Are Wayfinding Self-efficacy and Pleasure in Exploring Related to Shortcut Finding? A Study in a Virtual Environment

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Abstract. The analysis of individual factors supporting wayfinding ability is attracting increasing interest in the spatial cognition domain. The present study aimed to investigate whether two variables, wayfinding self-efficacy and pleasure in exploring, relate to shortcut-finding performance. A group of 124 university students were led along a route through one of two virtual environments that differed only in that one contained landmarks, while the other did not. Then they were asked to find a shortcut from the start to the end of the route they had learned. Two questionnaires were also administered to assess their wayfinding self-efficacy and pleasure in exploring. The results showed a better performance in the shortcut task for the environment containing landmarks. Individual differences correlated with shortcut-finding ability, but their predictive power was stronger in the without- than in the with-landmarks condition. The authors concluded that individual variables, such as wayfinding self-efficacy and a positive attitude to exploring, interact with environmental features (landmark availability) and relate to wayfinding performance.

Keywords: Wayfinding · Shortcut finding · Landmarks · Virtual environment · Wayfinding self-efficacy · Pleasure in exploring

1 Introduction

1.1 Wayfinding: A Multifaceted Ability

Wayfinding (WF) is generally defined as the ability to move around efficiently, and to find a route from a starting point to a destination [36]. It is an important component of everyday life and can even be vital in some circumstances, in adverse weather conditions or emergencies, for example [16]. It is generally acknowledged that WF is a multifaceted skill that requires a broad range of mental processes, cognitive functions, and strategies [14, 52]. It is also susceptible to wide individual differences [58]: some people find WF easy [8], while others have serious difficulties right from their childhood [18, 45], with all the gradations in between.

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Studying individual differences has helped to shed light on the neural substrates [54] and cognitive mechanisms implicated in WF ability [58], showing that optic flow [22], working memory [24, 31, 32, 56], attention and planning [8] functions are involved in WF tasks. Personal traits are not the only components affecting WF, however. Some studies have underscored that environmental features and the type of task at hand can strongly affect navigation [4]. What emerges is a complex pattern of individual and environmental features interacting in influencing performance in WF tasks, which can also vary considerably, from visual landmark recognition to retracing a route, estimating direction and distance, and finding a shortcut. Different tasks are assumed to demand different spatial representation strategies, with distinct implications for perception, attention, and memory [57].

1.2 Shortcut Finding

A psychologically relevant distinction exists between WF tasks that involve retracing an already-learned route and those in which a novel, hitherto unknown path has to be found. Examples of the latter are shortcut-finding tasks, which involve identifying the shortest route to reach a destination. Finding a shortcut involves using a configurational representation obtained by integrating information acquired during navigation [12].

A paradigm frequently used to test people's ability to integrate environmental information gleaned from navigation is triangle completion, in which participants are led along two sides of a given triangle-shaped configuration and have to find the shortest way back to the starting point [28]. Typically, performance in triangle completion is more accurate in the presence of landmarks than in their absence [13, 43]: participants integrate their information and find a shortcut more easily in relation to the landmarks, whereas without them they are only able to retrace their steps [9, 10].

The presence of landmarks does not always guarantee that environmental information will be integrated to form a configured representation, however. There is evidence of individual differences - in terms of working memory [24], visuo-spatial abilities [43], strategies [9, 47], and also subjective measures of Sense of Direction (SOD) [15, 21] - all contributing to explaining the variability in people's shortcut-finding abilities.

1.3 Subjective Measures and Wayfinding

People's subjective measures regarding their spatial preferences and attitudes, such as spatial anxiety, spatial strategies, and SOD, have been studied intensively in terms of how they relate to WF ability. Self-assessed SOD (an individual's estimation of their ability to locate and orient themselves in an environmental space) is perhaps the most often studied subjective index since Kozwlosky and Bryant [23] identified significant relationships between SOD and performance in pointing tasks after learning spatial information.

