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The Utility of Global Landmarks Based on Placement

by Shannon M Moore, Jonathan Z Bakdash, Laura R Marusich, Michael N Geuss, and Joseph A Campanelli

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14. ABSTRACT

This study examined if spatial knowledge improved depending on where highlighted landmarks were placed in a virtual city. We varied whether highlighted global landmarks were placed along the route participants viewed during passive navigation or in the distance (e.g., mountain). A total of 278 participants from Amazon's Mechanical Turk completed this online study. They were assigned to one of three conditions: 1) local landmarks highlighted along the route, 2) global landmarks (e.g., with a beacon light) highlighted along the route, or 3) global landmarks highlighted in the distance. Following passive navigation to learn the environment, we assessed landmark, route, and survey knowledge. Participants who viewed landmarks along their route (global and local) were better able to recognize landmarks and performed better on one measure assessing survey knowledge. There were no significant differences when assessing route knowledge. The results we found for another measure of survey knowledge were not consistent with our hypothesis. While we did not find a clear general benefit to highlighting on-route landmarks compared with highlighting distant landmarks, for all measures of spatial knowledge, we found partial benefits to two aspects of spatial knowledge. This suggests highlighting landmarks along a route can improve some aspects of spatial knowledge.

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Author Joe Campanelli is employed by DCS Corporation. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

<u>Author Contributions</u>:

Shannon Moore was the principal investigator of this study, responsible for the initial study design and management. She also did the initial data cleaning and analysis and was the lead author.

Jonathan Bakdash contributed to data cleaning, data analysis, and writing of the manuscript.

Laura Marusich contributed to data analysis and writing of the manuscript.

Michael Geuss contributed to motivation, study design, and editing of manuscript.

Joe Campanelli developed the study software.

1. Introduction

The ability to navigate an unfamiliar area is important in everyday life, emergency operations, and the military. Typically, landmarks are easily defined, salient physical objects, such as buildings, signs, or even a mountain. They may be distant, seen from many angles (e.g., global), or they might be local and only viewable in certain locations and from certain angles. For example, storefronts and trees are considered local landmarks. While landmarks can be used to improve spatial knowledge (e.g., Waller and Lippa 2007), technology can be used to further highlight or draw attention to landmarks, such as using landmarks in turn directions with guided navigation (Burnett and Lee 2005; Google maps: https://web.archive.org/web/20210326004740/https://www.engadget.com/2018-04-16-google-maps-uses-landmarks-for-directions.html). Here, we build on the idea proposed by Credé et al. (2020) that global landmarks may improve memory for an area only when they are placed along the route one travels (i.e., not in the distance) by evaluating spatial knowledge for "highlighted" global landmarks inside versus outside of a virtual city environment using a passive navigation task and measuring multiple spatial performance outcomes.

Landmarks play a large role in navigation or wayfinding (e.g., Lynch 1960; Sigel and White 1975; Sorrows and Hirtle 1999). This may be because they serve as an organizing concept (e.g., Sorrows and Hirtle 1999) and/or due to their ability to facilitate learning a route (Waller and Lippa 2007). Landmarks, both local and global, help improve the organization or processing of navigational information (e.g., Tom and Denis 2004). For example, for navigation in virtual environments both local and global landmarks are used for wayfinding (Steck and Mallot 2000).

However, landmarks are not necessarily always helpful in acquiring spatial knowledge and instead may sometimes have detrimental effects. This may depend on the type of landmark and the extent of reliance on it during navigation. For example, it has been proposed that local landmarks can harm one's ability to recognize the global shape of an area (Buckley et al. 2014). Yet, other work indicates it is global landmarks that can hinder spatial learning. For example, global landmarks can also act as "beacons". Specifically, a beacon is an object in an environment that points to a nearby target (such as a lighthouse referencing the presence of land) or it can be a target itself (e.g., a steeple for a church; Chan et al. 2012). When global landmarks, or beacons, point to a target's location, research has found it can disrupt the ability to learn other spatial information (e.g., Redhead et al. 1997). Still other work suggests that while not necessarily harmful, global landmarks may not be helpful. Some have concluded that when comparing the presence of local landmarks to the presence of local *and* global landmarks, the addition of global landmarks appeared to have no significant impact on wayfinding (e.g., Yesiltep et al. 2019). Overall, the effects of global versus local landmarks on spatial knowledge are mixed.

