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Perspective taking ability is important in map reading for navigation – Unless you follow the instruction

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1. Introduction

The pervasive use of navigation assistance may have unwanted side-effects on wayfinding skills. Wayfinding skills are necessary for successful unassisted navigation, map reading, spatial orientation, and acquisition of survey knowledge in the real world. Correspondingly, it has been observed that everyday skills required for navigation and orientation may decline in the population (e.g., Appleyard, 2017; McKinlay, 2016), and map reading skills for wayfinding were found to be weak, as people struggle to determine self-location and self-orientation on maps and pointing target places (Liben et al., 2010). Individuals differ remarkably in their ability to form and use mental spatial representations of their environment, and spatial abilities play a decisive role (e.g., Hegarty et al., 2006; Ishikawa & Montello, 2006; Kozlowski & Bryant, 1977; Malinowski & Gillespie, 2001). Low-ability individuals might therefore be particularly dependent on navigation assistance. However, spatial abilities, knowledge, and skills such as map reading are still important, even when using navigation assistance. Users need to make decisions between suggested routes, recognize and memorize turning points, double-check provided information and occasionally compensate for inaccurate wayfinding instructions.

1.1. Transformation of visual map information into route knowledge during reading

Map reading for wayfinding is a particular purpose for using a map. In wayfinding, the navigator is part of the environment that is depicted on the map. A considerable number of interrelated processes, abilities, and skills as well as reading strategies might be involved in successful navigational map reading (Lobben, 2007). If a route is to be learned from a (digital) map, the relevant information must be mentally transformed into an easy-to-memorize format during reading. So-called route knowledge is an obvious format for this purpose. Route knowledge has been defined as an ordered sequence of associated condition–action pairs, which presuppose the ground-level navigator's perspective (e.g., at the gas station, turn right, Gillner & Mallot, 1998; Golledge, 1991). This kind of knowledge enables the navigator to travel the same route again (or backward), but it would typically not include knowledge about spatial relations between locations (Kelly et al., 2015). The mental transformation to obtain route knowledge during reading may involve separable components, such as the selection of useful landmarks (i.e., salient places along the route that can help memorization), detection and re-coding (verbalization) of turning actions and the organization of information (arrangement in the correct order).

A particular crucial mental process in map reading for navigation is the shift of spatial perspective. In the map's allocentric bird's-eye view, spatial information is related to an external coordinate system with quantitative distances and relations, which are independent of the position and heading of the navigator. In contrast, the navigator in the environment experiences a ground-level view with an egocentric spatial reference frame, i.e., spatial information is coded in relation to one's own body axes (e.g., left, right, in front, behind). A decisive factor is the alignment which refers to the correspondence between the orientation of the map and the actual heading of the navigator in the environment. For example, stationary "you-are-here" maps are often not aligned with the orientation of the navigator who stands in the environment facing that map (Klippel et al., 2006; Levine, 1982; Levine et al., 1984). This affects spatial performances negatively (Levine et al., 1982; May et al.,

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1995; Palij et al., 1984).

Components also mirror influential factors in the environment that are known to affect route memory. It has been found that the number of decision points along the route is important (Arthur & Passini, 1990; Raubal & Egenhofer, 1998). The number of options at the decision points is influential as well (Giannopoulos et al., 2014; O'Neill, 1991). Landmarks at decision points support wayfinding and route learning (e.g., Deakin, 1996; Wunderlich et al., 2023), especially when they are salient and visible (Raubal & Winter 2002; Winter, 2003). However, these factors can interact. A decision point with four options and a landmark can be easier to remember than one with three options and no landmark (Deakin, 1996). The type of action at a decision point can also affect route learning. It is easier to memorize "go straight" than to remember a turning decision (as cited in Giannopoulos et al., 2014). Therefore, to ensure successful route learning, it is essential to identify and pay close attention to the critical decision points of the route.

1.2. The need for skill acquisition

Evidence related to route learning has been obtained from studies in which participants learned routes from navigational experience under different environmental conditions (e.g., landmark availability). Whether the same factors are involved when learning the route information from a map, and whether map readers actually attempt to form a mental representation of the route that resembles route knowledge, is not known yet. Map readers might not dispose of the optimal strategy to read a map for learning a route depicted in it, particularly considering the pervasive use of navigation assistance in everyday life. Therefore, people might differ in strategy and skill.

As map reading for wayfinding is a complex task that involves different processes, skill acquisition is important to be able to navigate independently without a need for assistance. Skill acquisition, in general, consists of a structured program of instruction and repeated practice. In the context of map-based route learning, instructions should direct map readers' attention toward map areas and information pertinent to the acquisition of route knowledge, pointing out the necessity for mental transformations. Specifically, instructions emphasizing recognition of the relevant landmarks, correction of the misalignment in the allocentric-egocentric spatial perspective shift, or verbalization and correctly sequencing the landmarks and turning directions, might help individuals to use the map effectively for that purpose. Such a "how-to-learn-a-depicted-route-from-a-map" instruction would convey a description of a procedure or strategy as part of the map reading skill. In the process of skill acquisition, such a strategy needs to be repeatedly practiced to eventually become procedural knowledge (Anderson, 1982). Therefore, training in the form of repeated practice of the instructed learning method might help to improve performance. To the best of our knowledge, no study has investigated the effect of instruction and/or repeated practice on how to read a map for learning a depicted route.

1.3. Map reading viewing behavior

Viewing behavior may reflect information processing during map reading. Kiefer et al. (2014) asked participants to locate their spatial position on a map. Fixation times on relevant features of the map were related to performance in the task, suggesting that gaze patterns indicated purposeful information processing during map reading. Moreover, effective instructions on map reading might be reflected in corresponding gaze patterns that reflect the instructed distribution of attention on the map. Gaze patterns can therefore be informative in two ways: They can indicate whether an instructed reading strategy would actually be reflected in corresponding gaze patterns that indicate the distribution of attention on the map, and they can be related to actual spatial performance, indicating that the indicated reading process was indeed relevant for task-related information processing.

1.4. Individual differences in transformations of spatial perspectives in map reading

Differences between individuals regarding the formation and use of mental spatial representations of the environment have been related to spatial abilities. Spatial abilities have been shown to affect performance in navigation and spatial environmental learning (Hegarty et al., 2006; Hegarty & Waller, 2004, 2005; Kozhevnikov & Hegarty, 2001; Münzer et al., 2012).

Mentally compensating for misalignment, which is a requirement in map reading (see above), might be dependent on a form of spatial ability: spatial perspective taking ability. Spatial perspective taking ability refers to the ability to take spatial perspective different from one's physical view point (He et al., 2022).

It has been demonstrated that spatial perspective taking ability is related to spatial learning based on navigational experience in real-world environments as well as in virtual environments (e.g., Münzer, 2012; Münzer et al., 2020; Wolbers & Hegarty, 2010). Its test (SOT; Hegarty & Waller, 2004; Kozhevnikov & Hegarty, 2001) requires imagining the perspective of an object presented on a map and assuming its relative direction to another object on the same map. Therefore, it involves a mental shift between a bird's eye view of the map and the ground-level view experienced by the navigator in the environment. Thus, in the SOT a more specific application of spatial perspective taking (He et al., 2022) is measured that was assumed to be a crucial mental transformation of reading route information from a map. In wayfinding with maps, individual differences in spatial perspective taking ability might be reflected in navigation errors when attempting to resolve misalignments at turning points of the route.

However, under particular circumstances, differences between individuals based on their ability might be suspended. For instance, additional visual information and/or digital assistance functions could compensate for low ability. A change of the role of ability in a task depending on condition (such as additional information) corresponds to an aptitude-treatment-interaction. An aptitude-treatment interaction regarding the role of perspective taking ability was demonstrated for allocentric-egocentric perspective shifts that were supported by an animation, as opposed to a control condition in which the perspective taking shift had to be performed mentally (Münzer, 2012). In other words, it is possible to diminish the role of individual differences in spatial ability with the change in the digital visual representation. Building upon this, we investigate whether providing instructions and training on map-based route learning would also lead to such an interaction to decrease the role of perspective taking ability.

