (6 to 12 years). For example, children within this age span improve their memory for landmarks (e.g., Cohen & Schuepfer, 1980).

The long tradition concerning the role of learning a map revealed that a map may be useful to adults as well as to children but it depends on contextual factors as it is for example the complexity of the environment: Studying a map enables people to develop survey knowledge, aids in navigation, and speeds up the acquisition of an experience-based representation of space (Thorndyke & Hayes-Roth, 1982). But when using maps, which are improperly aligned with the real space, participants can quickly loose their way (Presson & Hazelrigg, 1984). Being able to competently read a map constitutes an extended developmental achievement (Presson, 1982, 1987; Landau, 1986; DeLoache, 1987). Nevertheless, Bluestein and Acredolo (1979) showed that most 4- and 5-year-olds and even some 3-year-olds were able to use a map to find a hidden object in a real but small-scale space.

In a study by Uttal and Wellman (1989), 4- to 7-year-old children who learned a map before entering a playhouse composed of six adjoining rooms learned a route through it more quickly than children without map exposure. They also performed significantly better than the no-map children in the very first navigation trial. This indicates that children's map reading abilities are more substantial than previously assumed. Sandberg and Huttenlocher (2001) showed that 6-year-olds were able to plan their route to endpoints designated exclusively on the maps learned before. Taken together, information provided by a map can be used by adults as well as by children. Nothing is known about the use of structural maps that can be regarded as one kind of schematic maps, where shapes and structures are simplified.

Theoretical Approach to the Developmental Influence of Landmarks and Structural Maps

Presently there is no theoretical approach to the developmental influence of landmarks and a structural map and its possible interaction. What we do have is quite a lot of research concerning the integration of featural, as it might be the presence of landmarks, and geometric information, as for example the structure of the room, during reorientation in a vista space (see, for an overview, Cheng & Newcombe, 2005). Investigations carried out in a vista-space with younger children (around 2 to 4 years) revealed the importance of the geometrical properties of the environment on reorientation (Hermer & Spelke, 1996; Gouteux & Spelke, 2001). Learmonth, Newcombe, and Huttenlocher (2001) pointed out that the size of the room, however, was critical in obtaining the results found by Hermer and Spelke (1996). That means that concerning the existing data on the integration of featural and geometric information the likelihood of using both kinds of information seems to depend on contextual factors as for the example the room size (see Newcombe, 2005). Today there is a claim of more studies:

> ... exploring the room-size effect, as well as directly manipulating the salience, certainty, variability, and usefulness of featural and geometric information, hold the promise of specifying how the geometric and featural information are used and combined in different circumstances, and the developmental mechanism that underlie behavioral changes in feature use in enclosed geometric spaces as well as in more naturalistic ones. (Newcombe & Huttenlocher, 2006, p. 749)

For that it is unknown, if featural (landmark) information and geometric information, as it might be knowledge that is provided by learning a structural map of the environment, helps to ameliorate the different processing stages in the spatial knowledge acquisition process.

OVERVIEW OF THIS STUDY

The primary objective of this study was to investigate the different processing stages in the acquisition of spatial knowledge of children and adults depending on the influence featural information (landmarks) and geometric information (structural map). In a learning phase, spatial learning was operationalized as the time needed to learn a specific route and measured by the number of trials to reach a learning criterion. Spatial behavior was operationalized as strategic behaviour (see Jansen-Osmann & Wiedenbauer, 2004b) and measured by the number of chosen turns which (a) lie in the direction of the start position and (b) are chosen back to the start position. In a test phase, spatial knowledge acquisition was retrieved by a route reversal and two map tasks. Contrary to other studies, participants were allowed to explore the desktop-virtual environment in a self-determined way. Although this has the disadvantage that exposure to the environment cannot be strictly controlled, this method seems to be closer to reality and especially helpful for children when acquiring their knowledge (Feldman & Acredolo, 1979).