More recently, Janzen and colleagues [21] found that individuals scoring higher for SOD on the Santa Barbara Sense of Direction Scale (SBSOD) [15] consolidated landmark information better (with more activity in the hippocampus) than those reporting a weaker SOD. In the work of Labate and colleagues [24], higher SBSOD scores again coincided with better shortcut-finding skills in a real environment previously learned from navigation. Spatial strategies have also been found related to WF, and susceptible to gender-related differences, females being more likely to adopt route strategies, while males show a stronger preference for configurational strategies and survey representations [25, 26].

Several instruments have been devised to assess individual differences in a variety of subjective measures: spatial anxiety [25], strategies [25], preference for spatial representation [40], and SOD [15]. The last of these seems to be related to memory consolidation for navigationally relevant objects [20], and to WF in real [24] and virtual [42] environments. Interestingly, the strength of the relationship between subjective measures and environment learning tasks depends on the demands of the tasks and their difficulty: the relationship is stronger for spatial than for visual tasks, and for difficult than for simple tasks [55].

1.4 Emotions, Motivation, and Socio-cognitive Factors in the Spatial Domain

So far, research on WF has devoted little attention to the role of emotions, motivation, and socio-cognitive factors, although these variables have proved important in the performance of other spatial tasks. There is consistent evidence, for instance, that socio-cognitive factors such as stereotype threat (which refers to the risk of individuals seeing confirmed in themselves a negative stereotype applied to their social group) [29, 51], and gender identification [59] have a role in determining performance in mental rotation tasks. Young women performed less well in the Mental Rotations Test (MRT) when under stereotype threat than in a control, non-stereotyped condition [35]. It seems that personality factors should be taken into account too in explaining MRT performance, since gender identification interacts with stereotype threat in worsening MRT performance [39].

There are also studies supporting the link between emotions and WF. Schmitz [48] found that spatial anxiety (the degree of anxiety experienced when performing environment tasks) influenced WF speed in a virtual environment (VE). Lawton [25] showed that females experienced more spatial anxiety than males, and this factor correlated with route WF strategies. More recently, a number of studies have further demonstrated that anxiety interferes with WF performance [17, 53], particularly in difficult tasks [50]. On the other hand, no studies have so far investigated the role of positive emotions (such as pleasure in exploring) in sustaining WF despite a growing body of evidence of positive emotions enhancing performance in a variety of cognitive tasks [11]. The present paper aims to start filling this gap.

1.5 Wayfinding Self-efficacy

Over the years, an impressive amount of evidence has shown that motivational factors can sustain (or hinder) cognitive performance and goal-directed behavior. In this domain, one of the most often studied constructs is that of self-efficacy [2], described as a person’s belief about his or her ability to accomplish a task. Perceived self-efficacy has been proved to influence numerous domains, including cognitive development [1], self-regulated learning and academic motivation [49], sport performance [37]. One of the goals of the present study was to explore whether perceived self-efficacy in spatial tasks can predict WF performance.

1.6 The Present Study

The aim of this study was to explore the role of a positive attitude (pleasure in exploring) and perceived self-efficacy in spatial tasks in relation to WF performance in a VE. A VE was used because previous studies had shown that people are able to acquire spatial knowledge from VEs in the same way as they do in the real world (e.g. [46]). The use of VEs also enables variables of interest (such as the presence of landmarks) to be controlled, and is a useful way to objectively assess individual differences in WF [14, 55].

As mentioned in the above review, positive emotions have a distinct role in enhancing cognitive performance, and a number of studies have demonstrated the influence of socio-cognitive and personality factors on spatial learning. We feel that this line of investigation should be extended to WF ability, exploring its relationship with emotions, motivation, and personality factors.

In our study, participants completed two questionnaires, one designed to assess their WF self-efficacy, the other to assess their attitude to spatial tasks. They were then conducted along a path through an urban VE that they were asked to memorize. Immediately afterwards, they were returned to the starting point and asked to find a shortcut to the destination. In order to do so, the information they had acquired from an egocentric perspective while navigating needed to be integrated in an allocentric representation and a completely new route had to be identified. Our expectation was that WF self-efficacy and attitude to spatial tasks would relate to shortcut-finding performance.