1.5. The present study

The general goal of the present study was to examine whether map reading instructions on learning an indicated route from a map (or instructions plus training) can improve subsequent navigation performance from memory in a virtual environment. A particular focus was whether instructions and training would reduce the role of spatial ability in navigation performance. Moreover, gaze patterns obtained with eye-tracking during map reading were analyzed to examine whether instructed reading behavior was reflected in the gaze patterns. The general paradigm involved learning a predefined route from a map (Fig. 1) and navigating that route in a virtual environment (Fig. 2) from

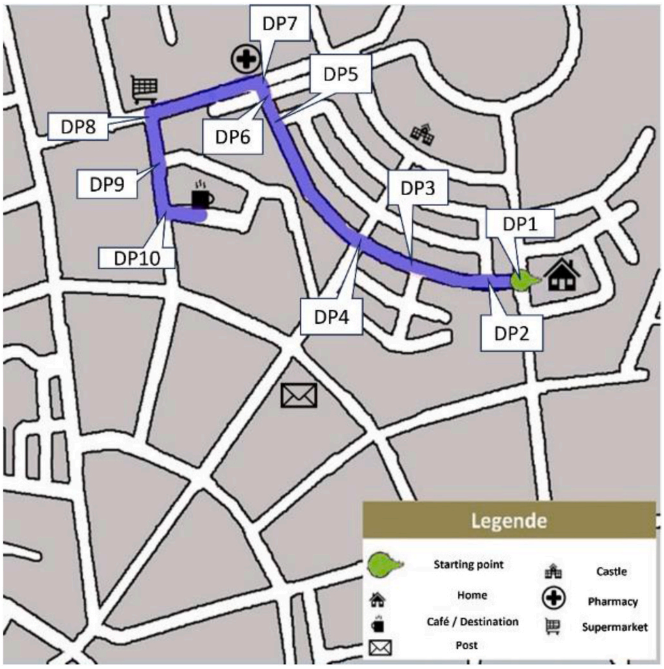


Fig. 1. Map with the route (blue) and starting point (green). DP = decision point. The original map showed labels in the German language. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

memory. Decision points along the route varied with regard to the existence of landmarks, the requirement to change the direction, and to resolve misalignment. During map reading, eye tracking was applied, and during navigation, the number of turning decision errors was measured. A control condition, an instruction condition, and an instruction + training condition were prepared. The purpose of the instruction was to convey a map reading strategy focusing on the relevant route information. In the instruction + training condition, three repeated training trials with different training maps and routes were additionally administered that were combined with a subsequent memory task in which participants attempted to recall the route information in the form of verbalized condition-action pairs ("at the pharmacy, left") in the correct order.

Insights into the map reading process were obtained using eye tracking data. We expected that gaze patterns in the conditions with instruction would reflect more attention towards the task-relevant areas of the map, as described in the instruction (compared with the control condition).

Hypothesis 1. It was expected that gaze patterns in the conditions with instruction would show longer views on those parts of the map that were explicitly addressed in the instructions as well as they would show more switches between specific parts, compared to the condition without instruction. (Note: More detailed hypotheses about those specific areas on the map are provided in the section "Analytical approach".)

Furthermore, we expected differences in the navigation performance between the conditions.

Hypothesis 2. It was expected that participants in the instruction condition would make fewer navigation errors, compared with the control condition (effect of instruction). Likewise, it was expected that participants in the instruction + training condition would make fewer navigation errors, compared with the control condition as well as with the instruction condition (additional effect of training over instruction).

Regarding the role of individual differences in spatial perspective taking ability, an aptitude-treatment-interaction was hypothesized. Spatial ability would play a decisive role in the control condition, but it would not be crucial if instructions were provided. The expected aptitude-treatment-interaction is, therefore, expected as an ability-as-compensator interaction, i.e., participants with lower ability will benefit more from the supportive instruction than participants with higher ability (Kühl et al., 2022; Mayer & Sims, 1994).

Hypothesis 3. An interaction between individual differences in perspective taking ability and condition was expected. A significant relationship between spatial perspective taking ability and the number of navigation errors would only be found in the control condition. This relationship would decrease or even disappear in the instruction condition and the instruction + training condition.

Additional explorative analyses were conducted regarding whether eye-tracking-based measures during reading would predict navigation performance (operationalized by navigation errors), particularly for decision points at which difficulties were realized (e.g., need for correction of misalignment, "go straight" option). The results were compared between the three condition groups for each decision point.

The current study is novel in various aspects. First, it introduces a new paradigm that combines allocentric learning of a route from a map with egocentric navigation in the absence of a map. This paradigm is underrepresented in the existing literature, although the formation of a mental representation of a route and the actual use of this representation in a wayfinding task is an ecologically valid test of the success of map reading. Second, the study investigates the effects of instruction and

Fig. 2. A street in the virtual environment (VE) from the player (participant) view.

short practice training as means to improve route memory when reading a map with a given route, which is a novel approach to strengthen route memory in the context of navigation assistance. Third, the study investigates aptitude-treatment interactions that are rarely explored in spatial cognition research. We aim to investigate the role of spatial ability in the map-based route learning task and test if instruction and training will diminish that role of ability. Finally, while eye-tracking methodology is used in map reading studies to improve map design principles, it is not commonly used to understand the formation of a mental representation through an explicit reading strategy and to predict the success of route learning in a subsequent wayfinding task.

2. Method

2.1. Design

There were three experimental conditions. The control condition consisted only of the map-reading study phase (with eye-tracking) and the subsequent memory-based navigation in the virtual environment. In the instruction condition, participants received a written instruction before the map-reading study phase. In the instruction + training condition, participants received both the written instruction as well as three training trials before the paradigm started. The dependent variables are gaze duration on areas of interest, the number of gaze switches in the study phase, and the number of navigation errors in the navigation phase.

2.2. Sample

Currently, there are no studies with a similar setting to estimate the effect sizes. However, it was expected that a specific instruction to extract the important information from the map would result in large effect sizes in a variance analysis to compare the three groups (i.e., $f = 0.40$). For a test power of 0.80 and $\alpha = .05$, the minimum sample size is N = 66 (according to G*Power, Faul et al., 2007). The multiple regression analyses with two predictors and their interaction would need N = 36 for large effects ($f^2 = 0.35$, power at 0.80, according to G*Power, Faul et al., 2007). The sample in this study consisted of 84 participants (60 female, 23 male, 1 divers) with a mean age of $M = 21.98$ years ($SD = 2.51$ years), ranging from 18 to 31 years. All participants were students at a German university and got course credit for their participation. There were 27 (20 female, 7 male) participants in the control condition, 26 participants (19 female, 6 male, 1 divers) in the instruction condition, and 31 participants (21 female, 10 male) in the instruction + training condition.

2.3. Materials

The map presented in all conditions (Fig. 1) showed the route and six landmarks out of which two are irrelevant to the route. The landmarks on the map were indicated by visual symbols that were verbally denoted in the legend. Decision points varied with respect to possible wayfinding difficulties. At the starting point (DP1), participants would find themselves oriented towards the house. An initial U-turn in the virtual environment would therefore be necessary to start the route in the correct direction. The following five decision points (DPs 2–6) did not require an actual turn. The choice at DP7 was forced because it was a T-intersection without a “go straight”-option. At DP7 and DP8, landmarks (“pharmacy”, “shop”) were available. In contrast, turns at DP9 and DP10 had to be remembered without a landmark. DP8, DP9, and DP10 included “go straight” options. Corrections of considerable misalignment were necessary at DP8 and DP10.