These conflicting findings may be due to *where* global landmarks are placed. Credé et al. (2019) found that there was no meaningful advantage to global landmarks, concluding "global landmarks are either not used spontaneously during navigation or do not improve spatial memory for local landmark configurations" (p. 21). However, Credé and colleagues (2020) later found that there can be an advantage for global landmarks, especially for those with high working memory. One difference between these works is that in 2019, the global landmarks (e.g., high-rise buildings visible from far distances and multiple angles) were not along the navigated route. In 2020, they were placed along the route. Specifically, Credé et al. (2020) selected four low-rise buildings and four high-rise buildings located along the route. Depending on the condition, one or the other set was highlighted, but both types of landmarks were present in both conditions. The task was to memorize the highlighted landmarks and navigate the route as quickly as possible. Local landmarks were visible typically one at a time (sequential), while global landmarks were visible from several different locations and typically participants could see more than one at a time (simultaneous). Results found that people were more accurate at learning global versus local landmarks, particularly those with high working memory capacity. Credé et al. (2020) infer, but did not directly test, that global landmarks can improve survey knowledge when landmarks are along the route (Credé et al. 2020) versus at a distance (Credé et al. 2019). The point mentioned in Credé et al. (2020), that global landmarks may only be helpful when on the actual route, is also supported by various other works (e.g., Lynch 1960; Sorrows and Hirtle 1999; Vinson 1999; Duckham et al. 2010; Chan et al. 2012). In a way, this may combine the relevance of local landmarks with the visibility of global landmarks.

Building on the supposition of Credé et al. (2020), this study focuses on directly comparing the potential advantage of highlighting global landmarks either on or outside the navigable area for spatial memory, as well as how this compares with highlighting local landmarks. However, this is not a direct replication of Credé and colleagues' (2019, 2020) work. There are several key differences to note that make our research unique.

1) *Type of Navigation.* Here we used passive navigation, which is the viewing of an environment along specified routes with neither spatial decision making nor control. Passive navigation was used in the current study to ensure that all participants viewed the same routes and landmarks at prescribed locations and to allow for online data collection where user-controlled movement

would have been difficult to implement. In contrast, Credé et al. (2019, 2020) utilized active navigation with participants following a given route.

2) *Cognitive Load.* Credé et al. (2019, 2020) also examined cognitive load, respectively using time pressure or a concurrent tapping task intended to interfere with working memory. This work did not manipulate cognitive load.

3) *Outcomes*. In terms of outcomes assessed, Credé et al. (2019, 2020) focused on survey knowledge, specifically judgements of relative direction. In this work, we assessed landmarks (a recognition test), route (partially retracing routes), and survey knowledge (map reconstruction of landmark locations).

4) *Landmarks:* We also chose to distinguish our landmarks in different ways. We used beacons for our global landmarks in addition to highlighting the landmark itself, while in Credé et al.'s work, no beacon was present. The addition of the beacon allowed for greater visibility of global landmarks from a distance.

This study was conducted online using Amazon Mechanical Turk (MTurk) with the Volunteer Science platform (Radford et al. 2016). Participants were randomly assigned to view a virtual city in one of three highlighted landmark conditions (local landmarks along the route, global landmarks along the route, or global landmark in the distance). Highlighting landmarks in the virtual city simulated augmented reality for this online experiment. In every condition, participants passively travelled along the same three routes. Thus, except for the type of landmark highlights, the environment was otherwise identical for all three conditions. Following passive navigation, we assessed multiple measures of spatial knowledge described in no. 3 "*Outcomes*". Our primary comparison of interest was the two global landmark conditions: whether global landmarks increase in utility when they are on versus off the traveled route.

2. Materials and Methods

2.1 Participants and Demographics

We recruited a total of 278 participants (139 male, 136 female, and 3 unspecified) from MTurk to complete this online study in exchange for $5 compensation. We planned on a minimum sample size of 180 (60 in each condition) based on an a priori power analysis which achieved 85% power to detect a medium effect size. See Table 1 for demographic information on participant age.

Table 1 Demographic information on participant age

Age bracket	Number of participants
18–25	12
25–30	43
30–35	70
35–40	50
40–45	32
45–50	28
50–55	13
55–60	17
60–65	9
65–70	2
70–	2

2.2 Method

Before beginning the study, participants read the following:

> In this study, you will passively navigate down 3 separate routes in a city. Each route will be traveled 3 times. While viewing the videos, your goal is to learn the spatial layout and try to build an accurate mental map of that space. To help you memorize the city layout, various objects and locations in the environment will be highlighted. Try to remember the landmarks highlighted in your environment, other objects in the city, and where these items are in relation to one another.