We hypothesized that the featural (landmarks) and the geometric information (learning of a *structural* map) improves the different processing stages of spatial knowledge in adults and children. It was decided to investigate the effects of both factors, the structural map and the landmarks, in one single study to see if their combination improves the spatial knowledge acquisition process more than only one of the two factors does. Finally, we assumed a developmental achievement from childhood to adulthood concerning spatial cognition in general. School-aged children were chosen because previous studies showed a related spatial cognitive developmental improvement between second and sixth graders over and above the general cognitive advancement found at that age (Allen & Ondracek, 1995).

METHOD

Participants

Eighty children from two grade levels (second and sixth) and 40 adults participated in this study. The mean age of the second graders was 7.53 years ($SD = 0.51$), of the sixth graders 11.53 years ($SD = 0.81$), and the adults' mean age was 24.25 years ($SD = 3.3$). There were 20 females and 20 males in each age group. Children were recruited through advertisements in local newspapers, adults were students of the Heinrich-Heine-University of Düesseldorf. Prior to testing, all parents gave their informed written consent for participation in the study. The local ethics committee approved the experimental procedure.

Materials

The experiment was conducted in a virtual world using the software 3D GameStudio A5. The virtual reality simulated an outdoor environment consisting of grassland and some trees. Trees were included to make the virtual environment more realistic, but in order to prevent the trees being used for orientation, they were positioned randomly in each trial. Participants were told beforehand that the position of the trees would vary within the experiment, and could not be used for orientation. Because of the high number of trees this was understandable even for the younger children. The structure of the maze was symmetrical and regular in order to permit that it was easily learned with the aid of a map.

The boundary of the maze consisted of a brick wall. Within the wall, routes were built by 16 squares that were bordered by brown coloured fences. As can be seen in the overview of the maze (see Figure 1), routes branched off at an angle of either 0° (straight ahead), 45°, 90°, 135°, or 180° (turn around) at intersections. The intersections along the wall differed from those within the maze in terms of the actual number of route choices and by the angles. The starting position (the lower leftmost corner, see Figure 1), which was always on the same place and the same for all participants, was marked by a sign. It was identifiable during each walk through the virtual world, and it changed its alignment according to the participant's viewpoint. When built to scale, the maze would be about 100 by 100 meters. Two versions of the maze existed: one with and another one without landmarks. Fifteen different virtual toy animals (e.g., a rabbit, a tiger, a dog), which were comparable in size, color, and brightness served as landmarks and were positioned at intersections. Figure 2a shows a snap shot into the maze without landmarks; Figure 2b into the maze with landmarks.

The virtual world was projected onto a 17-inch flat-screen monitor. The distance between monitor and participant was 0.5 meters. Participants

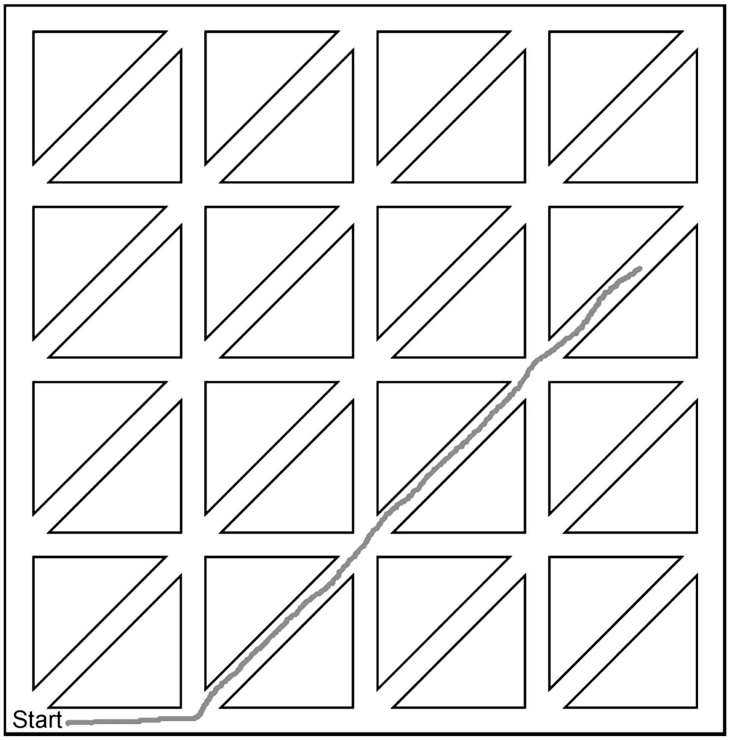

Figure 1. Overview/structural map of the maze including the correct route from the starting point to the target figure (recorded during a single trial of one participant).

explored the simulated maze by using a joystick. There were no detection-collision algorithms. A map of the maze's geometrical structure (bird's-eye view) was created. This structural map did not contain landmarks or the target point (see Figure 1); the start position was marked, however, so that the map could be properly aligned.