The virtual environment (VE, Fig. 2) was a fictional village. During navigation, the participants were passively moved in walking speed in the VE from one decision point to the next. At each decision point, participants could make turning decisions by selecting one of the possible options using a gamepad. The options are the paths that lead away from the intersection except the path they were coming from (e.g., at DP2, there are two options, and at DP4, there are three options, Fig. 1) If the choice was correct, the passive movement continued to the next decision point. If the choice was incorrect, feedback was given, and the participant was provided with another opportunity to select an option. The measure of navigation performance was the number of navigation errors (incorrect choices). The minimum number of navigation errors is 0. The maximum number is theoretically unbounded since each wrong selected option was counted, i.e., at each decision point more than one error could be made.

In both treatment conditions, an instruction was presented describing a map reading strategy for wayfinding (see Appendix). The instruction told participants (1) to inspect the legend and to match the symbols with the landmarks on the map, (2) to attend to the starting and the destination point of the route, (3) to identify the walking direction and initial orientation (heading) at the starting point, and (4) to recognize and to learn the turning directions at the decision points in the order of the route, considering landmarks (if available) and the actual egocentric orientations of the navigator approaching the intersections.

In the instruction + training condition, participants applied the instructed map reading strategy in three training trials with three different training maps. These maps were similarly designed as the map shown in Fig. 1, and the routes had the same appearance and complexity and the same number of decision points and landmarks. After studying the map, participants attempted to recall the correct turning decisions at the decision points in the correct order in verbal form. A printed table was used for the recall task in which the decision points were indicated as a numbered list (“1. …, 2. …. , 3 ….” etc.) If there had been a

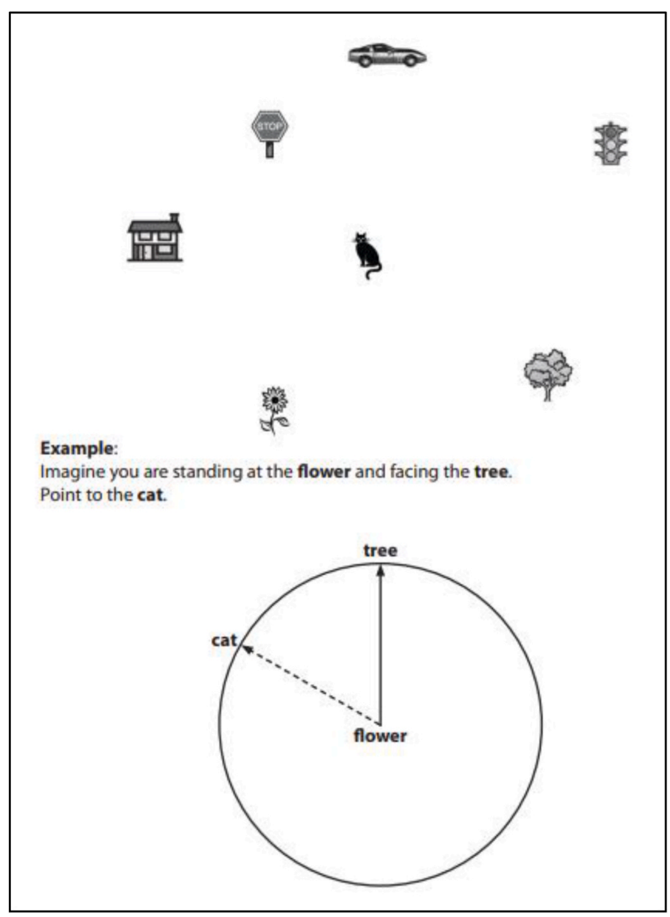


Fig. 3. Sample item of the Spatial Orientation Test (SOT, Hegarty & Waller, 2004).

landmark, then the landmark was mentioned (e.g., "4., gas station: …").

The Spatial Orientation Test (SOT; Hegarty & Waller, 2004; Kozhevnikov & Hegarty, 2001, Fig. 3) was used to measure the spatial perspective taking ability of each participant. The test consists of twelve items, each on a separate paper sheet. On the top of each page, the configuration of seven objects is shown from the bird's eye view as on a map (this is the same on each page). On the bottom, an item-specific instruction denoting three objects of the map and an answer circle is provided. The participant is asked to look at the map and, following the item-specific instruction, imagine standing at one object (which corresponds to the center of the answer circle), looking in the direction of another object (which corresponds to the top of the answer circle) and to draw an arrow from the center to the rim of the circle corresponding to the pointing direction to a third object. The test must be finished within 5 min. The test score is the average angular error over the solved items. The angular error of one item is the difference between the participant's arrow position and the correct solution with a theoretical maximum of 180°. Lower scores (lower angular error) indicate higher ability. Reliability estimates are good, $\alpha = .79$ and $\alpha = .85$ (Hegarty & Waller, 2004).

In addition, questions were asked to obtain information about the participants' sex, age, occupation, study subject, and study semester.

2.4. Apparatus

Gaze data were recorded with a Tobii TX300 remote eye tracker unit with a recording frequency rate of 300 Hz connected to a 23-inch monitor with an aspect ratio of 16:9 and a resolution of 1920 x 1080 pixels. The eye tracker was linked to the E-Prime 2.0 software (Psychology Software Tools Inc, 2012) with the extension for Tobii (Psychology Software Tools Inc, 2011). The calibration procedure included nine points.

The virtual environment (VE) was presented on three 32-inch monitors with a resolution of 2560 x 1440 pixels each (i.e., 7680 x 1440 pixels in total) that were set up in a curve around the participant to enhance the 3D experience of walking through the simulation. The VE was programmed using the game engine Unity (Haas, 2014).

2.5. Procedure

Each participant was tested individually, and each individual session took between 30 and 40 min. First, the participant completed the SOT. Thereafter, the participant completed a short practice phase in the VE. The purpose of the practice phase was to get familiar with the virtual movement in the virtual environment, e.g. to experience the optical flow and to use the controller to make a decision at an intersection. In the practice phase, a different part of the virtual environment was utilized. Participants followed ad-hoc instructions for turning at decision points. In the practice phase, they did not read a map and did not learn a route.

In the instruction condition, the participant then received and read the map reading instructions. In the instruction + training condition, the participant received and read the map reading instructions and performed the three-map reading and route recall training trials. In the control condition, neither instruction nor training was provided. In the main experimental task, the participant was presented with the map shown in Fig. 1 and asked to learn the predetermined route. The map was shown for 40 s. During reading the map, the participants' eye movements were recorded. Afterward, the participant navigated the route in the virtual environment from memory. Finally, the participant completed the demographic questionnaire.

2.6. Analytical approach

Hypothesis 1 was further specified regarding the four different components of the instruction (see above and Appendix):

Hypothesis 1.1a: The participants in the instruction conditions should view on the landmarks on the route longer than participants in the control condition (instruction component 1).

Hypothesis 1.1b: Participants in the instruction conditions should view longer on the legend (instruction component 1).

Hypothesis 1.1c: Participants in the instruction conditions should switch more between the legend and the landmarks (instruction component 1).

Hypothesis 1.2: Participants in the instruction conditions should view longer on the starting and the end point of the route (instruction components 2 and 3).

Hypothesis 1.3: Participants in the instruction conditions should view longer on turning decision points (instruction component 4).

The viewing time was measured by the duration of fixations on the predefined areas of interest (AOIs, Fig. 4). The switches between legend and landmarks (Hypothesis 1.1c) were measured by switches between fixations on the respective AOIs. The AOIs were defined according to the formulated hypotheses, i.e. each landmark (including starting and end point) and the legend as well as each point where the participants must turn have their own AOI. One exception is AOI-4, which includes, additionally to the turning point, the two previous decision points because they might be important for the turning point as adjacent decision points.

All hypotheses were tested by an ANOVA using condition as the independent variable and the respective gaze measure as the dependent variable. The comparisons between the conditions (control vs. instruction and control vs. instruction + training) were performed by post-hoc tests (Tukey test, one-sided) since the corresponding contrasts would not be orthogonal.

Hypothesis 2 was answered by an ANOVA using two contrasts with condition as the independent variable (between-subjects) and the number of navigation errors as the dependent variable. The contrasts were formulated orthogonal, (1) comparing the control condition with the instruction condition and (2) comparing the control and instruction conditions with the instruction + training condition.

