Journal of Environmental Psychology (1997) **17**, 215–228
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0272-4944/97/030215+14$25·00/0/

Journal of ENVIRONMENTAL PSYCHOLOGY

GENDER-RELATED STRATEGIES IN ENVIRONMENTAL DEVELOPMENT: EFFECTS OF ANXIETY ON WAYFINDING IN AND REPRESENTATION OF A THREE-DIMENSIONAL MAZE

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Abstract

Gender differences in wayfinding behaviour in a complex walk-through maze and in representation of the maze were examined, as well as the relationships between anxiety, wayfinding behaviour and maze representation. Participants were 45 girls and 54 boys, aged 10 to 17, who explored the maze in five separate start-to-goal runs. After the fourth run the participants were asked to represent the maze in drawing or writing. Anxiety was assessed prior to the task and task-specific fear was assessed during the task. Girls scored higher on anxiety and fear scales than boys. Girls moved through the maze more slowly than boys and mentioned proportionally more landmarks and fewer directions in maze representation. No sex differences were found in the total number of elements that were recalled in maze representation. In general, subjects who scored higher on the anxiety and fear scales traversed the maze more slowly and tended (although not significant) to recall a higher proportion of landmarks and a lower proportion of directions than less anxious ones. In conclusion, gender differences in environmental strategies can be explained, to a certain extent, as a result of different levels of anxiety and fear of girls and boys.

Introduction

In this study, gender-related environmental strategies in wayfinding and representation of the acquired environmental knowledge are examined against the background of an interactive theory in environmental cognition research. Recent literature has pointed out the need for a new multidisciplinary approach in order to provide a theoretical framework in which environmental–behaviour interaction can be explained to a more complete whole and individual differences can be discussed embedded in their environmental, methodological, societal and cultural context (Kitchin, 1996*b*). The basic argumentation and the supporting findings for this new approach are summarized hereafter. For a detailed explanation of environmental theories see Golledge (1987), Blades (1991), and Kitchin (1996*b*).

The early theories in environmental cognition research (e.g. Piaget & Inhelder, 1967; Hart & Moore, 1973) supported the view that the development of a subject's spatial knowledge progresses through a series of stages. In the egocentric stage, spatial knowledge is first related to the self. In the second allocentric stage, spatial relationships are acquired independently of the self and related to external spatial properties (topological and/or directional relations between locations). Finally, in the geocentric stage, spatial knowledge is related to abstract coordinates such as Euclidean properties (metric distances, angles and cardinal directions). Considering this theoretical framework Siegel and White (1975) proposed that landmark knowledge precedes route knowledge and both precede survey knowledge in environmental development as well as in microgenetic environmental learning processes. Although the results of some studies supported this argumentation (see Cohen & Schuepfer, 1980, for developmental processes; and Evans, 1980; Evans *et al*., 1981, for every-day learning processes) other studies revealed that the acquisition of environmental knowledge does not always follow this sequence of stages. Allen (1988) confirmed accurate route-learning without available landmarks for adults. Garling *et al*. (1982) found that subjects remembered locations of landmarks in an unfamiliar part of a Swedish town before they learned the system of paths accurately and these results corresponded with the findings from Evans *et al*. (1981). However, in another study of Garling *et al*. (1981) memory of paths was acquired prior to memory of the locations of landmarks. Even survey knowledge can be acquired during the initial period of an environmental learning task (Holding & Holding, 1989) or after brief experience (Montello & Pick, 1993). In a recent review Blades (1991) has pointed out that even young children are already able to remember routes and walk them again after minimal experience and that landmark information is not always necessary for successful wayfinding. The author supports the idea that the ability to use landmarks and routes to structure the environment is probably acquired simultaneously at an early stage of development rather than in successive processes and that landmark and route knowledge then develop conjointly to a progressively global (survey-like) environmental knowledge. Kitchin (1996*b*) pointed out that one serious restriction of the earlier theories on environmental cognition was that they regarded the subject as a passive receiver of environmental information. The author presents a new theoretical framework in which he emphasises the subject's *interactive* behaviour within the real world, involving environmental and social interaction, and his or her active role in choice of a particular environmental strategy. Within his conceptual schema, environmental learning and the acquisition of environmental knowledge are discussed with respect to a dynamic memory system that enables the individual to discriminate, learn and store new knowledge guided by previous information that is stored in long-term memory. In relation to the perceptual structures an emotional state filter works as a mediator of decision-making processes. In other words, a subject's decision to rely on particular spatial properties (e.g. directions) instead of other cues (e.g. landmarks) in wayfinding as well as in environmental representation (e.g. 'first go right, then left, then straight ahead and you will reach the campus' instead of 'go to the park, then left and after a great building you will reach the campus') is influenced by his or her prior experience and its emotional context. This interactive approach enables research not only to analyse individual differences in environmental learning and development but also to examine the effects of external and internal mediators on these processes. A number of recent reviews enumerate an extended range of such mediators: *task-specific influences* like artificial versus real world, small-scale versus large-scale or constant versus contingent environment (see Newcombe, 1981; Cohen, 1985; Golledge, 1987), *methodological influences* that derive from different techniques in measuring environmental cognition as building models, drawing maps, describing routes, estimating distance or direction and others (see Siegel, 1981; Bryant, 1984; Montello, 1991; Kitchin, 1996*a*), and *effects of early experience and social mediation* in a particular cultural context (see Blades, 1991; Matthews, 1992). The current study centres on two aspects of this multiple approach: (1) the interaction between wayfinding behaviour and the acquisition of environmental knowledge, and (2) the effect of anxiety and task-specific fear on wayfinding behaviour and environmental representation.