Procedure

Individual test sessions lasted about 30 minutes and took place in a laboratory at the Heinrich-Heine-University of Duesseldorf. First, children and adults completed a questionnaire about their computer-experience. They were asked how often they play computer games (in hours per weeks), which games they play, and which input device they use for playing. Younger children were helped in answering the question by explaining the time in more detail and helping them to recall the computer games. Second, to become familiar with the joysticks rotation and translation, all participants were navigating through

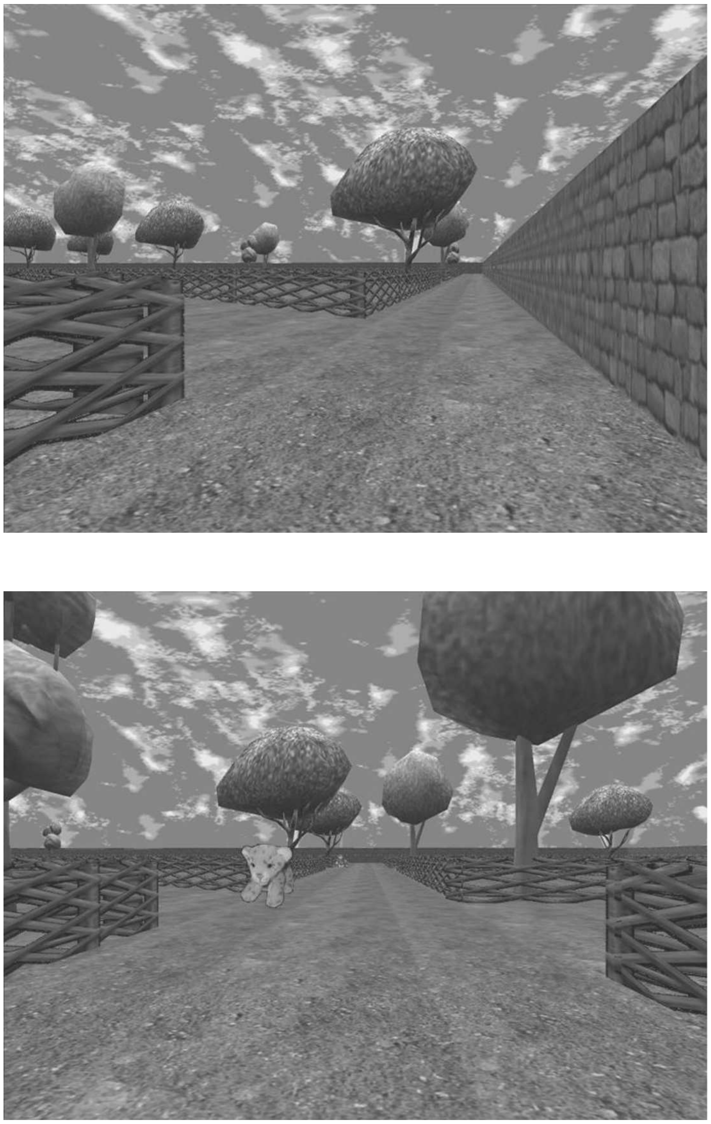

Figure 2. Snap shots into the virtual environment without landmarks (Figure 2a) and with landmarks (Figure 2b).

another—non-experimental—maze until they felt confident of handling the joystick. In this "learning maze" as well as in the following experimental maze the walking speed approximated a real-life walking speed (about 3 km/h). Participants from each age group were randomly assigned to one of the four conditions resulting from factorial combination of the type of virtual mazes (with vs. without landmarks) and the condition of learning the map before exploring the maze (yes vs. no). The structural map was presented for one minute before the learning phase.