Hypothesis 3 was tested by a multiple regression model with the number of navigation errors as dependent variable. The condition as

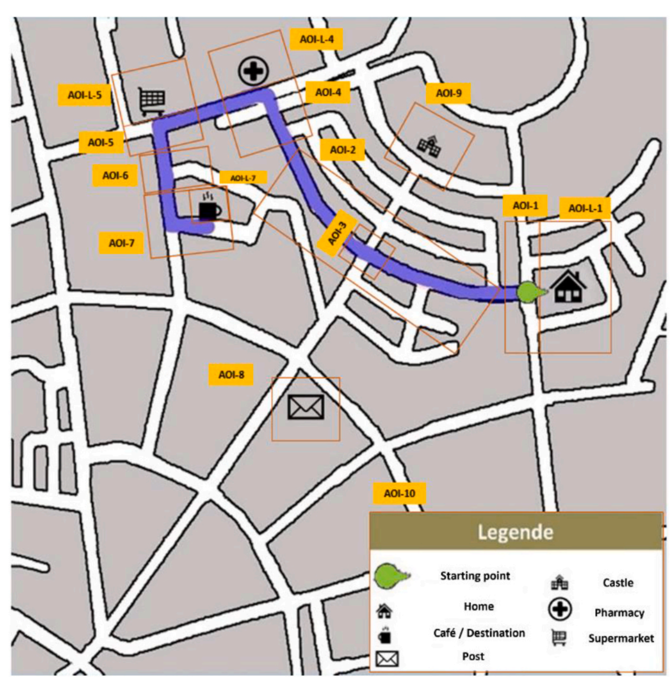


Fig. 4. Map with areas of interest (AOIs). AOIs 1, 4, 5, and 7 contain a separate sub-AOI (e.g., AOI L-4). These "L"-labeled sub-AOIs denote only the landmark and not the actual intersection.

independent variable was coded with two dummy variables, the first one indicating the instruction condition with 1 (both other conditions were indicated with 0) and the second one indicating instruction + training condition with 1 (and the other two conditions with 0). Additionally, the spatial perspective taking ability (measured by the SOT) and both aptitude–treatment interaction (ATI) terms (SOT x 1. dummy variable; SOT x 2. dummy variable) were included as predictors. Note, the first interaction term indicates the ATI for the instruction and the second interaction term indicates the ATI for the instruction + training.

Additionally, the statistical models of all hypotheses were also estimated including gender as control variable to reveal potential gender effects.

All statistics were conducted using R statistics (R Core Team, 2023) with the packages psych, version 2.3.6 (Revelle, 2023), afex, version 1.3–0 (Singmann et al., 2023), and emmeans, version 1.8.7 (Lenth, 2023).

3. Results

Table 1 shows descriptive statistics for the considered gaze measure for hypotheses 1.1–1.3 (msec for duration and counts for switches), the navigation performance (errors), and the SOT (average angular error). An ANOVA showed no significant difference between the three conditions for the SOT average angular error, $F(2, 81) = 0.02$, $p = .982$. However, there was a floor effect in the number of navigation error, since n = 47 participants had no error at all.

3.1. Analyses of the eye tracking measures

All hypotheses considering eye tracking measures were analyzed by an ANOVA with condition as independent variable. Hypothesis 1.1a could not be confirmed. There was no main effect of condition on the fixation duration on landmarks (AOI-L-1, AOI-L-4, AOI-L-5, AOI-L-7), $F(2, 81) = 0.07$, $p = .930$, $\eta^2 = 0.002$. However, as it was expected in Hypothesis 1.1b, there was a significant difference between the conditions in the fixation duration on the legend of the map (AOI-10, Table 2), $F(2, 81) = 6.47$, $p = .002$, $\eta^2 = 0.138$. The post-hoc tests revealed a significant difference between the control and the instruction condition, diff = 3005 [1228; ∞], $t(81)$, = 3.52, $p = .001$ as well as between the control and the instruction + training condition, diff = 1992 [289; ∞] $t(81) = 2.44$, $p = .022$, with a longer fixation duration in both instruction conditions.

There were no significant differences between the conditions with respect to the fixation switches between the landmarks and the legend, $F(2, 81) = 2.18$, $p = .120$, $\eta^2 = 0.051$. Thus, Hypothesis 1.1c could not be confirmed. However, further analyses differentiating the switching direction (from landmark to legend and from legend to landmark) revealed a significant difference between the conditions with respect to switches from the landmarks to the legend, $F(2, 81) = 5.31$, $p = .007$, $\eta^2 = 0.116$. Post-hoc tests confirmed this pattern only for the comparisons between control and instruction condition, diff = 1.70 [0.61; ∞], $t(81) = 3.26$, $p = .002$. Although there was a similar descriptive difference between control and instruction + training condition, the post-hoc comparison was not significant, diff = 0.78 [−0.26; ∞], $t(81) = 1.56$, $p = .136$. These results might indicate that instructed participants considered the symbols on the map and searched for the respective symbols on the legend.

The results of the ANOVA testing Hypothesis 1.2 showed a significant main effect of condition on the fixation duration on the starting and endpoint, $F(2, 81) = 5.15$, $p = .008$, $\eta^2 = 0.113$. However, the post-hoc tests revealed both treatment conditions did not differ from the control condition, $|diff| \leq 1494$, $p \geq .240$. However, further detailed analyses revealed a significant difference in the expected direction only for the endpoint (Café), $F(2, 81) = 10.00$, $p < .001$, $\eta^2 = 0.198$. This could be traced back to the difference between the control condition and the instruction + training condition, diff = 2296 [1004; ∞], $t(81) = 3.70$, $p < .001$.

Hypothesis 1.3 concerned viewing times on decision points with change of direction (DP 7/8/10 corresponding to AOI-4/-5/-7). There was a significant difference between conditions regarding the fixation

Table 1
Descriptive results of fixation durations [ms] on areas of interest, the Spatial Orientation Test (SOT), and the navigation errors, separated for each condition.

	Condition	M	SD	Min	Max	Range	Skewness	Kurtosis
Dur. on LM	**Control**	8906	3366	3372	15968	12596	0.25	−0.74
	Instruction	9031	4306	1702	16157	14455	0.01	−1.26
	Instruction + training	9288	3976	4374	21583	17209	1.30	1.56
	All conditions	9086	3857	1702	21583	19881	0.60	0.27
Dur. on legend	**Control**	2665	2001	0	7446	7446	0.49	−0.61
	Instruction	5671	3859	705	19559	18854	1.68	4.04
	Instruction + training	4658	3194	146	16826	16680	1.66	4.37
	All conditions	4331	3306	0	19559	19559	1.81	5.63
Switch. bet. LaL	**Control**	2.37	2.50	0	9	9	0.95	0.06
	Instruction	4.19	3.50	0	16	16	1.33	2.45
	Instruction + training	3.35	3.42	0	17	17	2.09	5.64
	All conditions	3.30	3.23	0	17	17	1.74	4.47
Dur. on SaE	**Control**	8413	3026	1431	14033	12602	−0.14	−0.34
	Instruction	6919	3097	1805	12236	10431	0.13	−1.16
	Instruction + training	9771	3769	2608	16967	14359	−0.29	−0.81
	All conditions	8452	3504	1431	16967	15536	0.01	−0.71
Dur. on TP	**Control**	11317	3811	4037	19365	15328	0.01	−0.78
	Instruction	11355	3900	2148	19714	17566	−0.31	−0.37
	Instruction + training	14108	5405	1780	26455	24675	0.11	−0.30
	All conditions	12359	4637	1780	26455	24675	0.29	0.26
Navi. errors	**Control**	1.07	1.30	0	4	4	1.19	0.25
	Instruction	0.38	0.57	0	2	2	1.06	0.01
	Instruction + training	1.00	1.39	0	5	5	1.58	1.85
	All conditions							
SOT	**Control**	28.73	24.51	6.00	99.67	93.67	1.53	1.46
	Instruction	27.89	25.13	5.67	116.90	111.23	1.88	3.63
	Instruction + training	29.07	21.19	6.67	90.78	84.11	1.16	0.49

Note: Abbreviations: Dur.: duration; LM: landmarks; bet.: between; LaL; legend and landmarks; SaE: starting and endpoint; TP: turning points; the theoretical minimum of the navigation error per participant is 0 and has an unbounded maximum, the theoretical scores of SOT range from 0° to 180°.