One particular focus was laid on *gender-related strategies* in environmental learning and development. Recent studies have pointed out some evidence that females prefer to use landmarks when they externalize environmental knowledge while males give greater emphasis to the Euclidean properties with reference to directions and metric distances. In a study by McGuiness and Sparks (1983) females spontaneously drew more landmarks and fewer routes in a map of their campus area than males. Galea and Kimura (1993) found that females performed better in landmark recall, whereas males performed better in route-learning following a mapping task. Males used a higher amount of additional distances in direction-giving from a novel map than females who used additional landmarks to a greater extent (Miller & Santoni, 1986). In a similar study by Ward *et al*. (1986) males reported more metric distances and cardinal directions in route instructions than females but there was no gender difference in the amount of landmarks. Some studies revealed a male advantage in directional accuracy (Miller & Santoni, 1986; Holding & Holding, 1989; Galea & Kimura, 1993), whereas others did not find gender differences in pointing accuracy to landmarks (Sadalla & Montello, 1989; Golledge *et al*., 1993; Montello & Pick, 1993).

Some interesting aspects arise from additional results in the studies mentioned above. In the study of McGuiness and Sparks (1983) the gender differences in spontaneous route recall favouring males diminished after the participants had been instructed to draw routes between three particular buildings on the campus area. Gender differences in the number of cardinal directions mentioned in route instructions (Ward *et al*., 1986) also diminished after the participants had been prompted to use cardinal directions. The authors assumed that gender differences in environmental knowledge derive to a greater extent from different preferences in the use of environmental strategies than from a difference in ability. This assumption is supported by results from Lawton (1994, 1996). She assessed self-estimated strategies in environmental behaviour as either orientation strategy (reference to cardinal directions and metric distances) or route strategy (reliance on relational directions and landmarks). Males reported higher use of the orientation strategy and females reported higher use of the route strategy. In a recent study (Schmitz, 1997) gender differences appeared even when route strategy was considered separately. Females recalled a higher amount of landmarks in representations of a previously unknown building that had been explored in a wayfinding task, whereas males recalled a higher proportion of relational directions.

The interactive approach leads to another set of questions: When do gender-related preferences in the use of different environmental strategies develop and how are they affected by external and internal mediators? Gender differences first occur from the age of 8 onwards. In the studies of Matthews (1986, 1987*a*) boys' maps of their home area were more detailed (number of elements), more accurate (positioning), more extended in dimension, and they involved a higher degree of complexity than that of girls of a similar age. The importance of early experience for environmental development was first pointed out by Hart (1979) who showed that the accuracy and extent of children's maps was highly correlated with the limit of their home range activities. Matthews (1986, 1987*a*) and Herman *et al*. (1987*a*) assessed a more extended activity range in the familiar neighbourhood for boys compared to girls, and in Matthew's studies these gender differences could be related to gender differences in map accuracy. Additionally, Matthews (1987*b*) reported that boys drew more routes in maps of a previously unknown environment than girls who recalled a higher proportion of landmarks.

Emotional factors have to be considered as another mediator in environmental learning and development (Russel & Snodgrass, 1987; Anooshian & Siegel, 1985; Kuller, 1991; Amedeo, 1993; Kitchin, 1996*b*). However, until today, only a few studies have centred on the analysis of interaction between emotional factors and the acquisition of environmental knowledge. Herman *et al*. (1987*b*) found that college newcomers underestimated distances to locations associated with positive affect to a greater extent than distances to locations associated with negative affect. Kozlowski and Bryant (1977) found negative interrelations between subjects' self-estimated spatial anxiety (worry about becoming lost), their sense of direction and pointing accuracy. As gender differences have been found in so far as females report higher ratings in spatial anxiety (Bryant, 1982; Lawton, 1994, 1996) and stronger feelings of disorientation (LaGrone, 1969) it may be proposed that these differences lead to gender differences in environmental knowledge as well. Lawton's studies (1994, 1996) showed that spatial anxiety correlated negatively with the use of the orientation strategy (used more frequently by males than by females) and with performance in either mental rotation or spatial perception tasks (in which males performed better than females). In the study of Schmitz (1997), higher spatial anxiety predicted a higher proportion of landmarks in the representation of environmental knowledge of females.

Against this background, an interactive model (Figure 1) proposes the relationship between experience, affective disposition, and strategies in wayfinding and environmental knowledge as follows: a child's previous experience gathered from interaction with the environment (e.g. activity range in the neighbourhood) prepares the ground for a set of wayfinding strategies to which the individual may refer in interaction with the outer world (e.g. using landmarks in wayfinding rather than directions and metric distances or vice versa). Affective disposition (e.g. anxiety vs security and even curiosity) is linked to a range of positive or negative experiences and to the use of particular strategies. As a result, some of the strategies will be used more often by the individual than others. They become preferred strategies on which the subject will rely even in a new situation. According to Kitchin's (1996*b*) theory, individual preferences in the use of particular strategies work as anticipatory schemata embedded in memory and emotional context and, thus, guide the decision-making processes in environmental behaviour with the result of a certain environmental knowledge (e.g. one which recalls more landmarks than directions and distances or vice versa).