Participants began by viewing themselves passively navigating three different paths throughout a virtual city, previously recorded by the experimenter. Each of the three paths were viewed three times by participants. Participants viewed different types of landmarks highlighted along these paths, depending on their randomly assigned condition. These landmarks were either highlighted as 1) local landmarks along the route, 2) global landmarks along the route, or 3) global landmarks in the distance (Fig. 1.) Each landmark is highlighted a different color. Example videos of the passive navigation in each condition are available at https://osf.io/2r5uq/.

Fig. 1 Showing a local highlight on route, a global highlight on route, and a global distant (highlight off the route)

After viewing the paths, participants were asked to select the previously seen landmarks among two images. One of their previously seen landmarks was displayed next to a distractor landmark (i.e., a building or object that was present though not highlighted during their walk). Neither option was highlighted at the time of testing. Participants completed nine such identification trials, and accuracy was calculated by summing correct identification of landmarks (range 0–9).

Next, participants viewed two video clips for each path. For example, for Path 1, they viewed themselves walking the path (with landmarks highlighted) and reaching an intersection. The clip then stopped. A second video clip then began at a different point and ended at a highlighted landmark. Participants indicated which way they would have turned at the intersection (left, right, forward, or backward) to go from Point A to Point B. They were asked to make a choice for each of the three paths they had viewed previously (Fig. 2). Choice accuracy was determined by summing over these three choices (range 0–3).

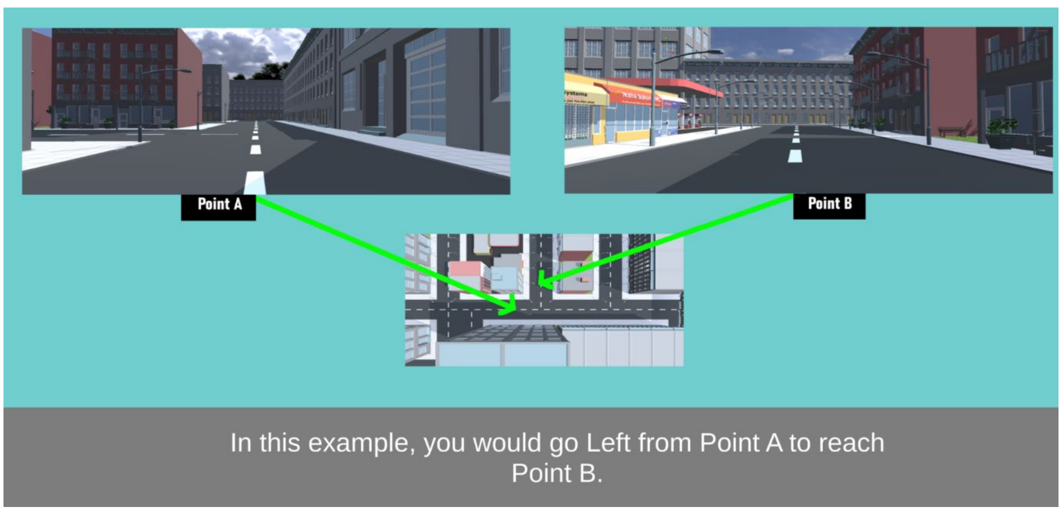
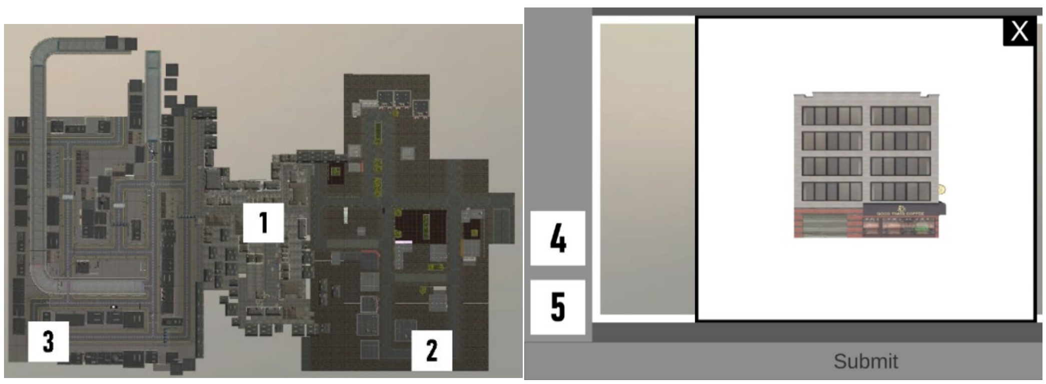