Table 2
Mean (Standard deviation) of the fixation duration separated for all AOIs and conditions, corresponding decision points, and results of comparisons between conditions.

	Corresponding decision points	Condition					
		Control *M* (*SD*)	Instruction *M* (*SD*)	Instruction + training) *M* (*SD*)	Averaged over all conditions	ANOVA value of *F* (2,81)	Post-hoc comparisons[a]
AOI-1	DP1	5630 (2977)	4308 (2308)	4692 (2044)	4875 (2487)	2.05	
AOI-L-1	–	2858 (2370)	1896 (1682)	2298 (1251)	2354 (1824)	1.94	
AOI-2	DP3/DP4	5066 (3200)	3278 (1880)	2032 (1217)	3393 (2533)	13.53[c]	C – I[a]; C – I + T[c]
AOI-3	DP4	658 (893)	484 (769)	557 (589)	567 (747)	0.36	
AOI-4	DP5/DP6/DP7	6206 (2271)	6050 (2325)	5495 (2928)	5895 (2538)	0.63	
AOI-L-4	–	792 (1083)	1474 (1460)	692 (1029)	966 (1229)	3.45[a]	I – I + T[a]
AOI-5	DP8	2327 (2089)	2694 (1536)	3535 (1901)	2887 (1911)	3.24[a]	C – I + T[a]
AOI-5-L	–	906 (1045)	1149 (1311)	1106 (1338)	1055 (1232)	0.30	
AOI-6	DP9	2287 (2731)	2053 (2950)	1771 (1975)	2024 (2533)	0.30	
AOI-7	DP10	2783 (1852)	2611 (1729)	5079 (3090)	3577 (2601)	10.00[c]	C – I + T[b] I – I + T[c]
AOI-L-7	–	1210 (1221)	1202 (1202)	1849 (1619)	1443 (1396)	2.13	
AOI-8	–	150 (359)	123 (227)	328 (504)	207 (396)	2.39	
AOI-9	–	219 (374)	775 (777)	620 (673)	539 (665)	5.55[b]	C – I[b]; C – I + T[a]
AOI-10	–	2665 (2001)	5671 (3859)	4658 (3194)	4331 (3306)	6.47[b]	C – I[b]; C – I + T[a]

Note: AOIs are depicted in the map in Fig. 4. "L" means the area with the landmark within the respective AOI. The corresponding decision points list all DPs that are contained in the AOI.
[a]p < .05.
[b]p < .01.
[c]p < .001.
[d]Control; Instruction; Instruction + Training.

duration on these decision points, $F(2, 81) = 3.73$, $p = .028$, $\eta^2 = 0.084$. However, the post-hoc comparisons showed only a significant difference between the control condition and the instruction + training condition, diff = 2792 [331; ∞], $t(81) = 2.36$, $p = .027$, but not between the control condition and the instruction condition, diff = 39 [−2531; ∞], $t(81) = 0.03$, $p = .500$.

3.2. Analyses of the behavioral measures

Hypothesis 2 was tested with an ANOVA with condition as independent variable and navigation errors as dependent variable. It revealed a nonsignificant effect of condition on the number of navigation errors (see Table 1), $F(2, 81) = 2.82$, $p = .065$, $\eta^2 = 0.065$ (Hypothesis 2). The first contrast showed significantly fewer errors in the instruction condition compared to the control condition, $b = -0.34$, $t(81) = 2.15$, $p = .034$. However, the second contrast was not significant, $b = 0.09$, $t(81) = 1.03$, $p = .307$, there was no significant difference in the number of errors between the control and instruction conditions and the instruction + training condition.

For testing Hypothesis 3, the multiple regression model with SOT, condition (indicated by two dummy variables), and their interaction terms as predictors were significant, $F(5, 78) = 4.65$, $p < .001$, with a significant interaction term between the first dummy variable (indicating the instruction condition) and SOT, $b = -0.029$ [−0.054; −0.005], $p = .018$, $f^2 = 0.05$. The interaction term between the second dummy variable (indication the instruction + training condition) and SOT was not significant, $b = 0.017$ [−0.043; 0.008], $p = .175$, $f^2 = 0.02$. Fig. 5 shows the stronger relationship between SOT and errors in the control condition and nearly no relationship in the instruction condition. The additional training, however, seems to increase the relationship between the error rate and the SOT.

Results did not change significantly (i.e., all significant results were the same) if gender was included as control variable.

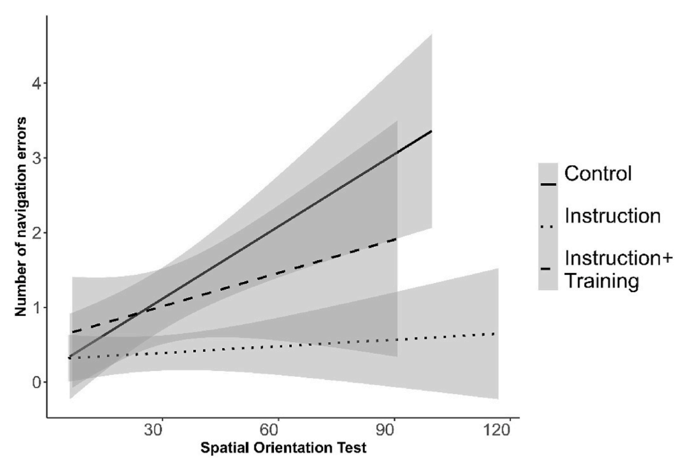


Fig. 5. Relationship between the results in the SOT and the navigation error rate separated for control condition, instruction condition, and instruction + training condition. SOT is indicated as angular error (higher = worse).

3.3. Explorative analyses of navigation errors and eye tracking measures

The correspondence between the distribution of the errors over the ten decision points (DPs, Fig. 6) and the fixation duration on the AOIs (Table 2) was exploratively considered. Table 2 includes the decision points that are contained in the respective AOI as well as the results of ANOVAs comparing the three conditions with respect to the viewing times on the specific AOIs and the significant pairwise post-hoc comparisons. Please note that these analyses are explorative and must be interpreted with caution.

Descriptively, the results suggest that there are differences between

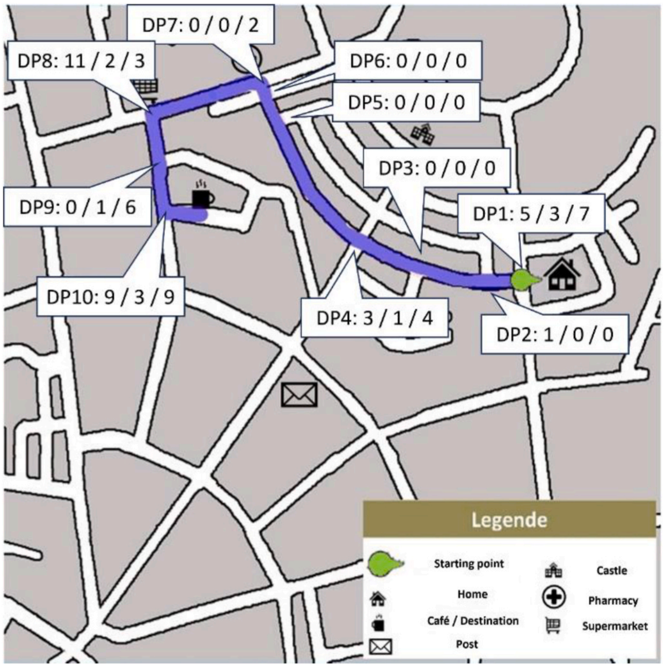


Fig. 6. Map with errors at the ten decision points (DPs) separated for each condition (control/instruction/instruction + training). The theoretical maximum of the navigation errors is unbounded.

the DPs and corresponding AOIs regarding the number of errors and the viewing times (Fig. 6, Table 2). Whereas navigation errors indicate actual challenges of learning the route from the map, longer viewing times on the AOIs might indicate that participants assumed wayfinding challenges while reading the map there. Some DPs/AOIs apparently show a correspondence between viewing times and performance, i.e., participants fixated longer on AOIs that covered difficult DPs (as indicated by the actual number of navigation errors). However, at other DPs/AOIs, there seemed to be a mismatch.