Participants were assigned to one of two groups: one group learned a VE that contained numerous elements that might be used as landmarks: buildings, a fountain, a traffic light, trees, etc. They are all items typically found in an urban environment. The other learned the same VE, but without any of these potential landmarks: only the layout of the streets was displayed. We expected WF self-efficacy and attitude to spatial tasks to be more strongly associated with WF performance in the no-landmark condition, based on past studies suggesting that personal features – such as anxiety [50] and SOD [38, 55] - were more predictive of performance in difficult spatial tasks than in easier ones. Muehl and Sholl [38] showed that SOD predicted participants' ability to path-integrate over longer routes with more turns in a VE, but not over shorter routes. In the same vein, Weisberg et al. [55] found that SOD explained a significant portion of the variance for between-route pointing trials, but was not a significant predictor for within-route pointing trials.

2 Method

2.1 Participants

A total of 124 undergraduates (63 females) took part in the study (age M = 23.6, SD = 2.11). They were randomly assigned to one of two groups: 59 participants (29 females) learned a route through a virtual environment with landmarks (Landmark) and 65 (34 females) learned the same route but without any landmarks (No Landmark).

2.2 Materials

Individual differences measures

Attitude to spatial exploration questionnaire (Attitude), revised from [41]. This is designed to assess attitude towards orientation tasks and pleasure in exploring. It comprises 8 statements that describe feelings, attitudes, and preferences in situations involving environmental orientation (e.g. "I love exploring different places that I still don't know well, and finding new ways to get to places"; "I would like to play a sport like orienteering, where people have to move very fast in unknown places"). For each statement, respondents indicate their agreement on a 5-point scale from 1 (not at all) to 5 (very much), and the total score is obtained from the sum of each item rating. Internal consistency (a measure of a test's reliability based on correlations between items) was good (Cronbach's α = .83, calculated on the current sample).

Wayfinding self-efficacy questionnaire (Efficacy), revised from [34]. This investigates how confident individuals feel about their ability to perform typical WF tasks. It consists of 8 items that describe precise tasks (e.g. "Finding the car in a large parking lot"; "Visiting friends who live in an unfamiliar neighborhood"), scored on a 6-point scale from 1 (not at all) to 6 (very much) in response to the prompt: ''Indicate how well you think you would cope in the situations described'', and the total score is given by the sum of each item rating. Internal consistency was good (α = .85, calculated on the current sample).

Learning phase

A virtual environment prepared with Superscape 5.61 software, adapted from [42]. Two versions of the same outdoor urban VE were used, one with and the other without landmarks (Landmark and No Landmark, respectively), with a path some 300 m long that consisted of 12 segments between two adjacent nodes, which included 2 roundabouts and 9 turns (4 to the right and 5 to the left). In the Landmark version the environment contained buildings, a fountain, a monument, trees, a traffic light, flower beds, and other elements typically found in an urban environment that can serve as navigation aids (Fig. 1, panels a and c). The environment without landmarks was identical except for the absence of any buildings or other elements of the urban landscape. Only the layout of the streets was displayed (Fig. 1, panels b and d). Another VE was used for practice.