Fig. 2 The example image provided to participants during the experimental directions

Then, participants were asked to reconstruct a map of the city. Specifically, they were told the following:

> Now, we are going to ask you to recreate the map of the environment you traveled based on what you remember. You will see an overall outline of the city; your job is to select each landmark, regular (non-landmark) building, or event and place it on the map where you recall seeing it. Make sure you think about where the landmarks, buildings, and events were placed in relation to one another as well. Essentially, create a map of the space you viewed that is as accurate as possible based on what you remember. If you do not recall where an item was located, please just make your best guess.

Importantly, participants completed the map reconstruction task both by placing their (non-highlighted) landmarks on the map and by placing colors on the map where they recalled that highlight color being (Fig. 3). That is, if a blue highlighted restaurant was in the top left corner of the city, the non-highlighted restaurant would be placed there for the first task and then the blue square would be placed there for the second attempt. We counterbalanced the order in which participants reconstructed the map (e.g., landmark vs. color). This was to examine whether participants were truly recalling the landmarks themselves or perhaps only remembering their colors. For the landmark image reconstruction, we first determined the true coordinate placement of each landmark. We then calculated accuracy for each individual landmark, where the score ranged from 0 (participant placed marker as far away from the correct position as possible) to 1 (a perfect placement). We then totaled these for a total score of landmark placement accuracy, ranging 0–5, and a total score for color placement accuracy, ranging 0–5.



a) b)

Fig. 3 a) This is the blank map participants viewed when asked to reconstruct the map. Here, they were placing the number of the landmark they viewed where they recalled it being on the map. b) This image shows how participants viewed their landmark associated with each number they were asked to place on the map.

After finishing the experimental tasks, participants completed the Santa Barbara Sense of Direction Scale (Hegarty et al. 2006), a measure of individual differences in environmental spatial abilities. This scale has participants self-report on 15 items using a scale of 1 (strongly agree) to 7 (strongly disagree), such as “I am very good at judging distances” and “my ‘sense of direction’ is very good”. After reverse scoring negative items, the possible range of participant scores was 15–105, with higher scores indicating better sense of direction.

Participants then reported their sex, age bracket, educational level, military or law experience, and video game experience.

3. Results

We conducted one-way Analysis of Variance (ANOVA) with condition (local route, global route, or global distant) as the independent variable, for each performance outcome (landmark recognition, route choice [choosing next turn], and map reconstruction accuracy of spatial locations for landmarks and highlight colors). For the ANOVAs with a significant main effect of condition, we also used Tukey HSD (honest significance difference) post hoc tests to test specific differences between pairs of conditions. All results reported here as well as additional exploratory analyses can be reproduced using the data and code available at: https://osf.io/2r5uq/.

3.1 Landmark Recognition

There was a significant impact of landmark condition on accuracy of landmark recognition, F (2, 275) = 4.219, p = 0.016, η_p^2 = 0.029, 95% CI [0.001, 0.076]. As shown in Fig. 4, performance in the two route conditions appeared similar, while accuracy was lowest in the global distant condition. Tukey's HSD post hoc tests indicate a significant difference between the global route and global distant conditions (*Mdiff* = 0.917, CI: [0.117, 1.720], p = 0.020). Those in the global route condition were consistently more accurate at identifying their landmarks (M = 7.181) than those in the global distant condition (M = 6.264). The local route condition did not significantly differ from the other conditions. Participants' scores for recognizing landmarks correctly (M = 6.835, SD = 2.335) ranged from 0 (no landmarks correctly recognized) to 9 (all landmarks correctly recognized).