1. *Learning phase.* Participants were instructed to explore the maze and to find a gold treasure chest, which served as the target figure. This exploration phase was not predetermined but lasted around three minutes for every participant. After exploration participants' spatial learning task was to find a specific route from the start position to the target figure in two errorless consecutive trials (learning criterion). Each walk from the start position to the target was defined as one trial. They were given the following instruction: "Now, it is your turn to find the correct route from the start to the treasure chest. The correct route is the one which is the shortest and has only one turn. All other routes are not correct. You have to find this route in two consecutive trials. If you choose a wrong turn you can go further on until you have found the treasure chest but this trial will not be a correct one." The correct route was chosen when participants walked along the dexter outside wall and turned left (at an angle of 45°) at the first intersection. All other possible routes had more turns and were not correct in the sense of the learning criterion (see Figure 1). One particular route was chosen because previous studies had shown that this was an understandable learning criterion even for the younger children (Jansen-Osmann & Wiedenbauer, 2004b; Jansen-Osmann, Schmid, & Heil, 2007a). Spatial learning was registered by (a) the number of trials needed to reach the learning criterion, and spatial behavior by (b) the relative frequency of decision points at which the participants chose angles in accordance with the direction of the target and (c) how often participants went back to the start of the maze based on the assumption that the latter strategy is used for re-orientation.

All variables were computed for the last trial in the learning phase before reaching the criterion. The last trial was considered especially important because it was assumed that all participants had formed a well-pronounced knowledge of finding their way by then. Two participants from each age group were excluded from the analysis because they need no learning trials, that means they only need two consecutive errorless trials. Thus, spatial learning was analyzed of 114 participants.

2. *Test phase.* After the learning phase participants completed the following spatial knowledge tasks.

Route Reversal Task. Participants were required to find their way from the target figure back to the start position using the same route. Their viewpoint was set behind the target figure looking in the direction of the start position, so that they were attempting the route reversal by starting out in the correct direction. The following instruction was given: "Now, you stand behind the treasure chest, looking in the direction of the start position, which is of course not visible from this point. Please find the correct route, you just learned, to the start position. Now, you only have to do this once." The distance traveled was measured.

Map Tasks. First, all participants were asked to draw an overview of the maze. Second, they were given a ready-made overview and were asked to mark the position of the target figure and the correct route to it. Map tasks were not time-limited. Dependent variables of the map tasks used were (a) the accuracy of the drawn map and (b) the linear distance from the marked to the correct position of the target-figure in the overview. Participants' drawings of the maze were coded by two raters. Discrepancies were solved by discussion. The map correctness score indicates how many of the following characteristics were observable in the drawing: outer boundary of the maze is rectangular, rectangular structure of junctions within the maze, structure of the maze is symmetrical, intersections at routes branch off diagonally (at an angle of 45°), diagonal routes branch off only up to the right and down to the left, respectively (not up to the left and down to the right, respectively), drawing includes the correct section from start to the target, the structure of intersections in the middle of the maze is drawn correctly (i.e., two routes that cross rectangular and another route that branches off diagonally up to the right and down to the left), and similar lengths of single route segments.

Furthermore, one point was assigned if the number of rectangular structures within the maze and number of intersections differed no more than 25% from the correct number. Finally, another point was assigned if the overview drawn was comprehensible. The map correctness score was the sum of all elements described, thus the maximum score that could be obtained was 11. All these variables were chosen because they represent the essential features of the maze. Cronbach's alpha was .84, which showed a high internal consistency of this coding scheme. Regarding the linear distance measure, a good performance was indicated by a small linear distance from the correct to the marked position of the target.

Each participant's position was recorded 6 times per second while they moved through the virtual maze and their paths taken in each trial were plotted onto an overview. This allowed for the counting of turns made, the registration of behavior at decision points, and the measurement of distance walked in units of the software.

