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The Interaction of Landmarks and Map Alignment in You-Are-Here Maps

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Abstract

Knowing where one is located within an environment is one of the most fundamental tasks humans have to master in their daily routines. Maps, as external representations of the environment offer intuitive ways to extend the capacities of the human cognitive systems. Operations such as planning a route can be performed on maps instead of in the environment. Question of how to design maps that support cognitive processes such as wayfinding in novel environments have been discussed in several disciplines. The research reported here addresses the question of how map alignment and the presence of landmarks in maps interact during wayfinding. For the purpose of systematically analyzing the relationship between map alignment and landmark presence, 9 virtual environments were designed. Routes learned from maps with different alignments and different numbers of landmarks present at decision points were used. While generally landmarks are assumed to foster wayfinding performance, our results indicate that misaligned maps can cancel out positive effects obtained through landmarks.

1 INTRODUCTION

Having spatial awareness, that is, knowing where you are and where things are located in your immediate environment is essential for human beings. The multi-billion dollar industry that has developed around spatial information such as location-based services (Raper et al, 2007), GPS guided navigation (Kealy et al, 2008), Wi-Fi technologies (Hills, 2005), and the integration of location ("Where") information into Facebook and smart phone applications is an expression of this desire and the demand for spatial information (Grossner et al, 2008; Torrens, 2008). Our reliance on technical support to guide us through spatial environments is increasing and it is only in situations where this support fails or provides false information that we become aware of this dependency (Parush et al, 2007).

In the area of navigation support, this reliance drives an urgency for cartographic methods that seamlessly integrate with our cognitive abilities to understand spatial environments and enable us to make spatial decisions efficient and effectively (Fabrikant et al, 2010). While not everyone has the same spatial orientation abilities (Allen, 1999; Hegarty et al, 2006), there are some general guidelines on how to provide spatial information to increase awareness of where we are and help us to navigate the world around us (Aretz, 1991; Arthur and Passini, 1992; Clark, 1997; Hölscher et al, 2007; Levine, 1982). A plethora of approaches exist that foster spatial awareness: physically installed you-are-here maps (Klippel et al, 2010; Levine et al, 1982; O'Neill, 1991; Warren, 1993), mapping of landmarks (Couclelis et al, 1987; Duckham et al, 2010), mobile navigation devices (Krüger et al, 2000; Raper et al, 2007), and other orientation equipment (Harrower, 2007).

Maps are prepared for a variety of functions, one of which is to guide travel from origin A to destination B (Chase, 1983; Golledge, 1999; MacEachren and Johnson, 1987). The use of maps (in general) for navigational purposes greatly fosters orientation and wayfinding in an environment (Devlin and Bernstein, 1995; Liben and Downs, 1993; Lobben, 2007). But how exactly do maps help us? Which elements represented in maps support our wayfinding abilities and which impede them? Understanding cognitive processes related to the acquisition of spatial knowledge and use of maps is essential for informing map design (for an overview see Montello, 2002). While many responses to these questions are discussed, the need for more behavioral assessments of wayfinding with maps remains.

We are particularly interested in two factors that have shown to affect wayfinding performance: the use of landmarks as a navigational tool (Newman et al, 2007; Presson and Montello, 1988; Richter, 2007) and map alignment (Levine, 1982; Rossano and Warren, 1989; Shepard and Hurwitz, 1984; Montello, 2010a). While these two factors have often been evaluated *separately*, very little research has explored their influence when *combined*. Both have considerable impact on map usability and their combined effects are therefore of significant interest to map designers. This combined effect of landmarks and map alignment on wayfinding performance will therefore be the focus of this article.

Map alignment is one of the best-defined and cognitively explored aspects of map design. Its cognitive grounding comes from research on mental rotation tasks (Shepard and Metzler, 1971) that clearly demonstrate the challenging nature of misaligned objects; in an object-matching task, a linear relationship exists between the angle of rotation (misalignment) and the time it takes to match two objects. The greater the angle of rotation deviates from being perfectly aligned (a perfectly aligned map would mean that the top of the map is in line of sight of the travel direction), the longer it takes participants to match objects. This relationship is well documented for objects as well as maps (Warren, 1994).

Landmarks have become the focus of current research as a natural way to communicate and organize spatial knowledge (Duckham et al, 2010; Golledge, 1987; Lynch, 1960). Landmarks, especially at decision points where a change of direction is required, are regarded as wayfinding enhancers, reducing navigational errors, and speeding up decision making processes (Caduff and Timpf, 2008; Coluccia and Louse, 2004; Deakin, 1996; Devlin and Bernstein, 1995).

A final aspect relevant to this article is the use of virtual environments (VE) that open new possibilities to spatial cognition research, including wayfinding research (Meng et al. 2012; Tang et al. 2009; Waller et al, 2004). As computer software and immersive technology develop further, more options will emerge (Bishop, 2001; Frey et al, 2007). The use of a virtual environment model in this study has allowed the design of controlled experimental environments, while maintaining the level of realism necessary for behavioral testing.

Three hypotheses are tested in this article:

> *1) An increase in landmark presence (at decision points that require a turn) on properly aligned maps results in improved wayfinding performance.*
>
> *2) Reading a properly aligned map (as opposed to a misaligned map), following Levine's Forward-up Principle (1982) results in increased wayfinding performance.*
>
> *3) An increase in landmarks on a map compensates, in terms of wayfinding performance, for increased map misalignment.*

The remainder of this paper describes the experimental setup using a virtual environment, details the results, and discusses their meaning and implications.