The above argument is supported by recent theories of neurophysiological compensation in the central nervous system in relation to external sensory input during the early development (Braught *et al*., 1991; Gibson & Petersen, 1991; Dawson & Fischer, 1994; Kolb, 1995). The tool for memorizing and encoding external configurations in the brain, i.e. the adequate central nervous network, develops under the influence of external stimulation. Although some changes in the central nervous

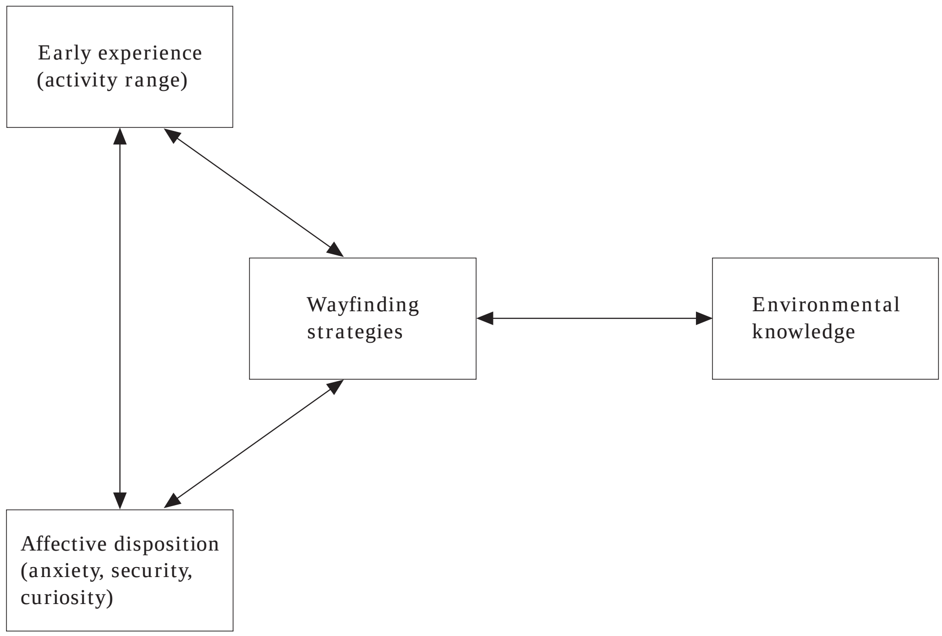

FIGURE 1. Interactive model of environmental learning and development (for explanation see text).

organization occur throughout life, the basic structures are laid down in early development. In interaction with neurophysiological differentiation preferences in learning strategies are formed and stabilized as a result of successful interaction with the outer world. Some of the preferred strategies are used throughout life, especially in new and contingent situations (fall back to use what you know as successful!), although every individual may refer to a set of possibilities, especially in familiar situations (try something new!). How then does the individual measure 'success' in interaction with the environment? One important link between the external input and the corresponding behavioural or 'cognitive' answer lies in the emotional system (Tucker, 1989; Ciompi, 1991; LeDoux, 1992). Every input into the central nervous system, every associative process and every output through the motoric system is linked with the emotional system, i.e. the limbo-cortical structures in the brain. We can assume, therefore, that every learning strategy, too, is coloured and mediated by positive or negative emotions.

In conclusion, recent research has already revealed an experience bias in children's environmental development and an interaction between spatial anxiety and the preferred use of particular environmental strategies in adolescence. Gender differences in the use of environmental strategies perhaps result from a different range of spatial experience for boys and girls (more limited for girls) interrelated with different levels of anxiety in the sexes (higher levels of anxiety for girls). The stronger reliance on landmarks stated for females may be due to the attempt to get more security in wayfinding and environmental knowledge. The aim of the present study was — as a next step — now to analyse the interaction between anxiety and environmental strategies in both wayfinding behaviour and the acquired environmental knowledge.

For two reasons it was decided to use a laboratory approach, i.e. a maze test, to examine the effects of internal mediators on gender-related strategies in environmental development. First, standardized external parameters could be presented by using an experimental design, whereas a natural setting involves, additionally, a multitude of external environmental features at each step of wayfinding that may influence environmental behaviour. Second, some studies have already shown gender-related effects of affective disposition on maze performance. Zimmermann (1988) examined the effects of achievement motivation and anxiety on the performance of female and male students (aged 16 to 18) in a competitive pencil maze task (time as critical performance measure). The blind-folded subjects had to find the correct start-to-goal-way in a complex maze in 25 runs. The male students reached the goal in less time than the female students, whereas no differences in error performance occurred. Females, in general, scored higher on anxiety scales than males and the higher the individual's anxiety was the longer was the time needed for one start-to-goal-run. Thus, effects of anxiety could, to a certain extent, explain gender differences in tactuospatial maze performance. In another experiment (Buchholtz & Schmitz, 1992) the interaction between anxiety and tactuospatial maze learning was examined for college students (aged 19–26) by using the same pencil maze task, with one exception. The tests took place in a noncompetitive task situation in which the subjects were instructed to use their own strategies instead of giving time as a performance criterion. No gender differences either in time or in error performance reached significance and only weak correlations between levels of anxiety and the time needed to find the goal could be detected although females again scored higher on all anxiety scales. Alvis *et al.* (1989) reported that in a maze task with adults, no gender differences occurred when accuracy instead of time was given as a performance criterion. In conclusion, gender-related affective disposition probably influences tactuospatial maze learning in interaction with the particular task situation (competitive vs noncompetitive).