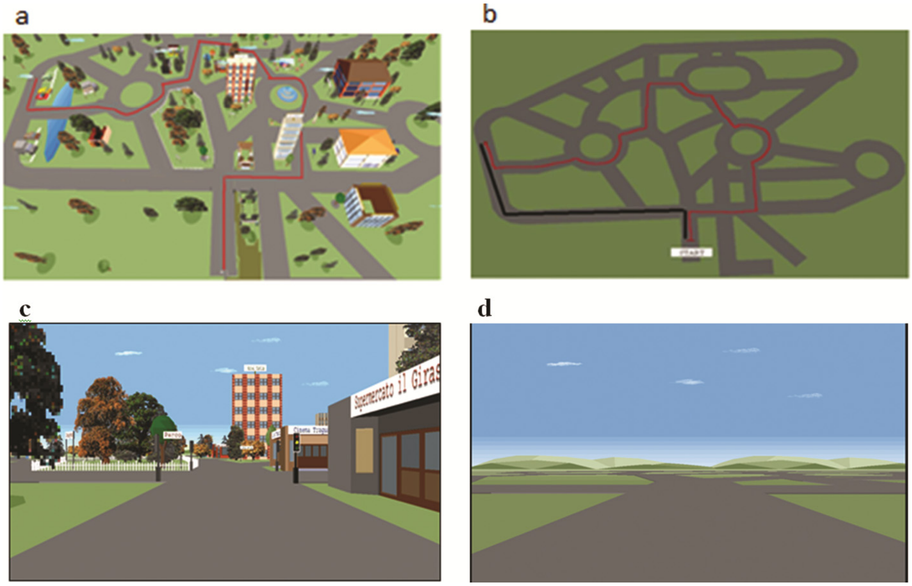

Fig. 1. The path through the VE with (panel a) and without landmarks (panel b). The best shortcut is shown on panel b. Panels c and d show the starting point from a participant's perspective (for the Landmark and No landmark conditions, respectively).

The virtual navigation (learning) phase was conducted on a desktop PC running Window 7 Professional 64 bit (SP1); processor: CPU intel i7, 3.33 GHz, Ram 12,0 GB; graphic board: NVIDIA QUADRO FX 3800, refresh rate 60 Hz; resolution: 1280 × 1024, Screen BENQ: FP93VW. The VE was presented on a 17-inch screen placed 50 cm away from the participant.

2.3 Procedure

Participants were tested individually during a single session lasting about 45 min. First they completed the Attitude and Efficacy questionnaires (in addition to other questionnaires that were not considered in the current study).

Then the route learning phase started. Participants were told that their task was to memorize a path through a VE and afterwards to perform a number of spatial tasks. They were familiarized with the use of the joystick (using the Logitech cordless Freedom R 2.4) and the desktop virtual reality apparatus in a sample VE for 3 min before starting the experimental task. Participants watched an avatar walk for about 3 min from the start to the end of a path through the Landmark or No Landmark VE. Immediately afterwards, they were returned to the starting point and asked to find a shortcut to the destination, using the joystick.

The task was complete when they reached the end point. The dependent variable was the error in the length of their shortcut, calculated by subtracting the length of the best shortcut (128 m) from the length of the shortcut identified by participants.

3 Results

3.1 Landmarks and Shortcut-Finding Performance

A univariate analysis of variance was run on the shortcut error (length of the shortcut identified by participants minus 128, which was the length of the best shortcut), inserting Environment (Landmark vs No Landmark) as a factor. The results showed a main effect of Environment, F (1, 122) = 24.84, $p < .001$, $\eta^2 p = .17$, with better performance in the Landmark ($M = 60.85$, SD = 94.21) than in the No Landmark condition ($M = 236.88$, SD = 255.96).

3.2 Attitude to Spatial Tasks, WF Self-efficacy, and Shortcut-Finding Performance

Correlations. Table 1 shows the correlations between Attitude, Efficacy and shortcut error. Given the high correlation between Attitude and Efficacy, we averaged the z-scores of the questionnaires in a single individual differences variable (Att-Eff). The correlations between Att-Eff and shortcut error were $r = -.23$, $p = .09$, and $r = -.33$, $p = .008$, in the Landmark and No Landmark conditions, respectively, with (as expected) a significant correlation only in the former condition.

Table 1. Correlations between attitude, efficacy and shortcut error.

	1	2
1. Attitude	–	
2. Efficacy	.67***	–
3. Shortcut error	−.26**	−.21*

Note. * p ≤ .05; ** p ≤ .01; *** p ≤ .001

Regression models. A hierarchical multiple regression analysis was run using a block-wise method, and considering Environment, Att-Eff, and their interaction as predictors, and shortcut error as the dependent variable. Environment (a dichotomous variable, i.e., 1 for Landmark and 0 for No Landmark) was input in step 1, and the Att-Eff scores on a continuous level were input in step 2; then the Environment x Att-Eff interaction was considered in step 3. The gender variable was taken into account in a preliminary Step 0, given the gender-related differences in visuo-spatial strategies and tasks (e.g. Lawton [25]), but its effect was not significant (F < 1) and the final regression model only considered Steps 1, 2, and 3.