2 EXPERIMENTAL SETUP

2.1 Participants

30 participants were recruited for the experiment through email and posters at the authors' university. The participant pool was equally split by gender, aged between 24 and 30 years. Seven participants had previous experience in the spatial sciences (Architecture, Geographic Information Systems, 3D Animation & Aviation). While every effort was made to ensure an approximate representation of the population, it should be noted that the majority of the participants were pursuing degrees at the university and therefore could be considered well educated. Every participant received a $15 bookshop voucher. Each participant was presented with the same set of instructions and scenarios (though the order of scenarios was randomised).

2.2 Materials

A virtual city was designed using a computer game engine and photographs of real buildings. Nine different environments and corresponding maps were created.

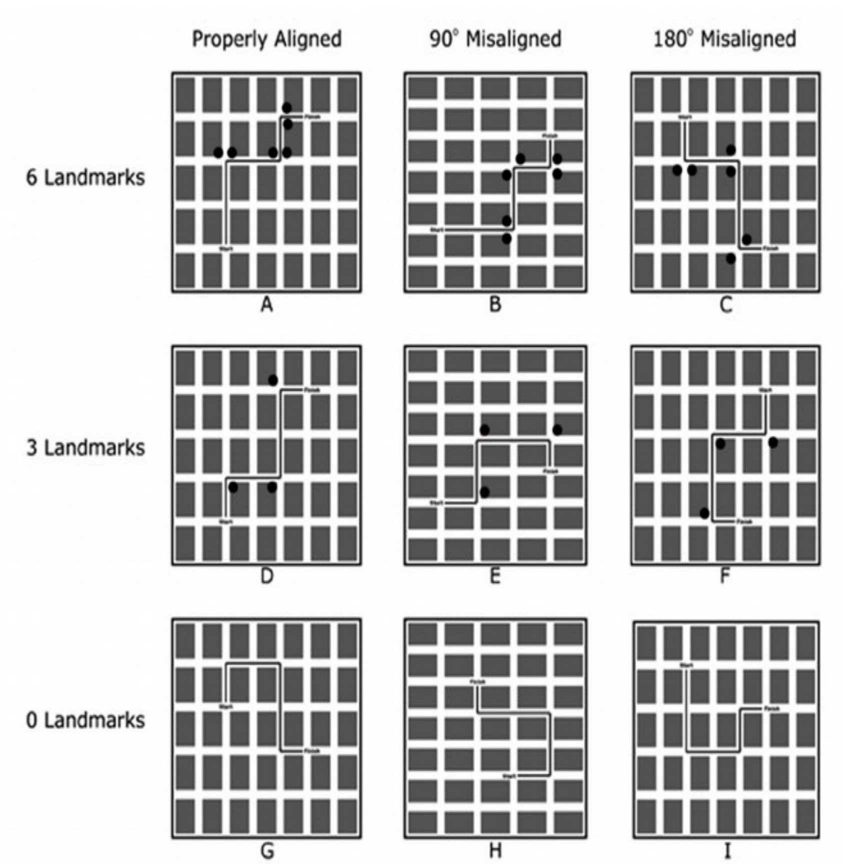

Figure 1a – Nine scenario maps

We refer to this combination of a virtual environment and map as a scenario. The experiment had a 3 x 3 factorial design (Figure 1a). Factor alignment used: properly aligned (meaning that the top of the map corresponds to the direction the subject views on entry into the virtual environment), 90° misaligned, and 180° misaligned. Factor landmarks used: no landmarks at decision points with a direction change, one landmark, and two landmarks, respectively.

2.2.1 Maps

Each map displayed a solid black line representing the route with the words "Start" and "Finish," printed at opposing ends. 35 gray rectangular city blocks made up the grid structure of the map with the white space between the blocks representing streets. The blocks were created as rectangles so that a difference between map alignments would be more apparent (proper alignment vs. 90° misalignment). Each route contained three turning and two straight-through intersections. Depending on the scenario, the turning intersections were marked by zero, one or two landmarks. Three maps contained six landmarks (e.g., Figure 1b), three contained three landmarks, and three showed zero landmarks.