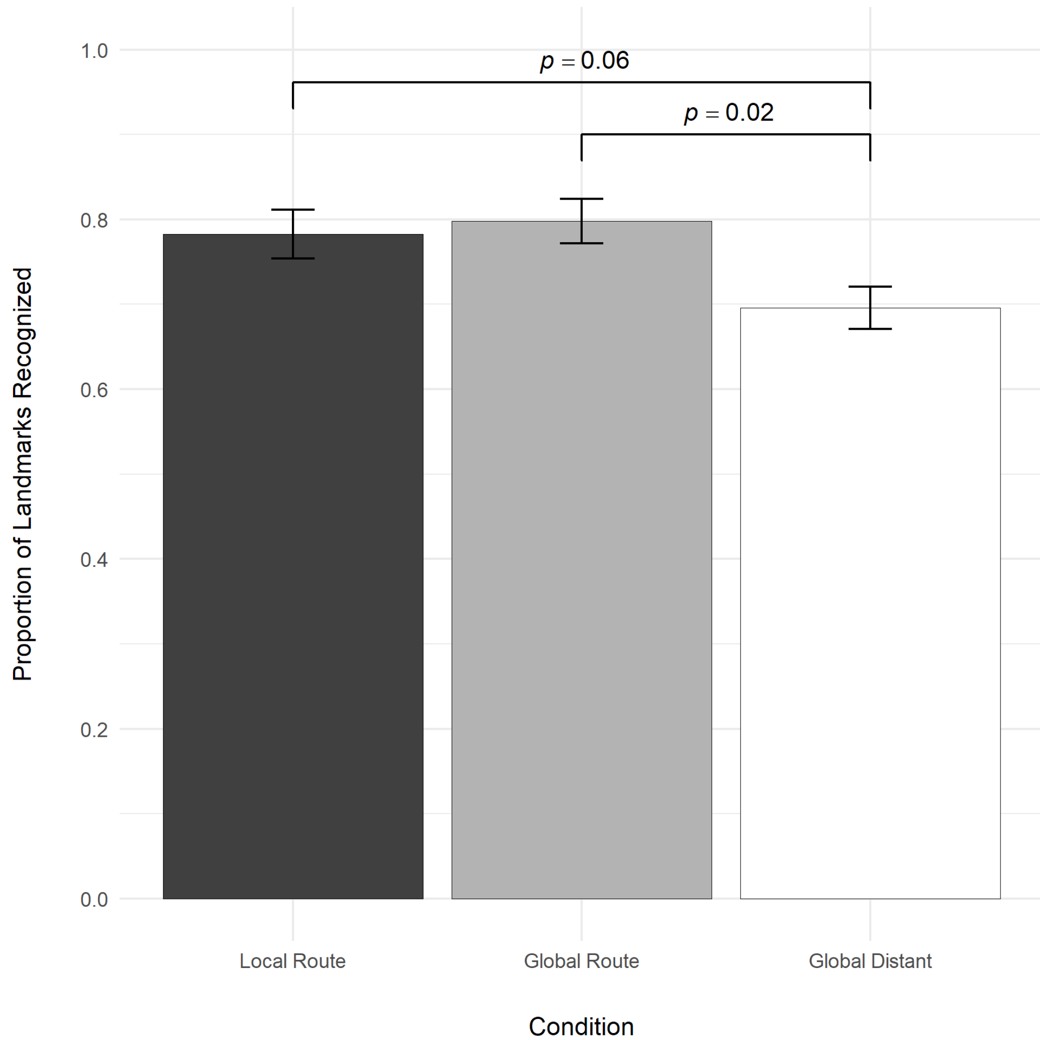


Fig. 4 Performance on the landmark recognition task in the three experimental conditions, shown as the proportion of correctly recognized targets out of a possible 9. Larger values indicate better recognition performance

3.2 Route Knowledge: Route Choice

For choosing the correct turn to take to get from Point A to Point B, the ANOVA showed no significant difference among conditions (p = 0.108, η_p^2 = 0.016). Participant scores (*M* = 1.38, *SD* = 0.99) ranged from 0 (no correct selections) to 3 (all correct selections).

3.3 Survey Knowledge: Map Construction

We evaluated the placement accuracy of spatial locations on the map by calculating bidimensional regression coefficients (Tobler 1994; Friedman and Kohler 2003) for each participant. Bidimensional regression measures the similarity for the configuration of spatial locations for one map (here, each participant's placement of landmarks or colors) compared with another map (here, the actual spatial locations for landmarks or colors). Coefficients range from 0 (no similarity between the two maps) to 1 (identical maps).

There was a significant difference in performance for both placing landmarks accurately on the blank map, F (2, 275) = 7.09, $p < 0.001$, $\eta_p^2 = 0.049$, CI: [0.399, 0.547]), and for placing the landmark colors on the map in the correct locations, F (2, 275) = 3.63, $p = 0.028$, $\eta_p^2 = 0.025$, CI: [0.000, 0.069]). As shown in Fig. 5, for map construction using landmark locations, the effect was largely driven by relatively poor performance in the global distance condition, whereas for map construction using the color of landmarks, surprisingly the local route had lower accuracy than global route (see Fig. 6).