Experimental Design

The factors *age group* (second graders, sixth graders, and adults), *landmarks* (maze with vs. without landmarks) and *learning of a map* (learning vs. without learning) were varied between subjects. Dependent variables in the learning phase were the number of learning trials, the choice of a correct direction and the orientation on the start point. Dependent variables in the test phase were the distance walked, the map correctness score and the linear distance to the correct map position.

RESULTS

There were no gender differences present in any measurement described above which is in accordance to our former study (Jansen-Osmann & Wiedenbauer, 2004c).

Computer-experience

An univariate analysis of variance revealed a significant difference in computer-experience between *age groups*, $F(2, 117) = 8.53$, $p < .001$. A Bonferroni adjusted post-hoc comparison revealed that older children played computer-games more often (hours per week) ($\overline{x} = 4.13$, $s_{\overline{x}} = 0.81$) than younger ones ($\overline{x} = 2.13$, $s_{\overline{x}} = 0.37$) and adults ($\overline{x} = .98$, $s_{\overline{x}} = 0.32$). There was no difference concerning the use of the joystick between age groups, $F(2, 117) = .8$. Most importantly, there were no significant correlations between the computer experience and the spatial cognition measurements reported here.

1. *Learning phase.*

Spatial Learning Measured by the Number of Learning Trials. The mean number of trials needed to reach the learning criterion for all three age groups is described in Table 1. The univariate analysis of variance revealed neither a statistical effect of *age group*, $F(2, 108) = 1.89$, n.s., nor of *landmarks*, $F(1, 108) = 2.63$, n.s., or *learning of a map*, $F(1, 108) = .15$, n.s. Moreover, there were no interactions between these three factors.

Table 1
Mean number of trials to reach the learning criterion (standard errors in parenthesis) for different age groups depending on landmarks and learning of a map

		Age group		
Landmarks	Learning of a map	Second graders	Sixth graders	Adults
With landmarks	With map	2.4 (0.4)	2.4 (0.58)	2.0 (0.42)
	Without map	1.8 (0.33)	3.5 (0.73)	2.3 (0.37)
Without landmarks	With map	3.2 (0.39)	3.2 (0.59)	2.3 (0.3)
	Without map	2.9 (0.57)	3.0 (0.73)	2.7 (0.54)

Spatial Behavior Measured by the Choice of the Target Direction. Regarding the choice of a turn that lies in the direction of the target figure, a significant influence of the factor *age group*, $F(2, 102) = 4.56$, $p < .05$, was found. Bonferroni adjusted post-hoc test comparisons revealed that the relative frequency of choosing a turnoff in the direction of the target differed between adults ($\overline{x} = 0.67$, $s_{\overline{x}} = 0.03$) and younger children ($\overline{x} = 0.51$, $s_{\overline{x}} = 0.03$), but there was no difference between older children ($\overline{x} = 0.57$, $s_{\overline{x}} = 0.04$) and the other age groups.

Spatial Behavior Measured by the Orientation at the Start Point. Concerning the strategy of turning back to the start, an univariate analysis of variance revealed a significant influence of the factor *age group*, $F(2, 102) = 14.21$, $p < .001$, and a significant interaction between the factors *landmarks* and *learning of a map*, $F(1, 102) = 5.16$, $p < .05$. Bonferroni post-hoc tests revealed that younger children ($\overline{x} = 0.71$, $s_{\overline{x}} = 0.11$) went back to start more often than the older ones ($\overline{x} = 0.42$, $s_{\overline{x}} = 0.09$) and the adults ($\overline{x} = 0.08$, $s_{\overline{x}} = 0.01$). As can be seen in Figure 3, the participants who were not shown the map of the maze in advance went back to the start more often if they had explored the maze without landmarks ($\overline{x} = 0.5$, $s_{\overline{x}} = 0.1$) than the maze with landmarks ($\overline{x} = 0.22$, $s_{\overline{x}} = 0.1$).