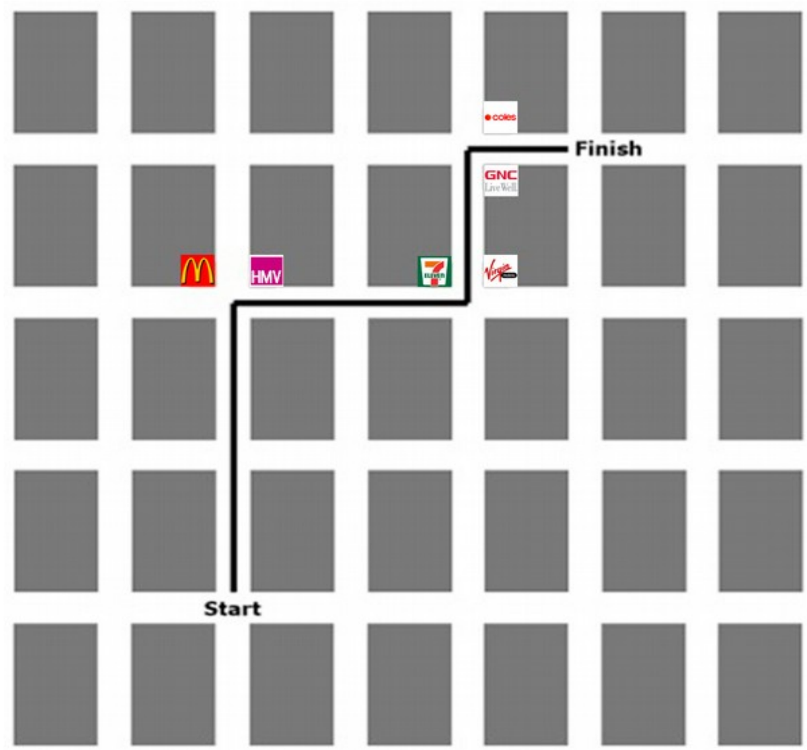

Figure 1b – Scenario Map A (Properly Aligned with 6 Landmarks)

2.2.2 Map Alignment

The nine scenario maps were divided evenly into three map alignments: properly aligned, 90° misaligned, and 180° misaligned. Given that existing research has shown similarities between the effects of 90° clockwise and counterclockwise rotation (May et al, 1995; Shepard et al, 1982), it was decided that the 90° misaligned maps would always be misaligned clockwise with no loss of generality. Every effort was made to provide an equal number of left and right hand turns on the maps overall.

2.2.3 Landmarks

Landmarks were carefully chosen, consisting of building facades with similar degrees of saliency: fast food restaurants, car rental agencies, convenience stores, etc. We also aimed to keep the names of the landmark the same length (i.e., the same number of syllables). Both landmark placement location (corner of an intersection) and type were randomized to remove bias. Along with the landmarks presented on the map and in the virtual environment, there were additional potential landmarks visible in the environment, but not on the map. Rather than allowing participants to make a decision based on the presence of a landmark alone, effort was made to ensure that they were making specific decisions at specific landmarks. By including additional landmarks in the environment, but not in the map, participants would be forced to not only remember the presence of landmarks at an intersection, but the presence of one or two specific landmarks at an intersection. Depending on the scenario, we randomly placed one or two previously unseen and unmapped landmarks at one of the straight-through intersections (non-turning decision points).

2.2.4 Virtual Environment

The virtual environment was created through the construction of the setting and terrain as well as buildings and streets. The *Torque* video games engine was used as the base code from which the environment was built. The buildings were created using photographs of real-world structures, manipulated and projected onto three-dimensional blocks. Each city block contained between six and ten buildings depending on building size, and measured approximately 40 m by 25 m. These blocks were designed to be smaller than typical real city blocks in order to reduce the time required of the participants, while not making their movement speed excessive. Depending on the scenario, the virtual city consisted of between 23 and 30 city blocks. The street width (space between blocks) measured approximately six meters. Shadows were minimised and the sun was placed at mid-day in an attempt to remove shadow as a navigational aid. The maximum speed of movement in the environment was limited to six meters per second and the camera height was set to average eye level (approximately 1.7 meters high). Figure 2 shows screen-shots of the virtual environment.

Figure 2. - The virtual environment.

3 PROCEDURE

The virtual environments, and their corresponding maps, were presented to the 30 participants in random order. Each session took approximately 45 minutes to complete. The experiment was designed as individual sessions and consisted of three parts:

1. Navigating nine routes in nine virtual environments.

2. Completing an anonymous profile questionnaire.
3. Completing a standardized spatial orientation test.

3.1 *Navigating the Virtual Environment*

Each participant was first given instructions and a demonstration of the controls necessary for movement in the virtual environment (see Figure 3).