The results of final regression models (shown in Table 2), revealed at step 1 the effect of Environment ($R^2 = .17$, F (1, 121) = 24.72, $p \leq .001$) and at step 2 the effect of Att-Eff ($R^2 = .05$, F (1, 120) = 8.25, $p < .01$), accounting together for 22% of variance.

Step 3 showed a significant Environment x Att-Eff interaction, F (1, 119) = 4.87, $p < .05$, explained by the fact that individual differences influenced shortcut-finding performance more in the No Landmark than in the Landmark condition (see Fig. 2).

Table 2. Hierarchical multiple regression model on shortcut error.

Predictors	ΔR^2	β
Step 1: Environment[a]	.17***	−.39***
Step 2: Eff-Att[b]	.05**	−.44**
Step 3: Environment x Eff-Att	.03*	.28*
Total R^2	.25	

Note. N = 124; [a] Environment: 0 = without landmark, 1 = with landmark; [b] mean score for Efficacy and Attitude z scores; *p < .05, **p < .01, ***p < .001.

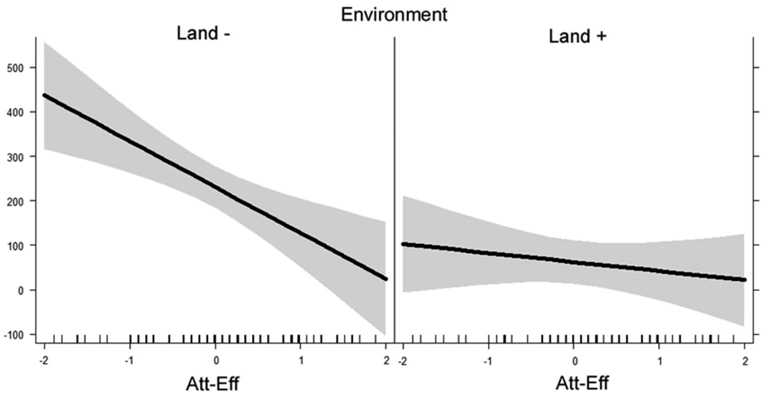

Fig. 2. Interaction between shortcut-finding performance (shortcut error) in relation to Att-Eff (individual factor, z score) by environment with landmarks (Land+) and without landmarks (Land−).

In other words, participants with a more positive attitude to spatial tasks and a higher WF self-efficacy rating found shorter shortcuts in the environment without landmarks; while these factors were less influential in the learning condition with landmarks.

4 Discussion

Previous studies found that environmental and individual features interact in contributing to WF performance [4, 14]. In the realm of general cognitive abilities and figural spatial tasks (e.g. MRT), numerous studies have pointed to the importance of socio-cognitive (e.g. stereotype threat), affective (emotions) and motivational (self-efficacy) factors in sustaining cognitive performance. The present study is the first to have explored how attitude to spatial tasks (pleasure in exploring) and WF self-efficacy interact with environmental features and relate to shortcut-finding performance.

Participants were asked to learn a path as they navigated through a VE with or without landmarks, and then to find a shortcut from their previous starting point to their destination. Their WF self-efficacy and pleasure in exploring were measured by means of two questionnaires.

As expected, the Landmark group performed better in shortcut-finding, confirming the findings of other studies that pointed to the informative value of landmarks for navigation [e.g. 3, 7, 19, 27].

Further, it newly emerged that the presence of landmarks and an aggregate measure of WF self-efficacy and pleasure in exploring accounted together for 22% of the variance in shortcut task performance. Notably, a significant interaction between environmental and individual difference factors showed that the latter were more predictive of performance in the more difficult condition (in a VE with no landmarks), whereas WF self-efficacy and pleasure in exploring were less influential in the easier condition (a VE with landmarks). Indeed, it is in the more demanding situations that personal factors intervene in coping with difficulties and finding appropriate strategies and solutions.