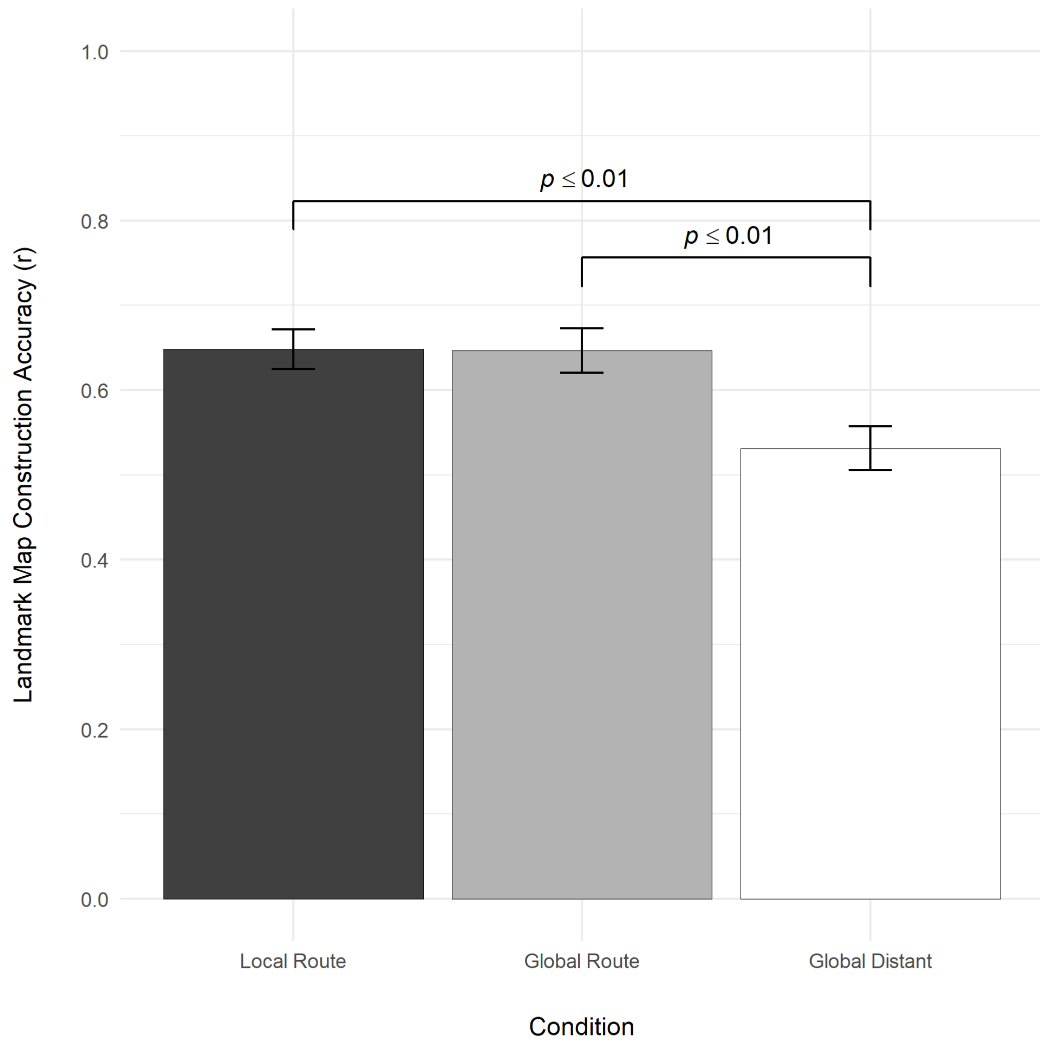


Fig. 5 Performance on the map reconstruction (landmarks) task, measured by the bidimensional regression coefficient. Larger values indicate more accurate map reconstruction