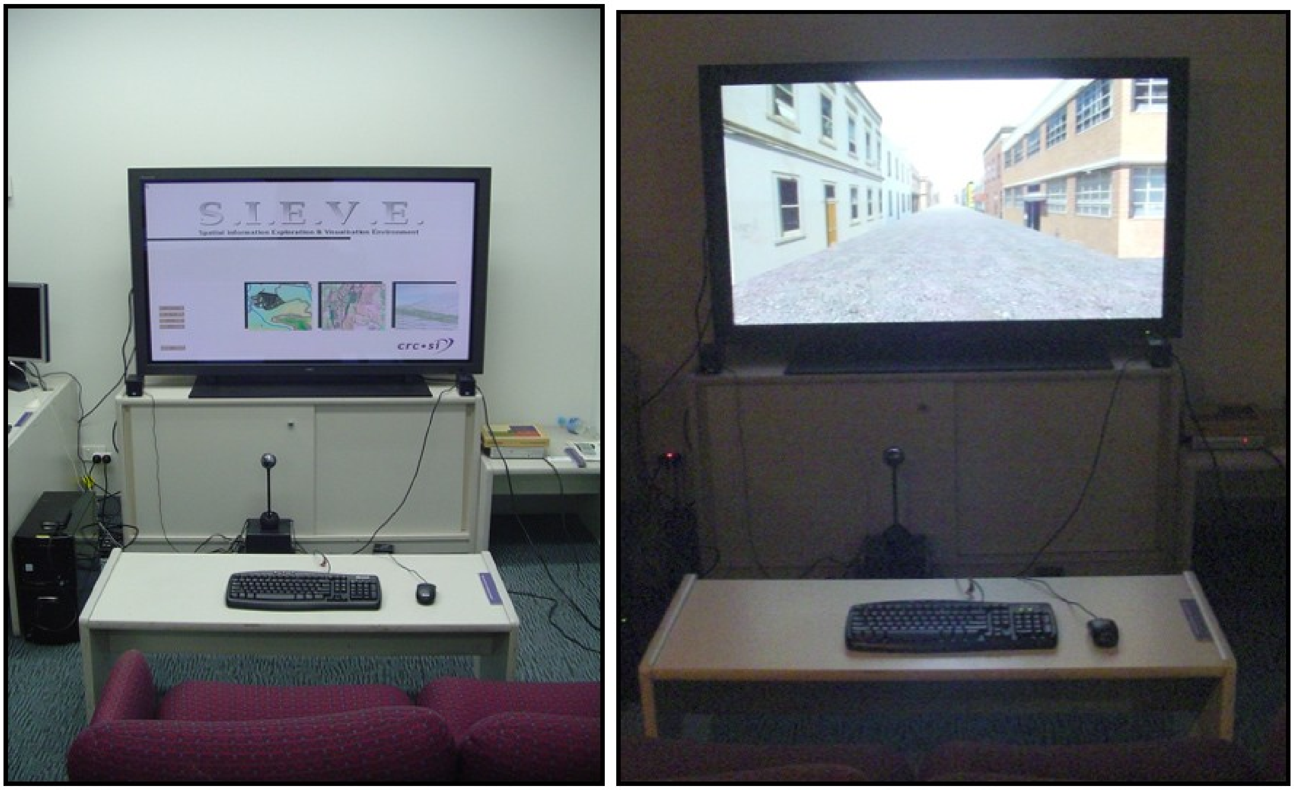

Figure 3. - Testing environment

A test scenario map was the first map shown to each participant. Each map contained a *Start* and *Finish* point connected with a solid black line. This line represented the route the participant was being asked to follow in the virtual environment. The participant was told that the alignment of the map and the presence of landmarks might differ between maps. He or she was also told that they would always be facing the first intersection, pointing in the initial direction shown on the map. As some of the participants had little first person computer game experience, controlling movement through a mouse and keyboard required some training. The purpose of the test environment was to familiarize each participant with the technology and controls. Each participant was told that he or she had to successfully navigate the test scenario path in less than 45 seconds in order to continue on in the experiment. If he or she did not succeed they were asked to redo the test scenario until the requirement was met. This time limit reduced the possibility of variations in scenario results being caused by movement control errors. Twenty seven participants completed the task within the required time on the first attempt, three on the second attempt.

After completing the test scenario, nine scenarios were presented in random order to each of the 30 participants. Initially, the participant was shown a map of the route he or she was required to follow. Each participant was given 20 seconds to examine the map and to inform the experiment controller when he or she was ready to move on to the virtual navigation component. The participants then completed the virtual navigation component. If the participant made an incorrect turn at any point during a scenario, he or she was stopped by the controller and returned to the intersection where the incorrect decision was made and oriented facing in the correct direction.

3.2 Questionnaire

The questionnaire asked the participant for biographical data as well as computer game experience, most common form of transportation, and spatial ability self-assessment.

3.3 Spatial Orientation Test

The Spatial Orientation Test, developed by Hegarty and Waller (2004), measured participants' spatial abilities. Each participant completed the Spatial Orientation Test by estimating the angle between two objects. The overall error between their estimation and the actual measurement angle was calculated for each of the 12 questions and then averaged to produce one numerical value for each participant.

4 RESULTS

In the following section we present the analysis of the data by looking at them from different perspectives. We also discuss the ways in which the different assessments of wayfinding performance were calculated (i.e., speed and success scores). The main analysis is split into two parts; the first part focuses on speed (as a measure of wayfinding performance). This analysis was performed using linear mixed models (LMM). LMM allows for a) use of all participants, even if they became lost in one scenario, which rendered time an inappropriate measure of wayfinding performance (e.g., the remaining eight scenarios are entered into the analysis), and b) integrating additional aspects into the analysis (such as the order in which the scenarios were presented).

A second approach was employed to cross-validate findings. Wayfinding performance was scored for each participant's behaviour at each decision point. This approach, termed *Success Score*, allowed researchers to have a second perspective on the wayfinding performance and to use the more classical approach of repeated measures ANOVA. Finally, we looked into the relationship between alignment and landmarks for each segment along the route. This latter aspect is important as the scenario routes consist of multiple segments with different orientations.

4.1 *Errors and Incomplete Data*

4.1.1 The Virtual Environment

Of the 270 *speed* measurements (30 participants by nine scenarios), only one error occurred and eight special cases were encountered. The one error can be attributed to a fault in the data collection process. In the eight special cases, the participants became completely lost and either wandered well off the specified route or stopped for a long period of time despite controller assistance as described in Section 2. While participants eventually finished the scenario, their *speed* value was not included in the analysis; their *success score* remained valid.

4.1.2 The Spatial Orientation Test

Twenty nine of the 30 participants completed the Spatial Orientation Test in the allotted time. The one participant who did not finish was removed from this part of the analysis.

4.1.3 Calculating Segment Speed, Overall Speed and Success Score

Each of the 30 participants completed nine study scenarios resulting in 269 tracking files (after subtracting the 1 error that occurred). These tracking files were composed of X, Y position values recorded every 0.1 seconds from the beginning of the scenario to the end. It was determined that the first segment would begin at the starting point and finish as the participant turned the corner and crossed a specific X or Y value line (a line across an intersection that joined two adjacent buildings). The second segment would start at the previous finish line and again conclude as the participant turned the corner, crossing the X or Y finish line and so on. Each of the tracking files was examined and the time taken to complete each of the segments was recorded.