The results, however, of two-dimensional tactuospatial maze learning can only with certain restrictions be transferred to complex visual orientation in three-dimensional space. Orientation and environmental learning in the real world involve visual encoding, continuous changes of perspective and further senso-motoric interactions such as complex kinaesthetic learning processes. The question was raised whether gender-related interaction between anxiety and environmental learning could also be detected in a three-dimensional wayfinding task and how this would influence the acquisition of the individual's environmental knowledge. An experiment was designed in which subjects could develop individual strategies in a series of wayfinding trials (5 start-to-goal-runs in a complex walk-through maze) and represent the acquired environmental knowledge afterwards. Gender-related effects of affective disposition on wayfinding performance in this maze have been presented in a recent paper (Schmitz, 1995). The boys reached the goal in less time than the girls but they made more errors in the beginning of the task. The girls scored higher levels of both anxiety and task-specified fear, and, in general, highly anxious subjects needed more time to reach the goal than did less anxious ones. The boys showed high attitudes toward time competition (measuring each others' time) and this could, to a certain extent, explain the boys' better time performance.

The presence paper centres on gender-related interaction between wayfinding behaviour such as speed and the acquired environmental knowledge with a special focus on the effects of anxiety and task-specific fear on these environmental strategies. The girls and boys were allowed to choose the technique of representation freely, either to draw a map or to write down a description of the explored maze. This was done in order to avoid influences of individual competencies in drawing or writing. One subject gave only one representation in one of the two conditions (map or description) because mutual effects of drawing on writing and vice versa should also be avoided. Methodological influences (see above) as a result of two conditions of representation were examined.

Method

Participants

For this study, 45 girls and 54 boys aged from 10 to 17 were chosen from five classes in two schools. All children of one class were asked to join in this experiment and nearly all of them participated.

Materials

The *maze* was set up in a fire brigade building and spread out over two 'floors', in a room of 95 m^2 (Figure 2). In a variable system of massive floor plates (1 m^2) with variable side railings (1 m^2) a start-to-goal route was arranged by closing or removing particular side railings and by removing certain floor plates so that changing between the first and the second 'floor' was possible. Every pathway had a diameter of 1 m, so that the younger children could walk and the older had to crawl through it. The start-to-goal route had a length of 61 m. It included 35 horizontal and five vertical 'route turns' (floor changing through a hole) and eight short cul-de-sacs. The five holes all differed somewhat, e.g. one involved a staircase that had to be climbed up or down, another was covered with a lid that had to be opened or else. Seven railings of 0·5 m and one tube with a length of 3 m were put in the maze all of them narrowing the pathway. The holes, the half-side-railings, the cul-de-sacs, the tube and a staircase at the starting point served as 22 landmarks. The light in the room was dimmed because under full illumination the overview through the side railings was too good.