The longest viewing times were found on AOI-1 and AOI-4 with around 4–6 s in all conditions. AOI-1 corresponds to the starting point on the map with a misaligned heading in the VE. This might be considered objectively difficult, and a higher number of errors were actually made here. At DP5, DP6, and DP7 covered by AOI-4, however, navigation performance was nearly error-free (Fig. 6). Here, the route had gone straight (no changes of direction needed) until the T-intersection with the landmark “pharmacy” was reached. “Go straight” was no option here, and the landmark served as a cue. Because of these features, the decision point might be considered easy. Although the invested viewing time at AOI-4 might have prevented participants from making errors, it might be possible that the long viewing time indicated overestimated difficulty.

The opposite pattern could be found for AOI-5/6/7 with shorter viewing times between 2 and 4 s across conditions. Apparently, the potential difficulty of these intersections might have been overlooked, since more errors were made at the corresponding decision points, DP8 and DP10 (and DP9 as well in the instruction + training condition), compared to other decision points. Difficulties were created by the necessity to deliberately deviate from the available “go straight” option, the absence of landmarks, and strong misalignment.

Additional exploratory observations and analyses (Table 2) reveal that conditions differed pairwise at seven AOIs with regard to fixation durations. For example, in the instruction + training condition, participants viewed longer on AOIs 5, 7, and 9 compared to the control condition, indicating that participants paid more attention to landmarks and the legend. In contrast, participants in both instruction conditions viewed shorter on AOI-2 compared to the control condition, presumably because the corresponding DPs (3 and 4) had no landmarks. A positive performance effect of both treatment conditions could be found at DP8, where the error rate was lower, compared to the control condition (Fig. 6). However, only the instruction + training condition showed a longer viewing time on the corresponding AOI-5, compared with the control condition (Table 2).

In further explorative analyses, a significant negative correlation of considerable size was found in the control condition between the fixation duration on relevant parts of the map (i.e., all AOIs except for the irrelevant AOI 8 and 9, i.e., the castle and the post station, Fig. 4) and the number of errors in the navigation activity, $r = -0.60$, $p < .001$. This relation suggests that individual variability in the distribution of the viewing times on relevant parts of the map predicted variability in the number of errors in the subsequent navigation activity. This relationship could neither be found in the instruction condition nor in the instruction-and-training condition. A reason might be a reduced variability in viewing times between participants ($SD_{\text{Control}} = 5995$ms; $SD_{\text{Instruction}} = 5569$ms; $SD_{\text{Instruction + Training}} = 4689$ms), which might be the result of a successful treatment that made viewing behaviors more similar between participants. Note that the summed viewing time on relevant parts of the map was the same in all conditions (27,150ms $\leq$ M $\leq$ 27,819ms). Thus, the differences in the relationship of viewing distributions to performances between conditions are not caused by longer average viewing times on relevant parts in a particular condition per se, but rather by its individual variation during individual reading processes.

Similar to hypothesis 3, a multiple regression model including condition by two dummy variables (indicating the instruction condition and the instruction + training condition), the summed fixation duration on the relevant AOIs (in seconds) as well as both interaction terms as predictors and the number of errors as the dependent variable. The model was significant, $F(5, 78) = 3.95$, $p = .003$ with two significant interaction terms between the dummy variable indicating the instruction condition and the fixation duration, $b = 0.109$ [0.003, 0.215], $p = .044$, $f^2 = 0.08$ as well as between the dummy variable indicating the training + instruction condition and the fixation duration, $b = 0.140$ [0.029, 0.251], $p = .014$. (Fig. 7).

Thus, if participants were not instructed, then a negative relationship between (longer) viewing times on relevant areas and (smaller) number of navigation errors was obtained. If, however, the participants were instructed where to focus on the map for learning the route, then there was a significantly smaller relationship found between viewing times and errors in the navigation task. This pattern indicates an aptitude-

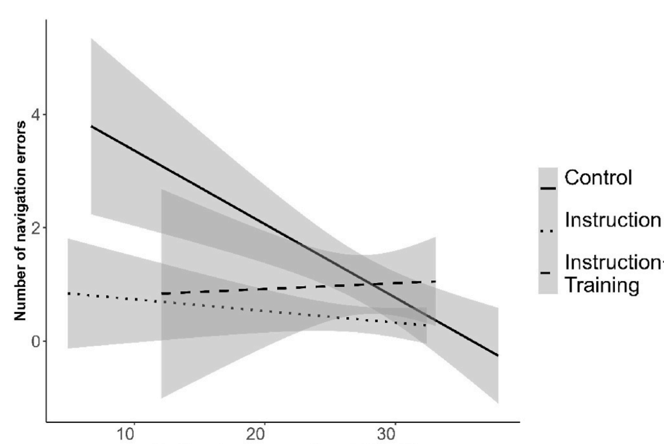


Fig. 7. Relationship between fixation duration on relevant AOIs and the number of errors separated for the three conditions, control, instruction, and instruction + training.

treatment-interaction. The aptitude is map reading skill here, as indicated by viewing times on relevant areas that reflect knowing where and how to look at the map to obtain relevant information for route learning. Without instruction, the relation between viewing and navigation performance reflects the pre-existing skill that participants brought to the task. With instruction to read the map, the decrease in the relation suggests that the navigation errors that occurred were not based on individual differences in map reading. The similar interplay with the fixation duration on relevant parts and the SOT on the one hand and the error rate and condition on the other hand (hypothesis 3) suggests a relationship between the fixation duration and SOT. Therefore, a mediation analysis was conducted to test whether the effect of spatial orientation ability on the error rate is mediated by the fixation duration on the relevant parts in the control condition. The path model showed that the direct effect from SOT on the error rate was not significant, $c' = 0.02$, $p = .272$, and the effect of SOT on the mediator, the fixation duration, was significant, $a = -0.15$, $p = .030$. However, the effect of the fixation duration on the error rate was not significant, $b = -0.08$, $p = .146$ and the bootstrapped 95 %-confidence interval of the indirect effect included 0, $a*b = 0.01$ [0.00; 0.03].

4. Discussion

The present study examined the effects of instruction and of instruction + training on reading a digital map for navigation, considering the role of spatial perspective taking ability. The experimental paradigm involved learning a pre-planned route depicted on a digital map and navigating that route in a virtual environment from memory. Map reading for navigation was thought to involve specific mental processes for the transformation of map-based visual information into route knowledge. It was assumed that spatial perspective taking ability would play a crucial role in a central transformation, the allocentric-egocentric shift of spatial perspective including the correction of misalignment. This transformation as well as further information processing for route learning from a map (e.g., using landmarks as cues) were reflected in a map reading instruction and in an additional short training. The goals of the present study were to examine (1) whether map-reading for navigation can be fostered by those instructions (or instructions + training), (2) whether the role of individual differences in spatial perspective ability for navigation performance would change after map reading instructions (or instructions + training), and (3) whether gaze patterns during map reading differed after map reading instructions (or instructions + training), compared to a control condition. In addition, exploratory analyses investigated navigation errors at specific decision points and their relationship with gaze patterns.