Equal Weighted Mean Speed was determined by first calculating participant *speed* over each route segment followed by computing the average for the 3 segments. This resulted in an equally weighted mean value for speed with no single segment having a greater impact on the overall route mean value. When the participants navigated the VE, they were either stationary or, when pressing the appropriate key, moving forward at a constant rate of 6 m/s. Therefore the final *speed* values are averaged measurements. The average was calculated based on the amount of time spent at each of the two speeds.

A *success* value was used to rank participant's wayfinding behaviour at each decision point that required a turn (three per scenario) on a scale of 0 to 3: "0" signified *completely lost* and "3" represented *no problems* according to observed participant wayfinding behaviour (independent of *speed*). Overall mean *success* values were calculated by averaging the *success* across the three turning decision points in each scenario.

4.2 Main analysis of speed using LMM

LMM allows the use of all participant data and additionally accounts for effects such as order in which participants received the scenarios (to account for potential learning effects). However, just like ANOVA (General Linear Model, GLM), the data needs to conform to certain distributional characteristics such as normality and homogeneity of variance. Using the Sapiro-Wilk Test for normality we found that this criterion is violated in our data; revealed by visually inspecting a stem and leaf plot finding that our data sets were negatively skewed. The speed data was also not compliant with the assumption of homogeneity of variances as revealed by a significant Levene's tests. We therefore decided to follow recommendations by Tabachnick and Fidell (2007) and Field (2009) and transformed the data. Specifically, we used the inverse and reflection to achieve normality. A new variable was created based on speed values using the following formula: *speedNew = 1 / (6 – speed).* This procedure improved the normality of the data and Levene's test showed that the data now is in compliance with the requirement of homogeneity[1].

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[1] This procedure was developed in collaboration with the Statistics Consultant Center at Penn State. We did not rely on this procedure alone however, but also used the success values that we assigned to the wayfinding performance at each decision point (see next Section). As both analyses provided us with comparable results, we are confident in interpreting them in the discussion section. We additionally incorporated the original variable whenever possible to corroborate our analysis and did not find substantial differences before and after the transformation.

The first analysis we performed was to test whether there exists a correlation between *spatial abilities* and *wayfinding performance* (speed/newSpeed). While the correlation between speed and speedNew is highly significant (r = .849, p < .001), neither of the dependent variables (speed/speedNew) showed a significant correlation with spatial abilities (r = .036, p = .57; r = .076, p = .226, respectively).

The validity of the specified LMM (with landmark, alignment, and landmark*alignment interaction as fixed factors and order as an additional random factor) was tested by examining the distribution of the residuals and the predicted values. For the residuals we found that they were normally distributed with a mean of nearly 0, which allows us to assume validity of our model. For the relationship between residuals and predicted values we would ideally expect no correlation. We found a mild positive correlation. No other model setting delivered the perfect no-correlation assumption.

With this model, we do find statistically significant main effects for all three factors (landmarks, alignment, and landmark*alignment interaction). In the presence of a significant interaction effect (F(4,210.892) = 6.96, p < .001), this effect has to be considered first as it indicates that landmarks do not have the same effect across all three levels of alignment.

To better understand the interaction effects, we depict the mean speed values with 95% confidence intervals. We show in Figure 4 the speed values to demonstrate that the transformation made the data compliant with the prerequisites for LMM but did not change the overall pattern. We therefore can interpret the original values as this makes it easier to follow this discussion.

In the case of proper alignment we find the hypothesised pattern: the scenario with two landmarks at each intersection allowed participants to find their way the quickest, the scenario with no landmarks yielded significantly slower speed values, while the scenario with one landmark is placed between the two other scenarios. In case of maps being 90 degrees misaligned, the picture becomes more complicated and statistically hard to distinguish as indicated by the overlapping confidence intervals. For maps 180 degrees misaligned, however, we find a clearer, yet unexpected picture. The wayfinding performance is highest in scenarios without landmarks, lowest (and significantly so) in scenarios with one landmark at each decision point, and somewhere in the middle for scenarios with two landmarks at each decision point. The main interaction effect to observe here is the change in rank of the scenario not using landmarks; in the case of proper alignment, missing landmarks lead to the lowest speed values (3^{rd} rank). In contrast, 180 degrees misaligned maps profit from the absence of landmarks and speed values are highest when no landmarks are present (1^{st} rank).