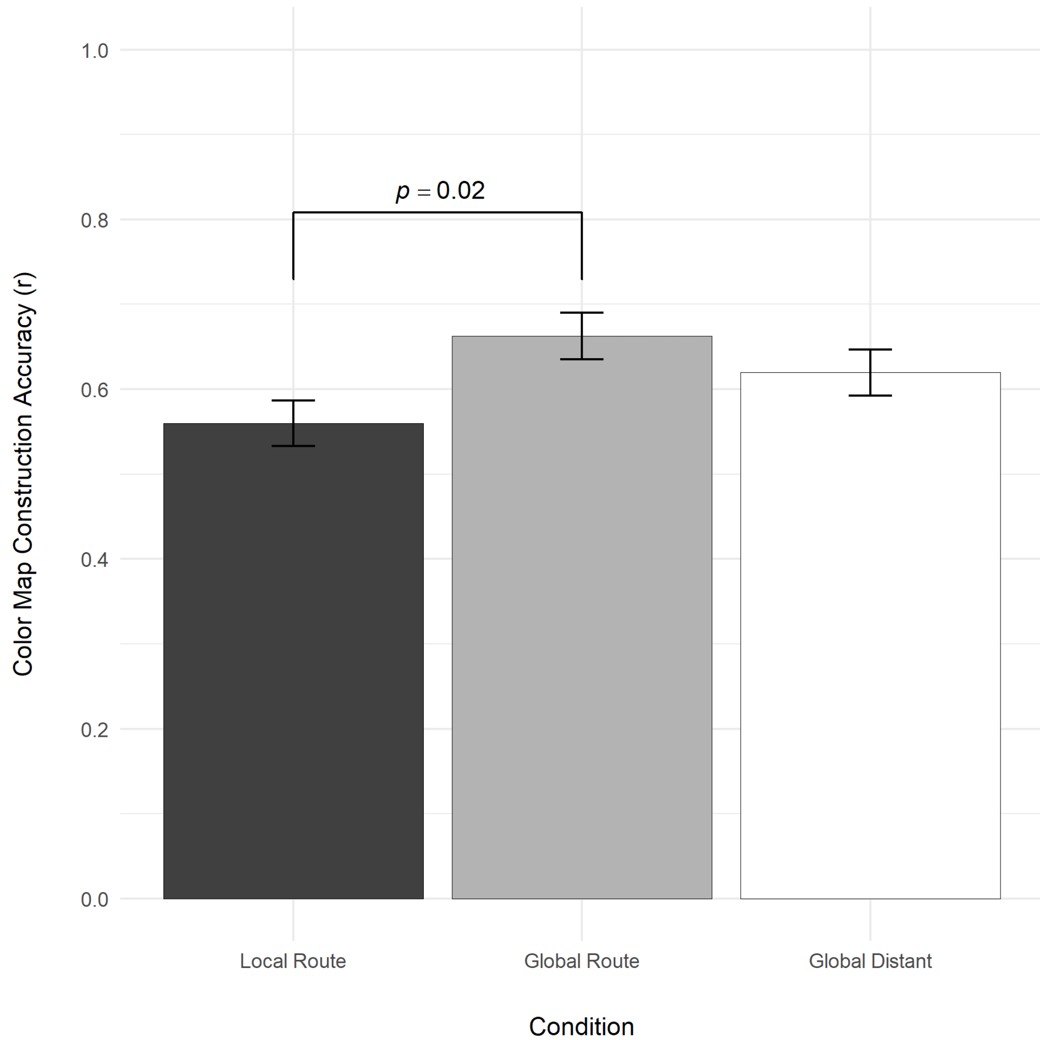


Fig. 6 Performance on the map reconstruction (color) task, measured by the bidimensional regression coefficient

4. Discussion

Credé et al. (2020) proposed that global landmarks might only improve spatial memory when those landmarks are along the route one travels versus in the distance, which would explain the seemingly inconsistent results in past work, such as between Credé et al. (2019) and Credé et al. (2020). However, this idea had not been directly tested by comparing participants' spatial memory for an area when they were provided with highlighted global landmarks along their route versus in the distance. This work aimed to address this gap in the literature by studying multiple outcomes while also adding a local landmarks highlight as a control condition. Overall, our findings partially support the idea proposed by Credé and colleagues (2020): Global landmarks in this study were helpful only when they were placed along the route participants traveled. For two out of three measures of spatial knowledge, those using global landmarks in the distance performed worse than those using landmarks (local and global) along the route. This is particularly interesting because even though we attempted to build on Credé et al.'s (2019, 2020) work, our study also differed in key ways: using passive navigation, assessing different outcomes of spatial knowledge, and more.

4.1 Landmark Type: Mixed Results for Spatial Knowledge

We found the local and global route conditions had higher spatial knowledge than the global distance condition for two dependent measures: landmark recognition and map construction accuracy using landmarks, whereas we did not find meaningful differences among conditions for route choice. Puzzlingly, map construction accuracy using color was lower for local route than global route. Differences in the two map construction methods may be due to memorizing colors and spatial locations rather than binding landmarks and colors together.