4.1. *Effect of instruction and training*

Results showed that the map reading instructions reduced navigation errors compared with the control condition (Hypothesis 2). We conclude that the instruction supported processing the route information in the map such that the route information was retrievable in memory in the subsequent navigation activity. However, the same instruction combined with a short training was not effective. One explanation might be that the training created an interference between training maps and the experimental map. Alternatively (or in addition), a change in the recall format between training and test might have contributed to confusion. During the training, the participants had to recall the route in verbal form with an ordered sequence of condition-action pairs and the landmarks as verbal cues. In the experimental test, the recall format changed, because participants walked through the virtual environment and experienced the decision points and landmarks in the environment visually, from a true egocentric view, and with more detail (e.g. regarding the number of choices, etc.).

The mismatch between practice training and the actual navigation task with regard to retrieval format (practice training: verbal; navigation task: visual-spatial) might have hampered a practice training effect. However, there was a rationale for the verbal retrieval format during practice. We assumed that explicitly verbalizing the information read from the map ("re-coding") would support understanding (e.g., "at the T-intersection with the pharmacy: left"). In addition, we assumed that the complete ordered list of such condition-action pairs would be easier to memorize in verbal form. This applies both to the retrieval in the training situation as well as in the navigation situation in the virtual environment. In the test map, there was the opportunity for a parsimonious memorization by consolidating the consecutive "go straight" decisions between decision points DP 2 and DP 6 (e.g., "go straight until you see the pharmacy", Fig. 6). This opportunity was not explicitly addressed in the instruction. Although it might appear obvious in the map, there were errors at decision point DP 4 suggesting that not all participants recognized that opportunity during map reading. Furthermore, the consolidation opportunity might not be an explanation for the ineffective practice training, because training maps provided the same opportunity (e.g., training map 1, see Appendix B).

4.2. *Aptitude-treatment interactions in map reading*

Results confirmed Hypothesis 3, demonstrating the expected aptitude-treatment-interaction. In the control condition, individual differences in spatial perspective taking ability played an important role in successful route learning from the map as indicated by the relation of the ability measure with the number of errors in the subsequent navigation activity. This relation suggests that ability differences in the mental process of allocentric-egocentric perspective shifts are generally relevant in map reading for wayfinding, including the correction of misalignment.

With instruction, however, that role of spatial perspective taking ability was considerably reduced or minimized. We conclude therefore that map reading instructions stimulated a change in the way in which the information was read and processed. Apparently, it was possible for participants even with lower spatial perspective taking ability to overcome the misaligned information if they were instructed to pay attention to this problem and to determine egocentric turning decisions during reading. More specifically, the form of the interaction is an ability-as-compensator interaction (Kühl et al., 2022; Mayer & Sims, 1994), because ability would compensate for a missing treatment (instruction).

Correspondingly, the multiple regression analyses considering the time spent viewing the relevant parts of the map and the subsequent navigation errors revealed a remarkable difference between conditions, also in the form of an aptitude-treatment interaction regarding map reading skills. Only in the control condition, a negative correlation between viewing times on relevant areas and navigation errors were found. This result reflected the role of pre-existing skills in map reading for navigation of the participants in the control condition. The map-reading instruction in the treatment conditions reduced the variability in viewing times. That is, participants were more similar in their map reading behavior in those conditions, and the relation of viewing behavior with subsequent navigation errors disappeared. We conclude that the instruction contributed to reducing pre-existing individual differences in reading behavior. This can also be interpreted as an aptitude-treatment interaction, again in the ability-as-compensator form (with map reading skill as the aptitude and instruction as the treatment).

Although a mediation analysis showed no significance in interpreting the fixation duration as mediator between spatial orientation ability and error rate in the control condition, the results suggest that it might be a problem in power. Future research should focus on this mediation effect.

The current study demonstrates that a simple instruction in a map reading strategy can be effective in eliminating the effects of individual differences in spatial ability. This highlights the valuable role of instruction in overcoming individual differences.

4.3. Influence of instruction on gaze patterns during map reading

Hypothesis 1.1 could only be partly confirmed. Participants fixated longer on the legend in both treatment conditions and showed more fixation switches from landmarks to the legend in the instruction condition compared to the control condition. Furthermore, there were shorter fixation durations in the control condition compared to the instruction + training condition on the endpoint of the route (Café, part of Hypotheses 1.2) as well as on the AOIs covering decision points with change of direction (Hypothesis 1.3).

These results demonstrate that the instruction + training condition changed the viewing behavior in the intended direction (increasing the attention to the landmarks), but not systematically. Parts of the instruction did not lead to changes in viewing behavior (e.g., there were no changes in the fixation duration on the starting point). In addition, there were changes that were not intended, e.g., there were longer viewing times on the castle (an irrelevant landmark) which might have been erroneously considered as a useful far-distance orientation point.

The decision for a specific reading time on the map can be crucial for the results, particularly regarding gaze patterns. The reading time of 40 s was a compromise resulting from several considerations and observations during pilot testing. The time of 40 s is sufficient to read the map carefully and to select the appropriate information for learning that specific route. This is confirmed by the rather low number of navigation errors on average. Deliberately, the time is not long enough to think first about a good strategy to read the map or to apply test-and-rehearse cycles (like closing the eyes, retrieving the route, opening the eyes, and checking the correctness of the retrieval). Reading time may also play a role in the effects of individual differences. In the baseline (control) condition, individual differences in spatial ability played a role, which was important for the goal of the present study. With regard to gaze patterns, a reading time that would be too long might induce redundant or unnecessary processes in studying the map, which would be reflected in additional gaze patterns that can be difficult to interpret. In summary, we attempted to make an informed decision based on considerations and pilot testing. Since the 40 s reading time was utilized in all conditions, this procedural decision cannot explain differences between conditions.

4.4. Explorative analyses of navigation errors at intersections and corresponding viewing behavior

The explorative analyses on navigation errors suggested overall that navigation errors were predictable and occurred at the more difficult decision points. Easy decision points were intersections at which the "straight" option was correct, or a T-intersection at which a choice had to be made which was supported by a landmark. More difficult decision points included the start where the initial heading had to be corrected, as well as intersections with misalignment, particularly when a "straight" option was available, but a turn had to be made, particularly in the absence of a landmark.

Creating those difficulties at decision points using features such as the absence of landmarks, number of options, etc. were deliberate design choices. Predictions of difficulty were derived from the literature on route learning, which is, as noted above, mostly based on learning routes from navigational experience (ground-level), but not from maps. A closer look at error patterns suggests that features creating difficulties may interact and that difficulties may be specific for map reading. For instance, there were errors at DP 9. DP 9 has only two options and the "go straight" option was correct, but the intersection appears misaligned on the map and the street for which the actual turning decision is correct is near. Thus, factors such as misalignment and context added to the difficulty. The difficulty-creating characteristic of misalignment is specific for maps, and the opportunity to get an overview over consecutive intersections might be specific for maps as well. Although the opportunity to transform and consolidate route information between DP 2 and DP 6 appears quite obvious, participants might not consistently recognize and use the opportunity, which in turn calls for an improved instruction regarding this feature. Thus, difficulties and learning opportunities differ between learning a route from a map and learning a route through navigational experience, and instruction as well as practice training might be adapted to support learner's understanding.

The descriptive observations of the viewing patterns revealed that participants distributed their attention unevenly on the map during reading. Mostly, participants focused longer on critical intersections (e. g., at the starting point and on intersections with a turning) and shorter on intersections with "go straight"-decisions as well as on irrelevant landmarks. However, the difficulty of some decision points might have been assessed inaccurately by the participants. For example, participants spent considerable time on the T-intersection where the choice was forced and a landmark served as a cue (and where the navigation errors were actually neglectable). In contrast, they spent less time on intersections with a strong misalignment and a "go straight" option, with or without a landmark (and at which errors were actually more often made). This indicates that participants had difficulties identifying specifically critical, but also specifically easy decision points on the map with respect to processing and learning route information purposefully. These observations can motivate an optimized instruction for map reading that guides the reader's attention to the most difficult aspects and the understanding of the relevant information.