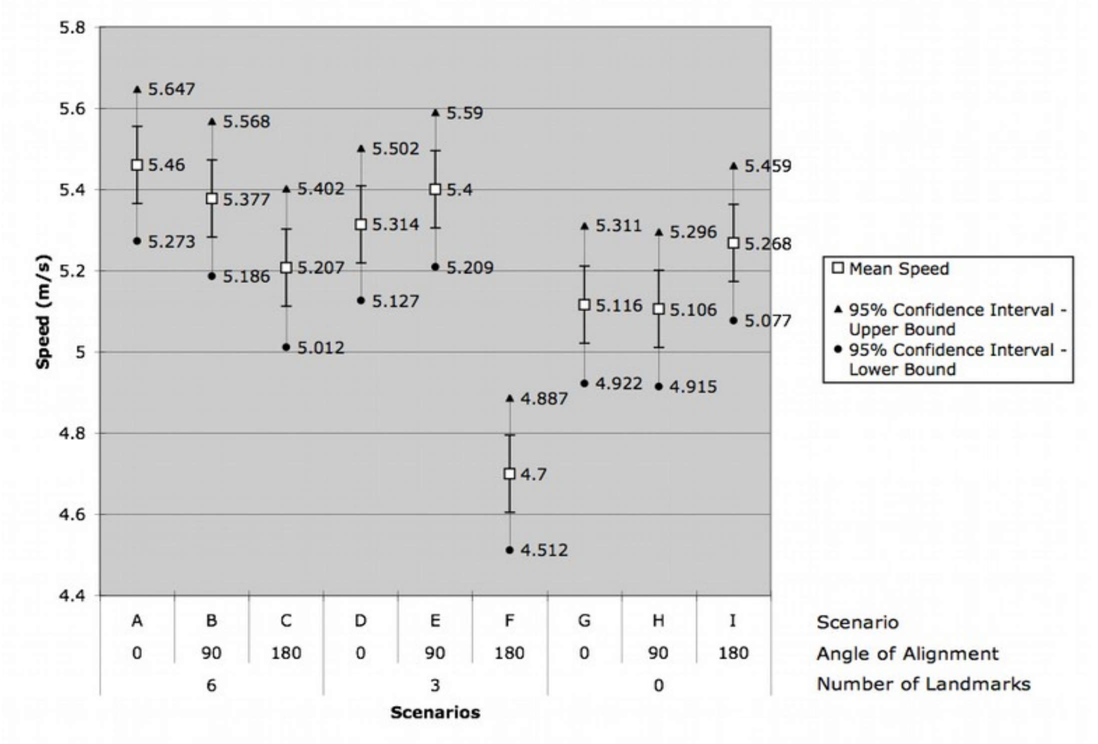
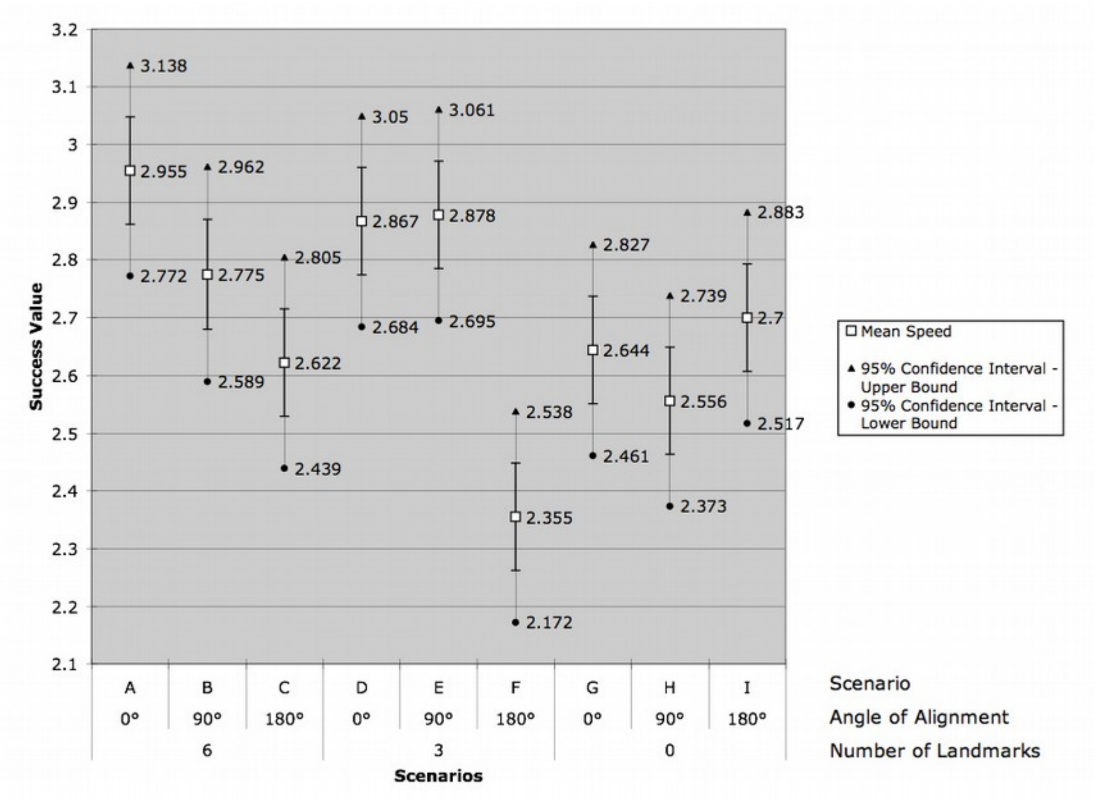


Figure 4. - Shown are the mean speeds (with 95% confidence intervals) for the nine scenarios.

4.3 Repeated measures analysis of success

To offer a different perspective on the wayfinding performance of participants (other than speed) and to complement the LMM analysis, we performed repeated measures ANOVA on the success scores. For the score values we excluded one participant (i.e., the one error data set) but were able to use data of participants who got lost at certain decision points (N=29). As expected, correlation analysis was highly significant comparing speed and success scores, adding to the general validity of using different assessments of wayfinding performance (i.e., speed and success). Mauchly's test of sphericity indicated that the assumption of sphericity was not violated for the main effects of landmark (X^2 (2) = 1.55, p > .05) and alignment (X^2 (2) = 4.77, p > .05). However, the interaction of landmark and alignment violated the assumption of sphericity (X^2 (9) = 19.71, p < .05) and the degrees of freedom were corrected using Greenhouse-Geisser estimates (ε = .75).