Maze representations were assessed in two con-

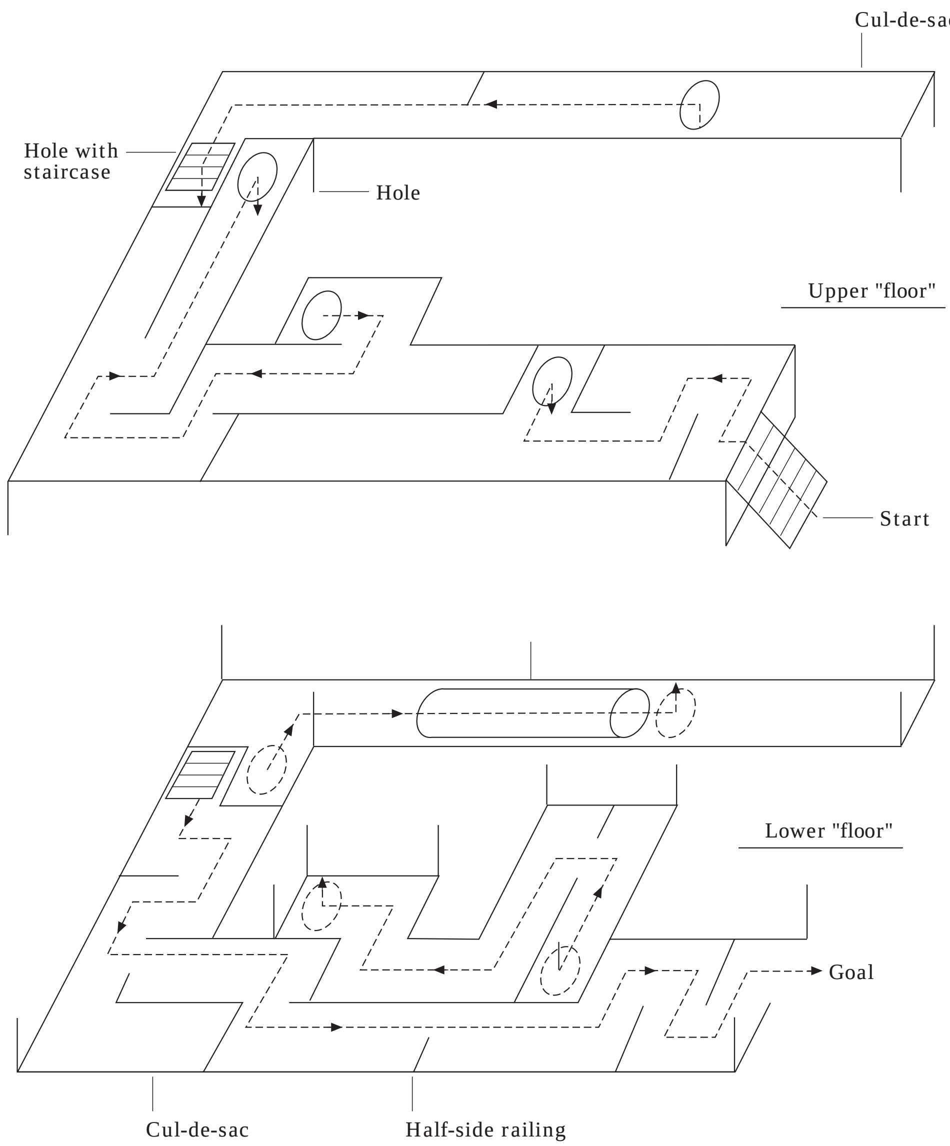

FIGURE 2. Ground plan of the two ‘floors’ of the three-dimensional maze. The starting point was at the staircase (right edge) that led to the upper floor; floor-changing was possible through the holes. The goal was at the right edge of the lower floor. The correct start-to-goal-route is drawn (- - -▶) in the corresponding parts of the two floors.

ditions: participants could either draw a map on a sheet of paper (21×32 cm) with the outlines of the room and the door as a frame of reference or describe the maze in writing.

Anxiety was assessed by using a mixed anxiety questionnaire. It included the scales general anxiety (15 items) taken from the ‘German Anxiety Questionnaire for School Children’ (AFS: Wieczerkowski *et al*., 1975), test anxiety (7 items), taken from the German version of the ‘Work and Family Organisation Test’ (WOFO II: Spence & Helmreich, 1978). A further question about darkness anxiety was added (1 item: ‘I am often afraid in darkness’). The answers could be ranked on a 5-point rating scale from ‘not at all’ (0) to ‘very much’ (4), except questions concerning general anxiety where only ‘yes’ or ‘no’ answers were allowed (AFS-specific). In addition, task-specific fear was assessed on a 5-point rating scale after the first and third run (1 item: ‘Were you afraid while you were walking through the maze’).

Procedure

The anxiety questionnaire was carried out in the classroom with all members of one class. On the following days three to five subjects were taken from the school to the maze in one session. The boys and girls could choose their companions freely which resulted in homogeneous sex groups, except for one. First, the illuminated room with the maze was shown to all subjects for a short time. They were assured that the maze could be opened at any point of the way and that they could stop the performance and leave the maze at any time. It was pointed out that this task was non competitive. Everyone was asked to develop his or her own problem-solving strategy and solution. No criteria of performance as time or accuracy were given.

Every subject performed five individual runs from start to goal in alternation with the others. Between the trials the boys or girls were supervised in an extra room by another experimenter who asked them about their fear in the maze after the first and the third run. After the fourth run the subjects were instructed to give a representation of 'the picture of the maze that you have in your head' either in drawing or in writing. The last run had to be carried out in the reverse direction from goal to start.

The task was not competed by all subjects because the time for one session in which the pupils could leave the school was strictly limited. Seven girls carried out only two runs and gave no maze representation. In addition, seven girls and one boy did not traverse the maze from goal to start (run 5).

Measures

Wayfinding behaviour. Every floor plate of the maze was connected to a magnetic contact so that every step on a plate (1 m) was shown on a display and could be entered directly into the computer. Speed/run was computed as total way in metres/second (m/s).

Maze representation. The elements in maps or descriptions were scored for two categories:

(1) *Directions*: every route turn, vertical and horizontal, in a map and every additional remark on vertical changes, e.g. 'up' and 'down' at a hole in the floor; every recall of a direction in a written description, e.g. right, left, up, down, straight ahead, way back, turn round; route turns in maps were categorized synonymous to directions according to Ward *et al*. (1986) and Blades & Medlicott (1991), who showed that children as well as adults used such directions to describe route turns of a pathway they had learned from a map;

(2) *Landmarks*: every drawn or recalled hole, half-side railing, the tube, the staircase at the starting point and every cul-de-sac.

None of the subjects in the present study mentioned metric distances or cardinal directions. The representations were scored by two persons, one of them naive with respect to the theoretical background. Scorer agreement (Pearson's product–moment correlation) was 0·91 for directions and 0·66 for landmarks. The number of elements (directions+landmarks) was computed as a measure of quantity of the subject's acquired environmental knowledge. The percentage of directions or landmarks was computed in order to calculate preferences in representation independently from quantity.

Anxiety and *task-specific fear* scores were assessed for test anxiety, darkness anxiety and fear after runs 1 and 3 as means of all items per scale on the 5-point rating scale. Scores of general anxiety were calculated as *t*-norms from the 'German Anxiety Questionnaire for School Children'.

Results

Wayfinding behaviour in the maze

Table 1 shows the mean speed of girls and boys in five runs. Speed/run was submitted to a repeated-measures analysis of variance (MANOVA) with sex as the between-subjects factor and successive runs as the within-subjects factor. A significant main effect of sex, $F(1,79)=23{\cdot}34$, $p<0{\cdot}001$, and a significant effect of successive runs, $F(4,316)=82{\cdot}65$, $p<0{\cdot}001$, was found. *Post-hoc* t-tests revealed significant speed differences between the sexes in all runs indicating that the boys, on average, walked through the maze more quickly than the girls. Speed in run 1 correlated significantly with speed in run 2, $r(96)=0{\cdot}49$, $p<0{\cdot}001$, with speed in run 3, $r(89)=0{\cdot}63$, $p<0{\cdot}001$, with speed in run 4, $r(81)=0{\cdot}57$, $p<0{\cdot}001$, and with speed in run 5, $r(81)=0{\cdot}46$, $p<0{\cdot}001$. These correlations indicated a permanent individual preference for quick or slow walking throughout the whole wayfinding task although all subjects showed an increase of speed until run 4.