2. *Test phase.*

Spatial Knowledge Measured by the Distance Walked in a Route-reversal Task. An univariate analysis of variance revealed statistical significant main

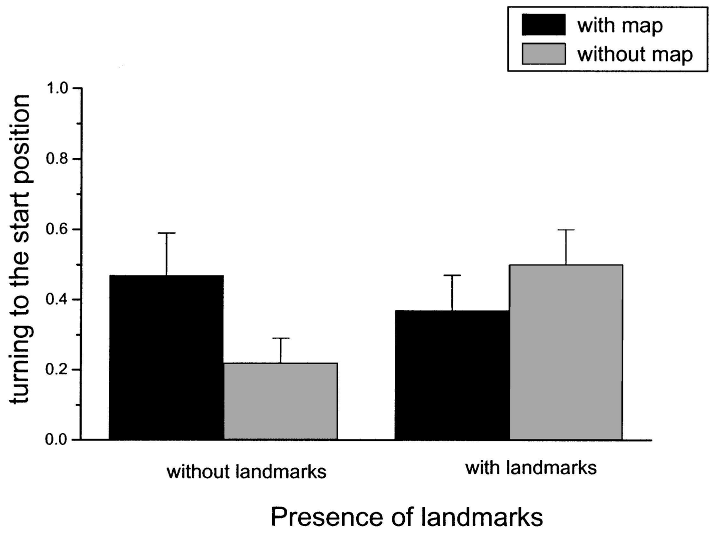

Figure 3. Frequency of going back to the start depending on *type of maze* and *learning of a map* (error bars indicate standard errors).

effects of the factors *age group*, $F(2, 108) = 3.21$, $p < .05$, and *landmark*, $F(1, 108) = 4.78$, $p < .05$, and a marginally statistical significant effect of the factor *learning a map*, $F(1, 108) = 3.80$, $p = .054$.

Adults and older children walked less distance from the goal back to the start (length of correct route back being 12200 units of the software) than younger children (adults $\overline{x} = 12498$, $s_{\overline{x}} = 22.56$; 6th graders $\overline{x} = 13252$, $s_{\overline{x}} = 550.73$; 2nd graders $\overline{x} = 14974$, $s_{\overline{x}} = 1189$). Overall, participants walked shorter routes in the maze with landmarks ($\overline{x} = 12681$, $s_{\overline{x}} = 82.59$) than in the one without landmarks ($\overline{x} = 14469$, $s_{\overline{x}} = 868.18$). Those participants, who had learned a map before, tended to walk shorter distances ($\overline{x} = 12777$, $s_{\overline{x}} = 142.2$) than those who had not learned a map ($\overline{x} = 14373$, $s_{\overline{x}} = 863.82$).

Spatial Knowledge Measured by the Correctness of the Drawn Map. The univariate analysis of variance revealed a statistically significant influence of the factors *age group*, $F(2, 108) = 45.93$, $p < .001$ and *learning of a map*, $F(1, 108) = 95.11$, $p < .001$, and an interaction between these two factors, $F(2, 108) = 8.35$, $p < .001$. The correctness-score was $\overline{x} = 8.1$ ($s_{\overline{x}} = 0.47$) for the adults, $\overline{x} = 6.7$ ($s_{\overline{x}} = 0.4$) for the 6th graders and $\overline{x} = 4.12$ ($s_{\overline{x}} = 0.35$) for the 2nd graders. Bonferroni-adjusted post-hoc tests revealed that all means reported here differed significantly. Those participants who had learned the map before scored higher ($\overline{x} = 7.89$, $s_{\overline{x}} = 0.4$) than those who had not ($\overline{x} = 4.63$, $s_{\overline{x}} = 0.25$). This especially applied to the adults (see Figure 4).

Spatial Knowledge Measured by the Linear Distance from the Marked to the Correct Position of the Target. The univariate analysis of variance performed on the linear distance between the marked and the correct position of the target revealed a statistically significant effect of the factor *age group*, $F(2, 108) = 12.31$, $p < .001$. Bonferroni adjusted post-hoc testing revealed that this distance was significantly shorter for adults ($\overline{x} = 3.45$, $s_{\overline{x}} = 0.31$) than for the older ($\overline{x} = 6.3$, $s_{\overline{x}} = 0.3$) and the younger children ($\overline{x} = 6.79$, $s_{\overline{x}} = 0.21$).