Figure 5.



Success scores for the nine scenarios.

The analysis, most importantly, confirmed the significant interaction effect of map alignment and number of landmarks present at a (turning) decision point in a map (*F* (3.01,84.15) = 4.03, p = .01). This is a further clear sign that the alignment of a map affects map reading processes (and subsequent wayfinding performance) differently depending on the number of landmarks present at decision points. To further understand this interaction effect, contrasts were performed. We depict the success patterns in Figure 5 to accompany this discussion. We found that comparing proper alignment and 90 degree misalignment for six and three landmarks was not statistically significant ($F(1,28) = 2.683$, $p = .113$). Comparing the interaction between six and three landmarks for 90 and 180 degree misalignment shows a statistical trend ($F(1,28) = 3.904$, $p = .058$), indicating that the performance of maps with only one landmark present at intersections suffered significantly more when the maps were presented upside down (misalignment 180). Comparing the scenarios with landmarks (both six and three) against the scenario without landmarks (zero) shows that there is a significant interaction effect comparing proper alignment and 180 degree misalignment ($F(1,28) = 6.843$, $p = .014$) as well as 90 and 180 degree misalignment ($F(1,28) =6.469$, $p = .017$). There is no significant interaction between these two landmark conditions and proper and 90 degree misalignment. Looking in detail at the interaction effects between 90 and 180 degree misalignment comparing zero landmarks against six, and zero landmarks against three, we find that only the latter interaction is statistically significant ($F(1,28) = 9.067$, $p = .005$).

4.4 Questionnaire

None of the results from the questionnaires correlated significantly with wayfinding performance. This suggests that the results apply regardless of gender, age, computer game experience, and level of education. The frequency at which participants consulted a map, purpose of consulting a map, and their most common method of travel also proved to be insignificant in this study. The implication in these results is that frequency and purpose of map consultation have little influence on one's ability to make correct wayfinding decisions in navigating a particular route. Similarly, difference in mode of transportation had no effect on wayfinding performance.

It is also important to note that participant's verbal actions were recorded as they completed each scenario. While most participants did not voice their actions, a number of participants mentioned navigation through counting blocks in the environment.

5 DISCUSSION

Our study addresses a critical gap in the current literature on wayfinding aids: the interaction between using landmarks in a map to improve wayfinding performance and the map misalignment that has been shown to negatively affect wayfinding performance.

Research on landmark usage in virtual and real environments suggests that a) landmarks are a natural way for humans to organize route knowledge and b) incorporating landmarks into representations (wayfinding aids such as maps) increases wayfinding performance (Allen, 1997; Janzen et al, 2007; Jansen-Osmann and Fuchs, 2006; Steck and Mallot, 2000).

While studies exist that show the benefits of using landmarks in aided wayfinding tasks (e.g., Tom, 2003; Goodman 2004), we also find literature that casts doubt on the unequivocal statement that landmarks are always the best way to provide wayfinding support (e.g., Harrower, 2007; Montello, 2010b). Harrower (2007), for example, analyzed different navigation aids for 3D-fly-over and found that landmarks, compared to other navigation aids, performed poorly. The point is not to say that landmarks are good or bad but to call for a more differentiated perspective on landmarks to reveal in which situations landmarks work and in which they do not.

One area that needs to be addressed when researching landmarks as wayfinding aids is the complexity of the representation (the map) and the effects this complexity might have on the map reading / map interpretation process. Map complexity has long been a topic of interest to cartographers (Phillips, 1979; Phillips and Noyes, 1982) and has more recently stirred research in the area of knowledge representation and maps (e.g., Freksa, 1999).

The question to ask is: Does adding (too many) landmarks make a map more (or too) complex? Do landmarks make maps complex not only from the perceptual perspective (which undoubtedly is the case), but also from the perspective of cognitive complexity (Bunch and Lloyd, 2006). In other words, does adding landmarks to a map make maps more cognitively adequate (reflected in better wayfinding performance) or not?

The effect of landmarks on orientation is an important question and is rooted in research on reference frames (Levinson, 1996) and mental rotation (Shepard and Hurwitz, 1984). In the introduction, we mentioned studies which show that misaligning maps inevitably leads to a decrease in orientation (and wayfinding) performance. We also know from research on mental rotation tasks that rotating more than one object lowers the performance (Koning and van Lier, 2004; Folk and Luce, 1987; Heil and Jansen-Osmann, 2008). This brings us to the intriguing question of whether adding perceptual complexity to a map in the form of landmarks reduces cognitive complexity and whether the advantage of representing landmarks outweighs the potentially increased efforts on having to mentally rotate a more complex object (or several objects represented in a map).

In our experiment participants followed a route in a virtual environment after learning this route from a map that contains landmarks. Our results indicate clearly that, as in most complex scenarios, the factor landmarks cannot be looked at in isolation. In other words, the assumption that providing a landmark is always the best way to cognitively adequately provide route information may or may not be the case.