Maze representation

Table 2 shows the mean number of elements as well as the percentage of directions or landmarks in maps and descriptions of the maze for girls and boys. These variables were submitted to a 2(sex)× 2(condition) analysis of variance. A significant effect of condition, $F(1,88)=4\cdot59$, $p=0\cdot03$, but no effect of sex, $F(1,88)=1\cdot36$, $p=0\cdot25$, could be confirmed for the number of elements in representation. The maps included more elements than the descriptions, a result that was found for the representations of both the girls and the boys equally (no interaction effect between sex and condition, $F(1,88)=0\cdot01$, $p=0\cdot92$).

In general, all subjects recalled proportionally more directions than landmarks in representation.

TABLE 1
Wayfinding behaviour in the maze: mean speed (m/s) in 5 runs for girls and boys

	Girls			Boys				
	n	*M*	(S.D)	*n*	*M*	(S.D)	*t*	*p* (two-tailed)
Run 1	43	0·30	(0·13)	53	0·43	(0·12)	–5·16	<0·001
Run 2	43	0·50	(0·13)	53	0·58	(0·12)	–2·85	0·005
Run 3	36	0·52	(0·14)	53	0·68	(0·16)	–4·19	<0·001
Run 4	36	0·54	(0·14)	53	0·69	(0·19)	–4·03	<0·001
Run 5	29	0·48	(0·10)	52	0·63	(0·18)	–4·96	<0·001

TABLE 2
Maze representation: mean number of elements and mean percentage of directions and landmarks in drawn maps or written descriptions for girls and boys

	Number of elements			*% directions*		% landmarks	
	n	*M*	(S.D)	*M*	(S.D)	*M*	(S.D)
maps							
girls	25	24·08	(11·17)	62·47	(25·86)	37·53	(25·86)
boys	43	27·12	(9·07)	76·19	(8·35)	23·81	(8·35)
descriptions							
girls	13	19·15	(8·36)	55·38	(25·84)	44·62	(25·84)
boys	11	21·72	(12·40)	63·81	(25·84)	36·19	(19·06)

TABLE 3
Spearman rank correlations between wayfinding behaviour (speed in run 1) and quantity (number of elements) or preferences (% directions, % landmarks) in maze representation

	Number of elements	% directions	% landmarks
Speed in run 1			
entire sample	0·34**	0·22*	–0·22*
girls	0·27	–0·15	0·15
boys	0·35**	0·31*	–0·31*

*$p<0\cdot05$, **$p<0\cdot01$.

TABLE 4
Anxiety and task-specific fear: mean scores on the scales of general anxiety, test anxiety, darkness anxiety and fear in runs 1 and 3 for girls and boys

	girls			*boys*			*F*	*p*
	n	*M*	(S.D)	*n*	*M*	(S.D)	(df.=1)	(two-tailed)
general anxiety	45	63·80	(11·29)	50*	53·29	(8·91)	25·84	<0·001
test anxiety	45	2·30	(0·50)	50	1·95	(0·57)	9·94	0·002
darkness anxiety	45	1·64	(1·64)	50	0·70	(1·05)	11·37	0·001
fear in run 1	43	0·91	(0·87)	53	0·45	(0·87)	4·39	0·04
fear in run 3	33†	0·24	(1·35)	50	0·10	(0·30)	1·14	0·29

Note: Response scaling 0–4 except scores of general anxiety (*t*-norms from AFS-specific); *anxiety questionnaires of 4 boys could not be evaluated; †fear in run 3 was not assessed for 12 girls.

Remember that the maze included 40 route turns and only 22 landmarks. The main effect of sex on the proportion of directions or landmarks was significant, $F(1,88)=6{\cdot}03$, $p=0{\cdot}02$, indicating that the boys preferred directions both in maps and descriptions more than the girls did. In addition, more boys than girls choose map representation instead of written description but these differences were not significant, χ^2 (1, $n=92$)=2·22, $p=0{\cdot}14$. A significant effect of condition, $F(1,88)=4{\cdot}66$, $p=0{\cdot}03$ was also found as the percentage of landmarks was higher in descriptions than in maps. Especially those girls who described the maze in writing recalled nearly as many landmarks as directions. An effect of interaction between sex and condition, however, was not significant, $F(1,88)=0{\cdot}34$, $p=0{\cdot}56$.

Correlation between wayfinding behaviour and maze representation

Speed in the first run represented the initial wayfinding behaviour in the still unknown environment and as it related significantly to speed in all other runs this initial speed was chosen to examine relationships between wayfinding behaviour and maze representation (Table 3). Speed in the first run correlated significantly to the mean number of elements, indicating that the higher the speed was the more elements were recalled in maze representation. This significant correlation held for boys, considered separately, and a similar trend ($p=0{\cdot}10$) could also be stated in the girls' group. In addition, speed initial related positively to the percentage of recalled directions and negatively to the percentage of landmarks, i.e. the higher the speed was in the first wayfinding trial the higher was the preference for directions over landmarks in maze representations and vice versa. These correlations were confirmed within the boys' group but not for girls.