DISCUSSION

First, our results show that featural (landmarks) and geometric information (the learning of a structural map) did improve most of the spatial cognition measurements but did not affect spatial learning as it is the trials to reach the learning criterion. Whereas both the existence of featural and geometric information eased performance in the route reversal task, only the geometric information did ameliorate the drawing of the survey map. Looking at the effect of the presence of landmarks and the pre-exposure to a structural

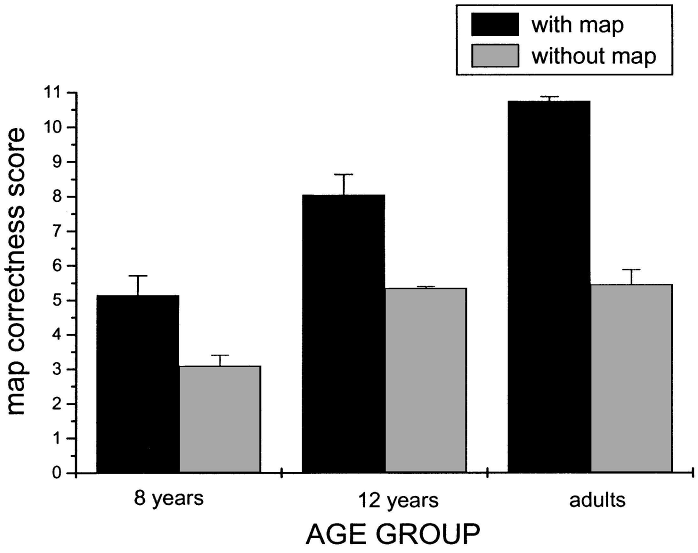

Figure 4. Mean correctness score of drawing a map depending on *age group* and *learning of a map* (error bars indicate standard errors)

map, there was only one interaction present between these two factors: When participants did not learn a map, they went more often to the start when landmarks were present. The presence of both factors did not ameliorate the spatial knowledge acquisition more than the presence of only one factor. This is in accordance with a study of Parush and Berman (2004) demonstrating in a virtual environment situation that relative direction pointing in an orientation task was better for those who learned with a map without landmarks than with landmarks.

Overall, our results show that different factors influence different aspects of spatial cognition in an environmental space. This accounts for a dissociation between spatial learning and spatial knowledge and is in accordance with studies of Creem and Proffitt (1998, 2001). They assumed that there are two different systems for processing spatial information: a perception-action system where spatial information is provided for guided action (spatial learning) and a cognitive system, which contains internal representations (spatial knowledge). The dissociation is also substantiated by our own earlier work (for example, Jansen-Osmann & Wiedenbauer, 2004c; Jansen-Osmann & Fuchs, 2006).

The influence of the factors "landmarks" and "learning of a map" are: The presence of landmarks had an effect on the route reversal task. All participants found their way back more easily when they had learned the maze with landmarks. This is in accordance with other studies that emphasized the importance of landmarks on spatial knowledge tasks for both adults and children (e.g., Cohen & Schuepfer, 1980; Cornell, Heth, & Broda, 1989; Cornell, Heth, & Rowat, 1992). At first glance, the fact that landmarks did not decrease number of learning trials may appear astonishing. Parush and Berman (2004) could show a similar effect: Initial navigation with landmarks appeared to be harder than without landmarks, but this difference became insignificant at the end of the learning phase. Another possibility is that this result might be due to the specific structure of the maze used in this study: the symmetric geometry of the virtual environment might have facilitated spatial learning even if no landmarks were present. This was investigated in another study of our working group where we could show that the youngest children need less learning trials in a symmetric compared to asymmetric maze without landmarks (Jansen-Osmann, Schmid, & Heil, 2007a). There was no such an influence within older children and adults. Further studies have to follow to investigate the influence of the environmental structure in more detail.

Furthermore, the results presented here substantiate the facilitating influence of learning a structural map, that means learning something of the geometric information of the environment. The available empirical evidence suggests that any kind of learning of an unknown environment by means of a map, even a rudimentary one, eases the acquisition of spatial knowledge in some way. Even a schematic map helps to ameliorate spatial cognition, because geometric information is provided in it. Surely, this result has to be confirmed in further studies, because of the regular structure of the environment used here that eased the schematization.

