Representation of Local Landmarks in Bicycle Navigation Applications and their Effect on Learning Planned Routes

Florian Sturzenegger (florian.sturzenegger@uzh.ch), Dr. Tumasch Reichenbacher (tumasch.reichenbacher@geo.uzh.ch)

Department of Geography, University of Zurich, Switzerland

Abstract. Learning and remembering a specific route in advance is beneficial to cyclists. As landmarks are known to improve route learning, we tested this in an experiment with 39 participants, where the effect of landmarks displayed as symbols or pictures is compared to no display of landmarks. Participants learned the route from a map and had to remember the route. They were shown the route on a video, simulating the bike ride. At decision points the video was stopped, and participants had to give their turning decisions and their confidence. The study revealed no significant differences between the three groups.

Keywords. landmarks, bicycle routing, user study

1. Introduction

Cycling is becoming more popular in urban and sub-urban spaces. Many cyclists face the problem of memorising route information when navigating in unfamiliar environments. Using navigation tools, such as smartphone apps while cycling, is not always an option since they should pay attention to traffic. However, getting off the bike is interrupting the trip. Thus, we designed a study to test if the way route information is shown to cyclists before a trip could influence their memory of route and hence their performance (rate of wrong turns at decision points).

The main objective of this research is to find out whether the spatial learning process of a planned bicycle route in an urban environment can be improved, in regards of better memorability, by displaying local landmarks in a routing app and by displaying them with either simple, abstract symbols or real-world pictures. We assume the spatial learning process can be improved, when specific local landmarks are shown in addition to the exact planned

Published in "Proceedings of the 18th International Conference on Location Based Services (LBS 2023)", edited by Haosheng Huang, Nico Van de Weghe and Georg Gartner, LBS 2023, 20-22 November 2023 Ghent, Belgium.

This contribution underwent single-blind peer review based on the paper.
https://doi.org/10.34726/5727 |

route, resulting in less direction change errors at decision points when navigating this same planned route. We also hypothesise that a real-world picture, having a higher degree of realism, leads to an increased spatial learning of the planned route compared to an abstract symbol, meaning that the route can be memorised better, resulting in less errors at decision points for changes of direction.

2. Related work

As for pedestrian and car navigation, landmarks play a central role for bicycle navigation, wayfinding and spatial learning (Burnett et al., 2001; Cheng et al., 2022; Credé et al., 2019; Duckham et al., 2010; Keil et al., 2020; Lynch, 1960; Richter and Winter, 2014; Siegel and White, 1975; Sorrows and Hirtle, 1999; Yesiltepe et al., 2021). According to Lynch landmarks are significant points of reference that are easily identifiable, contrast with their environment, and exhibit unique or specific properties making them prominent (Lynch, 1960).

Landmarks can be categorised according to scale and visibility into local and global landmarks (Yesiltepe et al., 2021). There is a plethora of properties defining landmarks: uniqueness, distinguished location, visibility, semantic salience (Burnett et al., 2001), singularity (with respect to surroundings, prominence of location, (Sorrows and Hirtle, 1999), visual salience (size, form, colour), meaning, function (Duckham et al., 2010).

Löwen et al. (2019) found that local features and global features have a positive influence on the survey knowledge. Different landmark visualisation styles (e.g., degree of abstraction) have different effects on how those landmarks get recognised and how those can affect spatial knowledge (Kapaj et al., 2021).

3. Methods

To answer the two research questions, we designed a user study, conducted from January 17 until February 14, 2022. 39 participants were recruited by Email from the first author’s private and educational network, of whom 21 are male and 18 female. 70 % of the participants were between 25 and 28 years old. All participants gave their informed consent.

The study was conducted in an indoor laboratory at XXX, to allow for a more controlled environment. In addition to a large-screen projection, a bicycle ergometer was installed for the experiment. The bicycle ergometer has no resistance, so that the participant does not have to exert any effort but can simulate the bike riding process.