Effects of anxiety and task-specific fear on wayfinding behaviour and maze representation

Table 4 shows the mean scores for anxiety and fear that were assessed before and during the task. A multivariate analysis of variance (MANOVA) revealed a significant main effect of sex on the level of anxiety and task-specific fear, $F(1,76)=2{\cdot}91$, $p=0{\cdot}02$. Girls scored significantly higher anxiety values than boys on the scales of general anxiety, test anxiety, darkness anxiety and fear in the first run. Only after the third run all subjects scored similar low fear scores. Table 5 shows correlations between anxiety and task-specific fear on the one hand and initial speed in wayfinding, number of elements and percentage of directions or landmarks in maze representation on the other. General anxiety, test anxiety, darkness anxiety and the reported fear in the first run correlated significantly with initial speed in run 1, indicating that subjects who scored higher anxiety levels walked through the maze more slowly than less anxious ones. A similar trends was also found in the girls' group, considered separately, with a significant correlation between darkness anxiety and speed and marginally significant correlation between both general anxiety and fear in the first run and speed ($p=0{\cdot}06$). In the boys' group negative correlations could only be confirmed between task-specific fear and speed.

The correlation analysis between anxiety or task-specific fear and maze representation revealed significant values only for the mean number of elements and, respectively, test anxiety and fear in the first run. Correlations with general anxiety and darkness anxiety were also negative but not significant. Within the sex groups constantly negative correlations between anxiety scores and the number of elements could be found for girls but only fear in the first run related significantly to the number of elements, i.e. the higher the fear score in the first run the lower was the number of recalled elements. For boys, correlations were also negative but on a weak level. A weak but permanent tendency (although not significant) to recall fewer directions and more landmarks could be detected for all subjects with high anxiety scores and vice versa. Fear in the first run correlated with an enhanced percentage of landmarks and a reduced percentage of directions nearly significantly ($p=0{\cdot}06$).

Discussion

This study examined gender-related strategies in wayfinding behaviour (wayfinding speed in a previously unknown and complex walk-through maze) and in representation of the acquired environmental knowledge against the background of anxiety and task-specific fear. Gender differences in wayfinding behaviour could be confirmed, as boys walked through the maze more quickly than girls in five successive runs. A recent paper of Schmitz (1995) showed that boys reached the goal of the maze in less time than girls but in the second run they made more errors. High speed at the beginning of the task therefore probably diminished accuracy performance.

Girls described themselves as being more anxious than boys on all scales, i.e. general anxiety, test anxiety and darkness anxiety. Moreover, the girls reported higher fear during their first run through the maze than the boys. Higher anxiety correlated with a reduced speed in the first run mostly for girls and higher task-specific fear correlated with a reduced speed for both boys and girls. Correlations between anxiety and task-specific fear and, respectively, time and errors have been presented in the paper of Schmitz (1995). In short: correlations between anxiety or fear and time were similar to those with speed but the other way round, i.e. the higher the anxiety or fear score was the higher was the time score. Error performance was not affected by anxiety for both sexes but task-specified fear related to an enhanced number or errors in the first run concerning boys as well as girls. Thus, anxiety and task-specific fear corresponded to wayfinding strategies especially in a still unfamiliar environment.

A second particular focus of this paper was the analysis of the acquisition of environmental knowledge as a result of wayfinding behaviour. Gender differences could be confirmed not in quantity (mean number of elements) of maze representation but in preferences to use either more directions or more landmarks in maps and written descriptions. Boys preferred directions more than girls did, whereas girls gave a greater emphasis to landmarks, especially in written descriptions. Subjects with high speed at the beginning of the task recalled more elements in general and a higher percentage of directions versus a lower percentage of landmarks. Highly anxious subjects with high task-specific fear showed a tendency (although not significant) to recall fewer elements and to use a higher proportion of landmarks than directions in maze representation. With respect to the sex groups: boys who showed higher speed in the beginning of the task (first run) recalled more directions but fewer landmarks than girls who walked through the maze more cautiously. Especially girls (who scored higher anxiety in general) showed a weak but continuous tendency of anxiety effects on maze representation which, except for task-specific fear, seemed to vanish in the boys' group.

Task-specific and methodological influences have also to be considered. In general, all subjects used proportionally more directions than landmarks in their representation. To a certain extent, this preference can be attributed to the structure of the maze with a higher number of right-angled pathways (40 route turns) as compared to the number of additional landmarks (22). A further influence concerns the condition under which the subjects could represent their acquired knowledge. The reference to similar types of elements (relational directions for route turns and the same landmarks) in maps or written descriptions support the idea that different methods of environmental representation recall

TABLE 5
Spearman rank correlations between anxiety or task-specific fear, wayfinding behaviour (speed in run 1) and quantity (number of elements) or preferences (% directions, % landmarks) in maze representation

	speed in run 1	number of elements	% directions	% landmarks
General anxiety				
entire sample	−0·36***	−0·16	−0·13	0·13
girls	−0·28	−0·16	−0·08	0·08
boys	−0·13	−0·07	−0·06	0·06
Text anxiety				
entire sample	−0·20*	−0·23*	−0·14	0·14
girls	−0·18	−0·20	−0·14	0·14
boys	−0·01	−0·15	−0·03	0·03
Darkness anxiety				
entire sample	−0·24*	−0·14	−0·14	0·14
girls	−0·40**	−0·23	−0·12	0·12
boys	0·04	−0·09	−0·09	0·09
Fear in run 1				
entire sample	−0·35***	−0·28*	−0·20†	0·20†
girls	−0·28†	−0·33*	−0·17	0·17
boys	−0·31*	−0·21	−0·12	0·12
Fear in run 3				
entire sample	−0·13	−0·05	0·06	−0·06
girls	−0·09	0·12	−0·02	0·02
boys	−0·14	−0·19	0·12	−0·12

†p<0.10, **p*<0·05, ***p*<0·01, ****p*<0·01.

related abilities (Bryant, 1984). However, drawn maps included more elements than written descriptions and proportionally more directions and fewer landmarks. Thus, these two types of representation seem to refer to somewhat different aspects of environmental knowledge. A drawn map presents simultaneous environmental information whereas a verbal or written instruction can only present a step-by-step sequence of information (Galea & Kimura, 1993). Perhaps additional landmarks are used more frequently in a route description in order to enhance security of wayfinding.