The question arises how geometric information in an environmental space is used when the environment is less regular as the one in this study. It is the question how valide is the geometric information of an environment as a cue for spatial learning and spatial knowledge acquisition in a more naturalistic setting. Furthermore, cultural aspects might be integrated at this point: The study was conducted in Germany where grid patterns are known but are not as common as in the United States. Davies and Pederson (2001) showed that residents in the United Kingdom, where grid environmental patterns are also rare, put less emphasis on the central grid in their sketch maps than residents of a U.S. city. For that a cross-cultural comparison study concerning the influence of the environmental structure seems to be quite interesting.

Regarding the more general assumption of a developmental achievement from childhood to adulthood we provided evidence that spatial learning and spatial knowledge do indeed improve. Younger children walked longer distances than older children and adults when learning a specific way to a target. Moreover, younger children's spatial knowledge was less pronounced. This is in accordance with the work of Cornell and colleagues (Cornell, Heth, & Broda, 1989; Cornell, Heth, & Rowat, 1992), who also found age differences in a route-reversal task. In the study presented here, younger and older children had more difficulties than adults regarding the acquisition of spatial knowledge, which was investigated by analyzing the correctness of the drawn map and the linear distance from the marked to the correct position of the target figure in a ready-made overview. The children did not profit from learning a map as much as adults did, which was shown by the drawings of the maze sketch map. This means that the geometric information given while learning a structural map is not that helpful to younger children than to older ones or adults. Furthermore, our results show a different spatial behavior of younger children than older ones. They had more difficulties to choose a turn that lies in the direction of the target.

In addition, they re-orientated themselves more often at the start position, which is in accordance with the behavior found in our earlier developmental studies (Jansen-Osmann & Wiedenbauer, 2004b). We might conclude that the difference found in the acquisition of spatial knowledge was not due to the specific behavior in the learning phase here; rather it was based on cognitive development. This would be in accordance with a study of Allen and Ondracek (1995), which showed that the developmental improvement in children's performance on tasks requiring the acquisition of spatial knowledge was indeed related to age-sensitive cognitive abilities.

One important point still has to be mentioned: the results presented here are in contrast to the study of Cohen and Schuepfer (1980), which showed that the influence of landmarks seemed to be larger for younger children than both for older ones and for adults. This discrepancy might be due to differences between the two studies such as the specific kind of task. The exact reasons should be investigated in detail in future studies. Nevertheless, the discrepancy suggests that the context of the spatial development analysis has to be integrated further in any theoretical developmental implication. For that, the perspective has to change from a cognitive-constructive perspective to a contextual one, which assumes that spatial knowledge is more than thinking about the environment; "... it also involves acting-wayfinding, exploration, orientation-activities that enable the individual to function adaptively in the environment" (Heft & Wohlwill, 1987, p. 199).

The study presented here was conducted in a virtual environment. To be fair, the robustness of findings and the generalization using the desktop system has to be discussed. The advantages and disadvantages are described elsewhere (i.e., Jansen-Osmann, 2007; Ruddle & Lessels, 2006). Studies are needed that compare directly the knowledge acquisition in real and virtual environments under a developmental perspective. There is evidence from studies with adults that at least the most important properties of the spatial representations that underlie spatial behavior can indeed be analyzed in both real and virtual environments (Loomis, Blascovich, & Beall, 1999), and that testing in virtual and real environments leads to similar results (Tlauka, 2007). With the exception of two studies (Laurance, Learmonth, Nadel, & Jacobs, 2003; Plumert, Kearney, & Cremer, 2004) this comparison, however, is still missing in studies with children. Interestingly, Laurance et al. showed that children used the virtual space as if it was real space.

CONCLUSION

This study gives a hint that adults and children at school age use featural and geometric information while acquiring spatial knowledge of an unknown environment. The use of this kind of information seems to depend for example on their cue validity, as Newcombe (2005) already stated for the reorientation tasks in a vista-space.

AUTHOR NOTES

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