The maps for the spatial learning process were created with ArcGIS Pro (see Figure 1) and served as a Web Map Application in ArcGIS Online. The web maps were interactive, and participants were able to pan and to zoom between 1:100 and 1:15 000.

The video projected to a large screen represents a route of around 2.5 kilometres and lasts of about 14 minutes. It was recorded with a GoPro camera from a cyclist's perspective. At decision points the video was paused, and different arrows were displayed in the video for the possible directions. The placement of landmarks was done following the approach of *decision points* and *potential decision points* (Keil et al., 2020).

The size of the displayed landmarks was chosen, that they were clearly visible in the scale range. All symbols have the same size, resolution and same level of abstraction to ensure. Symbols of the building are coloured in the main building colour. In addition to that, all of the pictures had to be taken from the front view which the participant sees in the video.

Our experiment follows a *between-subject design* with three conditions (groups of participants): The *without* group sees a map showing the route only, and without any additional landmarks. This group represents the baseline for our experiment. The *symbols* group sees a map with additional landmarks visualised as abstract symbols (see Figure 1). The *pictures* group sees a map with additional landmarks as shown as pictures (see Figure 1). As outcome we measured the performance of the spatial learning process, measured as the number of correct turns.

We controlled for spatial abilities, demographics, geographical knowledge and bicycle experience of participants by balancing them between the three groups. Moreover, we controlled for the experiment conditions characteristics (room temperature, light etc.).

Before the experiment the spatial ability of participants was tested with the Santa Barbara Sense of Direction (SBSOD) test. The experiment was structured into three phases. In the *learning phase* the participants looked at the map according to their group (*without, symbols, pictures*) for two minutes and had to remember the route and the turnings to take. In the *performing phase* participants "drove" the route as displayed by the recorded video. At decision points participants were asked to indicate the direction they need to take to follow the remembered route (see Figure 1). Participants verbally reported their decision (A, B, or C) and how confident they are with the decision (unsure, neutral, sure) to the study conductor. Moreover, decision time, i.e., the period between the stopping of the video at a decision point and when the study conductor is informed of the direction, was recorded. Finally, in the *questionnaire phase* participants filled in a questionnaire (task, map etc.) about the two previous phases.

Figure 1. Maps for participants in *Symbols* (top) and *Pictures* group (bottom).

4. Results

Overall, our results revealed no significant improvement of the spatial learning process when landmarks have been shown on the map in comparison with no display of landmarks. Also, no significant difference could be found for the way the landmarks were displayed, i.e., as abstract symbols or as real-world pictures.

There are indications that landmarks in the beginning of the route helped more in the spatial learning process and the navigation in comparison with the ones visualised at the end.

Participants were asked to make decisions at various points, with landmarks visualized for the *pictures* and *without* groups. The medians depicted on the y-axis in Figure 2 represent the ratio value on how many decisions have been correct over the defined decisions. The analysis revealed that the *symbols* group performed the best overall, while the *without* and *pictures* groups performed slightly worse. However, when considering decisions with landmarks, the *without* and *pictures* groups performed better.

Looking also on spatial abilities, we observed weak positive correlations between performance and spatial ability pre-test scores for all groups, no significant correlation for the *without* group, very weak negative correlation for the *pictures* group, and a moderate to strong positive correlation for the *pictures* group. However, only the correlation for the *pictures* group is significant. We split participants into two groups based on the median of the SBSOD scores which was at around 5 and used it as a second factor in a *Scheirer-Ray*-Hare test. This test showed that the scores in the spatial ability pre-test significantly influenced the participants' decision-making, particularly regarding the number of correct decisions. However, only for decisions where landmarks are displayed the influence of spatial abilities is significant.