4.2 The Route Condition Outperformed the Distant Condition

This is consistent with Credé et al.'s (2019) finding that using high-rise buildings in the distance as global landmarks provided participants with no advantage. However, unlike Credé et al. (2020), we did not find that global landmarks along the route were remembered better than local landmarks along the route. This may be due to one of the four major differences in our study (varying outcomes, passive navigation, no cognitive load, and the use of beacons). Overall, though, this result does fit Credé et al.'s (2020) proposal that global landmarks are most useful when on the route one travels versus in the distance. Importantly, we directly tested this idea by comparing a global route landmark condition to a global distant landmark condition within the same study.

There are several possibilities as to why global route outperformed global distant: greater proximity to the road participants traveled (Duckham et al. 2010), greater accessibility (Sorrows and Hirtle 1999), the combination of landmarks and paths as two vital city elements (Lynch 1960), or the increased closeness to decision points (Chan et al. 2012). Being able to use the highlighted landmarks as reference points to organize one's sense of the space may have been easier for those whose landmarks were inside the navigable area (e.g., along the route; Sadalla et al. 1980). As the literature indicated, it appears that beacons placed in the distance, such as tall buildings or cranes, may be too far outside one's area of focus—failing to help people learn and remember the space. In contrast, the global landmarks placed along one's path did appear to combine the relevance of local landmarks (which also saw good performance) with the visibility of global landmarks. At times (such as landmark identification), this combination of benefits may be what led to global route landmarks significantly outperforming global distant landmarks when the local landmark condition did not.

Overall, this research contributes to resolving the debate as to whether highlighting global or local landmarks helps improve navigation of virtual environments. While our findings using a passive navigation paradigm generally fit with that posited by Credé et al. (2020)—that global landmarks are useful for navigating only when they are highlighted along the route one travels—our results were not entirely consistent with expectations. The global route condition did not meaningfully outperform the local route condition; indeed, there was often no significant difference between the two conditions. We explore this in more depth in Section 4.3.

4.3 Limitations

It was surprising that our global route condition did not outperform our local route condition. There were many reasons to expect that it would; they are more constant and visible from more places (e.g., Wenig et al. 2017). The more constant visibility was expected to help participants offload burden from one's mind to an external space, seemingly enhancing processing of the area (Tversky and Lee 1999; Wenig et al. 2017). Future work could determine what differences between our work and Credé et al.'s (2020) led to our findings regarding local landmarks: What conditions might have caused global landmarks on the route to outperform local landmarks on the route for Credé's work that were not present in our study?

Another point of note was the lack of findings for our "choose the next path" task. There, participants were shown a video clip of themselves arriving at Point A. An unseen turn was made, and then participants viewed themselves arriving at Point B. They were asked to choose if they would have gone left, right, forward, or backward to travel from A to B. There were no significant findings for this outcome. This route task might not have been sensitive enough to assess differences among conditions given the general difficulty of the task and limited range of possible responses. In the future, we will try to assess spatial knowledge and learning through other ways because overall this task ended up being very difficult for participants.

5. Conclusion

Addressing an important gap in the literature, our results indicate that highlighting global landmarks in an attempt to improve spatial memory and recall is beneficial only when those highlighted landmarks are along the route one travels. For landmark recognition, participants relying on highlighted landmarks in the distance were outperformed by both the local landmark condition and global route conditions. However, results for other measures of spatial knowledge did not have the clear pattern. This partially supports Credé et al.'s (2020) proposition regarding past contradictory findings (e.g., Credé et al. 2019, 2020) even though our study differed in several ways. Thus, these findings suggested by Credé et al.'s work are further supported by this research, which used passive navigation, did not affect cognitive load, added beacons to global landmark highlights, and assessed three different outcomes from that of Credé et al. (2020). Overall, those in the global route condition were better at identifying their landmarks and more accurate at rebuilding a map of the area than the global distant condition.

Here, we simulated augmented reality using highlights on landmarks. As advances in augmented reality devices continue, these results have possible implications for how navigational information could be displayed using augmented reality in the real-world. When such devices are used to help people navigate or learn a new or uncertain environment, their ability to highlight certain buildings could be most effective when they highlight buildings that the user passes directly next to on their travels—not those further in the distance. Particularly in situations where users may need to later draw a map of this unknown area or recall specific buildings, the ability of augmented reality devices to select and highlight the right landmarks could be crucial.

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List of Symbols, Abbreviations, and Acronyms

ANOVA	Analysis of Variance
HSD	honest significance difference
MTurk	Amazon Mechanical Turk

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