The most important result of our analysis is the significant interaction effect that we found between the number of landmarks present at decision points that require a turn (zero, one, or two) and the alignment of the map that participants used to learn a route (proper aligned, 90 degrees rotated, and 180 degrees rotated). We confirmed this interaction effect by looking at both a linear mixed model (LMM) analysis of the speed with which participants navigated through the virtual environment after learning routes from maps, and, by using a success score that more directly assesses participants' wayfinding performance at individual decision points in the different scenarios (A to I, see Figure 1).

By combining the two aspects we discussed above (map complexity and mental rotation), together with findings that landmarks are not always the best way of keeping people oriented (Harrower, 2007), we can conclude that relying on a landmark-based wayfinding strategy is not always the most efficient one. In scenarios where participants are forced to adopt a non-landmark-based strategy, that is, in scenarios in which no landmarks are presented in the map, the wayfinding performance (measured as speed and success) exceeded the scenarios in which wayfinding was aided by landmarks—if the map was 180 degree misaligned. If we consider landmarks as supporting wayfinding performance and also as elements in a map that makes maps more complex, we can make the point that having to mentally rotate a complex object (that may consist of several individual objects), at some point, outweighs positive landmark effects.

The quantitative results are supplemented by the qualitative collection of utterances of participants who got confused, for example, by the side on which they expect a landmark to be. And, more importantly, people reported that they indeed used a different strategy in scenarios in which no landmarks were present, that is, they counted blocks rather than using landmarks. While the results presented in this work show significant interaction effects, it is important to keep in mind that the findings presented are based on a sample of the global population. While efforts were made to ensure an appropriate sample (e.g., equal gender split and age divisions), additional aspects associated with the participant pool may not have been controlled (e.g., level of education, etc).

An additional aspect is important to note. Our results also show that the number of landmarks influences the overall mean speed at which a participant navigates a route and that having two landmarks at each turning decision point not only yields the highest wayfinding performance when the maps are properly aligned, but also that the presence of two landmarks at decision points is not as susceptible to confusion as the case where only one landmark is present at turning decision points when the maps are 180 degrees misaligned. This supports Levine et al.'s *Two Point Theorem* which states that in order to orient oneself in an environment, the minimum information that must be known is the location of two points in addition to one's own location (Levine et al, 1982). In case of a forward movement one could make the argument that one landmark should be sufficient as the wayfinder's current location is not a point but rather a directed axis and the presence of one additional point (a landmark) should be sufficient. However, our results indicate that this is not necessarily the case and that especially in situations where maps are 180 degrees misaligned, providing redundant information has positive effects on the wayfinding performance.

Last, the results of the spatial orientation test did not significantly correlate with *speed* or *success* in wayfinding. Since participants had to mentally realign two thirds of the scenario maps before traveling the route in the virtual environment, we were expecting to find that participants who performed poorly on the spatial orientation test also had greater trouble with misalignment, but this was not the case. The spatial orientation test was perhaps not suitable for this study because different spatial encoding methods were used to create a mental representation of the environment depending on the scenario map. A change in encoding behavior no doubt alters the way one interprets and mentally realigns a map. An alternate explanation lies in the complexity of the route and the number of decision points. The spatial orientation test simply tests one's ability to realign 2 points; conceivably an increase in the number of points (landmarks) influences one's ability to spatially orient a map.

6 CONCLUSIONS

Having *spatial awareness* is a necessity for successful wayfinding and navigation activities. While familiar environments allow us the luxury of unguided success in reaching our destinations, unfamiliar or partially familiar environments require the use of external spatial information in mostly map-like or verbal form. With the omnipresence of location-based services (LBS) our dependence on information about individual location-action pairs has increased. One focus of current developments to make wayfinding aids *cognitively adequate* is to incorporate landmarks into maps and route directions. Landmarks are omnipresent in both linguistic and graphic human-generated route directions. However, our results are in line with other researchers (Harrower, 2007; Montello, 2010a) showing and questioning the value of landmarks in every situation; incorporating landmarks into wayfinding aids is not always the best way to improve wayfinding performance. Especially when we are interested in wayfinding *in the wild* it will be of critical importance to look at landmarks as part of an orchestra of aspects that influence our ability to find a destination. Two such factors are the well-known cartographic aspect of map complexity and the cognitive effort (we could say the cognitive load, e.g., Bunch and Lloyd, 2006) that is induced by the requirement to mentally rotate maps. That these aspects are still taken too lightly has been revealed in a recent assessment of YAH maps that showed that YAH maps are almost never properly aligned, surprisingly so even when used as emergency maps.

What is required is an even more detailed analysis of the interaction effects of landmarks and map rotation when traveling multi-segment routes as well as research on how YAH maps contribute to research on creating spatial awareness (Klippel and Hirtle, 2010). While our data did not allow for an in-depth analysis of the alignment/landmark effect for each segment, we consider it crucial to shed more light on this aspect as traveling multi-segment routes is the norm, not the exception. This research direction is becoming particularly important in the light of findings that turn-by-turn directions impede the creation of spatial awareness (Parush et al, 2007; Bakdash et al, 2008). With spatial information available in a much wider array for formats, it is time to rethink how to provide spatial information for wayfinding from the perspective of increasing wayfinding performance and creating spatial awareness. Every mobile application user has opportunities to explicitly incorporate location information into their interaction with their mobile device. Research on leveraging the dependence on navigation devices, a deeper understanding of how spatial information is acquired with both mobile and stationary You-Are-Here information, and the integration of new technologies is necessary in the pursuit of turning passive users into active spatial thinkers.

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