4.5. Limitations

The number of errors made on the route was overall rather small, possibly resulting in a reduced variability of navigation performance and might lead to reduced power. However, substantial differences between conditions regarding the navigation errors were still found. The training procedures in the instruction + training condition were apparently not optimal. A possible positive effect of the training might have been prevented by interference or confusion created by the procedure. Likewise, the instruction could be improved by guiding the participants' attention more to the most difficult aspects of the route.

In the present study, one route within one virtual environment was utilized. While we consider the design features of the route (such as the presence or absence of landmarks at decision points) as rather general and transferable to other routes, maps, and environments, we acknowledge that it would be desirable to extend the investigation of the effects of instruction and training on map reading to different types of environments, different routes, and different maps. In this way, the replicability and generalizability of the results could be ensured.

Another potential limitation of the present study is the difference in time spent in different conditions. Additional time (e.g., in the instruction + training condition compared with the instruction-only condition) might induce additional mental effort or fatigue which might have hampered a positive effect of the instruction + practice condition. We had assumed that additional time spent in the experiment practicing the tasks in the instruction + training condition would have rather a positive effect, but it could have had a negative influence.

5. Conclusion and future research directions

The results of the present study show that a rather simple and unpracticed instruction on map reading for navigation can both reduce the roles of pre-existing individual differences in map reading behavior as well as in spatial perspective taking ability, which both play an important role in navigation performance if a map is read without such instruction. The scenario of the present study is valid for everyday use of navigation assistance and digital route planners that show pre-planned routes within a map. Instructed map reading skills in this assisted context can reduce variability between navigators in using this information, prevent users from making unnecessary errors, understand relevant information on the map and in the environment. Purposeful map reading and learning of routes would enable users to learn spatial information and navigate without assistance.

Future research might extend gaze measures to analyze the influence of the instruction on the changes in reading behavior. To this end, better and more specific instructions might be combined with more specific expectations about gaze patterns. In addition, further research might investigate the mechanism of the aptitude-treatment interaction (with map reading skill as the aptitude) by analyzing changes in gaze patterns as mediators for changes in the roles of pre-existing ability and skill.

In addition to extending the focus on gaze measures, it is also critical to consider the essential role of memory in the map-reading navigation tasks addressed in this study, particularly as the map is not available during navigation. Participants must not only recognize key decision points and determine appropriate actions but also recall them in the correct sequence to navigate successfully. According to a study by Günalp (2020), individuals with good perspective-taking skills navigated more effectively only when the map was accessible during navigation. However, when the map was absent, both good and poor perspective takers showed similar performance levels. This suggests that memory might face additional challenges in this context. Future research could further investigate the impact of memory on this task.

Gaze pattern analyses may have practical implications in the future. If devices such as smartphones would use eye-tracking to diagnose the user's attentional focus and information processing during reading a digital map shown on the display, an application could diagnose whether users adopt a probably successful or unsuccessful reading strategy. Supportive additional information or instructions could be provided accordingly.

Institutional Ethics Committee Statement: According to the statutes of the ethics committee of the university where the study was conducted, there was no need for an approval of the ethics committee for the study described in the manuscript.

CRediT authorship contribution statement

Benedict C.O.F. Fehringer: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Formal analysis, Conceptualization. **Stefan Münzer:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Hatice Dedetas:** Writing – review & editing, Writing – original draft, Conceptualization.

Appendix A

Verbal Instructions—translated to English

Hereafter you will be presented with an (exercise) map. You have 40 s to memorize the marked route and then reproduce the route. Keep the following points in mind to learn the route correctly.

- First, look at the legend. It contains your location as well as various landmarks. These are prominent objects at fixed positions that facilitate navigation. Not all landmarks are on your route, however. At some of the landmarks on your route, you have to make a turn. Other landmarks, you simply walk past. And in some places, you will have to make a turn without a landmark being at that location.
- Internalize your location and the end of your route. Your location is also the starting point of your route.
- Pay attention to the direction you need to take from the starting point.
- If you have to make turn decisions along the route, consider which direction you would be facing while navigating and which direction you will have to turn during navigation because of it.

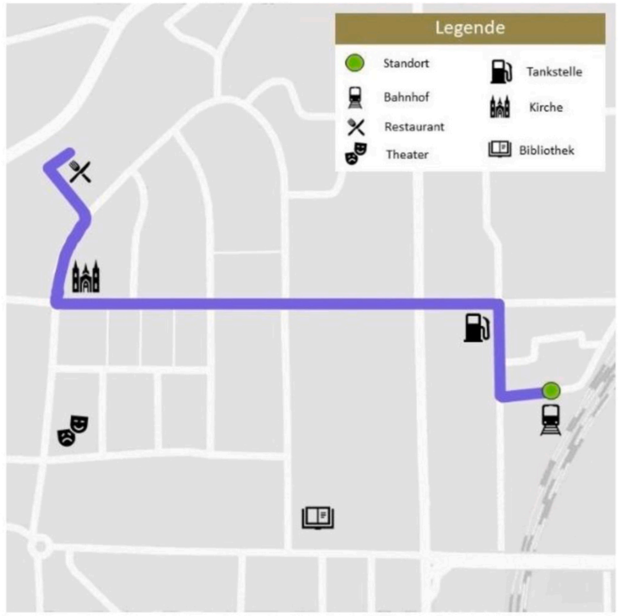
Verbal Instructions—German original

Im Folgenden wird Ihnen eine Übungskarte präsentiert. Sie haben 40 Sekunden Zeit, um sich die eingezeichnete Route zu merken und die Route im Anschluss wiederzugeben. Beachten Sie dabei folgende Punkte, um die Route richtig zu lernen.

- Schauen Sie sich zuerst die Legende an. Sie beinhaltet Ihren Standort sowie verschiedene Landmarken. Dies sind markante Objekte an festen Positionen, die die Navigation erleichtern. Nicht alle Landmarken liegen aber auf Ihrer Route. An manchen der Landmarken auf Ihrer Route müssen Sie abbiegen. An anderen Landmarken laufen Sie lediglich vorbei. Und an manchen Stellen müssen Sie abbiegen, ohne dass eine Landmarke an dieser Stelle steht.
- Verinnerlichen Sie Ihren Standort und das Ende Ihrer Route. Ihr Standort ist gleichzeitig der Startpunkt Ihrer Route.
- Achten Sie darauf, welche Richtung Sie vom Startpunkt aus einnehmen müssen.
- Wenn Sie entlang der Route Abbiegeentscheidungen treffen müssen, dann berücksichtigen Sie, in welche Richtung Sie beim Navigieren schauen würden und in welche Richtung Sie während der Navigation deswegen abbiegen müssen.

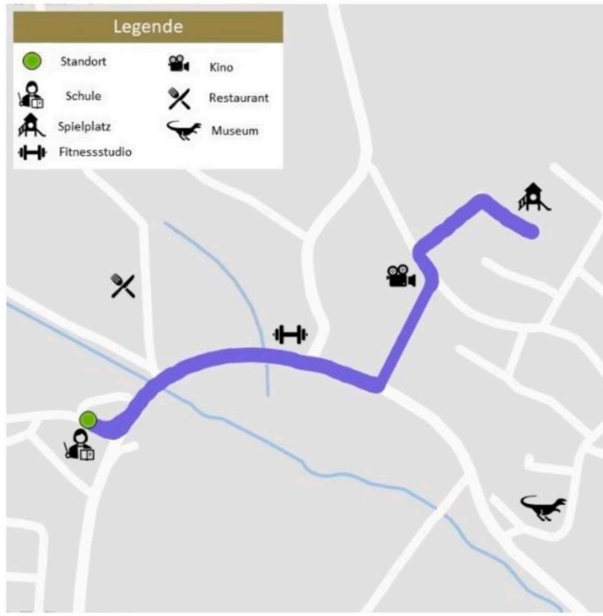
Appendix B

First training map.



Second training map.

Third training map.



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