5 Conclusions

The multicomponent nature of WF abilities means that many variables relating to the environment, the task in hand, and individual factors, alone and in combination, need to be considered in order to account for its complexity. So far, cognitive processes (attention, memory, planning) and self-report measures of SOD and spatial anxiety have been the most often studied of the individual variables, [24, 32], whereas less attention has been paid to the potential enhancing value of a positive attitude to spatial tasks and WF self-efficacy, although an impressive amount of research has demonstrated the relevance of self-efficacy [1] and positive attitudes [5] in a variety of tasks and behavior.

The present study demonstrates that pleasure in exploring and WF self-efficacy relate to WF performance. This is a novel result, which can be explained by people's daily experiences. From childhood to old age, people frequently engage in orientation tasks - WF, planning routes, estimating direction and distance – more or less successfully (finding a destination or getting lost) and with variously positive (satisfaction, pride, relief), or negative (frustration, anger, sense of insecurity, fear of getting lost) associated emotions. It is plausible that past and present experiences contribute to building cognitive-affective units [33] relating to spatial orientation that, in turn, mediate future feelings and behavior, prompting fear and avoidance or pleasure and high self-efficacy when it comes to engaging in spatial tasks.

A limitation of this study lies in the small portion of variance (5%) explained by Att-Eff. This could depend on the instruments used and/or on the task. To measure WF self-efficacy we used a questionnaire in which the items describe spatial situations commonly found in everyday life. Bandura [1, 2] made the point, however, that the predictive power of perceived efficacy is stronger when it is assessed just before engaging in a specifically related task. It might therefore be useful to investigate the predictive power of self-efficacy by asking participants to assess it immediately before they perform a specifically related task. In addition, if WF self-efficacy derives partly from previous experience in spatial orientation tasks [1, 2], it may be that it is more predictive in previously experimented situations, i.e. in real-life tasks rather than in VEs. In future studies, it might also be interesting to test whether WF self-efficacy actually increases after spatial training and whether it can contribute to boosting any positive effects of training.

As for pleasure in exploring, this is a hitherto little analyzed construct and ours should be seen as a pilot study. Our participants were presented with relatively few items exploring their attitude to a variety of environment tasks. A broader range of situations, and the related positive emotions (satisfaction, pride, desire, fun, challenge) warrants more thorough investigation.

Finally, the specific contribution of WF self-efficacy and attitude to spatial tasks, also vis-à-vis spatial anxiety and subjective SOD, should be further analyzed in future. The existence of a strong correlation between the two variables raises questions about their actual distinctiveness and the direction of the relationship. Concerning the first point, it is worth noting that WF self-efficacy is a motivational variable likely to support performance through task-orientation and strategic behavior, whereas attitude to spatial tasks is mainly an affective component that pertains to the valence of emotions that anticipate and accompany the completion of a wayfinding task.

Motivational theories typically emphasize the close relationship between motivation and emotional states, but still consider them as two distinct components, both likely to favor goal achievement [2]. Interestingly, the affective component may be seen as a direct consequence of self-efficacy, based on the assumption that a high self-efficacy in relation to a specific task enhances positive emotions and strategic behavior, which in turn positively affect performance. A future study on a large sample should clarify this question, comparing two alternative predictive models: one where spatial self-efficacy and attitude give independent contributions to WF task performance; the other where attitude acts as a variable mediating between self-efficacy and WF task performance. In the present study, we averaged the instruments to obtain a single Att-Eff score in order to emphasize their predictive power, but the use of richer and more diversified measures might enable us to better distinguish between different variables and clarify how they relate to specific environment learning tasks.

Nevertheless, our results are innovative and should inspire further research on these topics: other non-cognitive aspects (e.g. personality traits) could be explored in relation to emotions, self-efficacy, and exploring, as recently suggested by Condon et al. [6]. Further research could also investigate the relationship between WF behavior and children's autonomy and freedom to explore their neighborhood [30, 44]. Taken together, these studies could open up new scenarios in the study of wayfinding behavior.

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