In correspondence to the interactive model of environmental learning and development that had been presented in the beginning some relationships between anxiety or fear and both wayfinding behaviour and environmental knowledge can be summarized: highly anxious subjects often move through an unknown environment cautiously and slowly while acquiring directional changes of the route and, in addition, a lot of landmarks, which perhaps enhance security in wayfinding. Less anxious subjects more often walk with higher speed and pay attention mostly to directional changes of the route. A gender polarization develops as girls score higher on the anxiety scales and their wayfinding behaviour in an unknown environment is probably influenced to a greater extent by anxiety, whereas boys are less anxious and their strategies seem to be less influenced by anxiety (although influenced by task-specific fear). At this point it has to be stressed that there is a great variability within the sex groups and that individual differences often superimpose sex differences. Fast girls and girls with a clear preference for directions as well as slow boys and boys with a high percentage of landmarks in representation were also found in the study. However, in general, more girls than boys tend to acquire anxiety-related strategies.

Based on the above conclusions gender differences in environmental development have to be discussed as a question of strategy rather than as a question of skill. Every individual has the a priori capability to acquire a range of spatial skills in development rather than one single ability. Environmental development embedded in a socio-cultural and emotional context, however, may lead to gender differences in learning strategies. Girls and boys learn to favour particular parts of their repertoire and to transform them into individual gender-related preferences. A number of approaches support the idea that gender differences in spatial ability depend to a large extent on the type of task that is examined and on the particular cognitive skill that is addressed by this task. Applying a general term of 'spatial ability' to particular spatial skills seems to be as problematical as the comparison of results between different categories, such as spatial perception, mental rotation, spatial visualization or spatial orientation (Caplan *et al*., 1985; Linn & Petersen, 1985).

The neurophysiological approach puts down male advantages in spatial orientation to sex differences in brain lateralization (McGlone, 1980; Harris, 1981; Witelson, 1988). However, until today we do not know to what amount the differentiation of the central nervous system is determined by biological factors as compared to the influences of early external input. Within an interactive approach the controversy of 'biological determination' against 'cultural experience' seems to be an artificial one (Self *et al*., 1992). As Nora Newcombe stated:

> 'Although differential lateralization patterns cause cognitive differences, cognitive differences could also cause lateralization patterns: this can be called the *strategy* issue . . . A third possibility is that another variable (such as sex-differentiated experience) could also cause both lateralization and cognitive differences independently of each other.' (Newcombe, 1982, p. 232).

At this point we come back to experience. The development in a socio-cultural environment and individual experiences with the outdoor physical world in childhood prepare the individual problem-solving strategies (Liben, 1981). As mentioned above, a number of studies pointed out that boys who have an extended home range as compared to girls of the same age, show an enlarged number of map elements and this correlates with activity range (Matthews, 1992). Matthews also stressed again that there is a range of strategies rather than a distinct gender polarization and

> 'girls who travel most freely and widely in their local area represent similar proportions of environmental detail on their maps as boys' (Matthews, 1986, p. 264).

Differences favouring boys in the mean number of recalled elements of a previously unknown environment were reduced when both sexes (aged 8 to 11) were primed with maps before the orientation task (Matthews, 1987*b*).

Matthews also noted that although both sexes showed an increasing awareness from landmark to route knowledge over age boys recalled more routes and girls gave more emphasis to landmarks in all age groups. In addition, Hazen (1982) pointed out the importance of active versus passive exploration as a predictor for accuracy of spatial knowledge.

Considering the influence of affective mediators we may establish the link between these interactions. Reduced experience in the early development perhaps forms the basis of anxiety in environmental learning later on in life and these subjects need many landmarks to feel secure in wayfinding — mostly girls. Extended experience in the environment, in contrast, enhances security and mostly boys use more directions in wayfinding and environmental knowledge.

Early experience and affective-mediators are only two cues helping us to understand the development of 'environmental-behaviour interaction' (Kitchin, 1996*b*) and there is a great need for further work in this direction. The next step of research now has to be to go out into the real world. Studies dealing with gender-related interaction between previous experience, affective disposition, wayfinding behaviour and environmental knowledge are in progress.

Acknowledgements

The project was supported by the 'Hessischen Ministerium fur Wissenschaft und Kunst'. I am especially grateful to the teachers and staff of the Richtsbergschule Marburg and the Gesamtschule Niederwalgern who participated in this experiment. I also gratefully acknowledge the help of Tina Geserich and Tina Maleta who assisted in the data collection and Helga Breuer who analysed maps and descriptions of the maze. I want to thank Ruth Schmitz and Eva Neidhardt who read and commented on an earlier draft of this paper and three anonymous reviewers who gave helpful comments on an earlier version of the manuscript.

Note

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