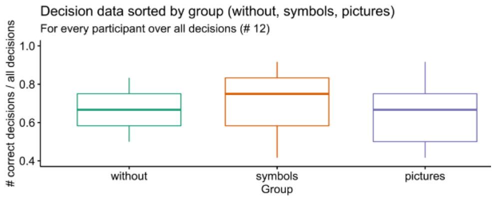

Figure 2. Decision data by group for all participants over all decisions where there are/are no landmarks visualised.

For the confidence in decisions results indicated that the *symbols* group generally exhibited higher confidence in their decisions than the other groups. However, no significant differences were found between the groups in terms of confidence.

Results for decision time are very similar. Decision times are not significantly different for the three groups. Yet, results suggest a tendency for longer decision times in the *without* group compared to the *symbols* and *pictures* groups. Additionally, the *pictures* group had slightly shorter decision times compared to the *symbols* group.

The results of the *post-experiment questionnaire* can be summarized as follows: The majority of participants from the *symbols* group and *pictures* group (26 participants) indicated that the landmarks helped them to some extent to recognize them in the video and with the spatial learning process The first four landmarks were identified as most prominent more frequently than the last three, with landmarks one, three, and four being selected the most. Over 70% of all participants (39 people) stated that they would find it useful if landmarks were displayed as symbols or images in a routing app.

5. Discussion

Our results indicate that there was no significant improvement in spatial learning when landmarks were represented either as symbols or pictures. This contradicts some previous studies suggesting that landmarks are helpful in spatial cognition. The study also analyses the performance of participants in individual decisions along the route and identifies some tendencies. The cognitive load and working memory could affect the impact of landmarks on navigation. The discrepancy between participants' perceptions of the usefulness of landmarks and their actual performance is noted, which is a common phenomenon in research.

We observed that decision time for the participants in the *without* group is marginally higher than for participants in the other groups. One explanation is that through the display of the landmarks the spatial knowledge increased (Credé, 2019, p. 6). So, through the acquired spatial learning process with the help of landmarks, there is a possibility that the answer could be given faster (Li, 2020, p. 432). In contrast, Parush and Berman (2004), stated, that the visualisation of landmarks leads to the further processing of information of the participants, which then can increase the time needed for.

Participants in the *symbols* and *pictures* group were slightly more confident with their decision. This can be explained by the fact, that the spatial knowledge increased, and the spatial learning process was improved (Credé et al., 2019) and (Li, 2020). Participants in the *pictures* group overall achieved more correct decisions than the participants performing in the *symbols* group. A study by Zhu et al. (2022) also found similar results, where the study setting was comparable. (Zhu et al., 2022, p. 677). However, it must also be mentioned that other reasons could have contributed to this result, such as the fact that the participants mostly learned the route from the beginning and that maybe the symbols and pictures in the beginning of the route have been more suitable.

Regarding limitations, the chosen route might have been too simple for most participants due to the high number of participants with a geography background, thus minimising the variability between the different groups. For a follow-up study, attention should be given to the selection of a route and landmarks. The time spent to learn the route from the map has also an important influence (hence lower the effect of landmarks). This assumption is backed up by the fact that participants in the *without* group in this study performed similarly than the two other groups.

6. Conclusions

How local landmarks may influence the spatial learning process and how the symbolisation of those can have different influences was researched in a study at the University of Zurich with 39 participants. Participants were assigned to three groups, which differed in the landmarks were visualised on a map used to learn the route. One group saw a map that additionally showed seven landmarks as abstract symbols (*symbols* group), a second saw them as real-world pictures (*pictures* group), and the third group had only route only without any landmarks (*without* group).

Although no significant results were found on whether landmarks improve the a priori spatial learning process, there are some tendencies that presentation as both symbols and pictures may help and that less time for decision-making and higher confidence may result. It should be kept in mind that a different study design (e.g., different symbolisation) could have led to different results. Future work could employ different landmarks, test other symbolisations, and use eye-tracking to determine which objects are looked at most frequently by people.

References

Burnett, G., Smith, D., May, A., 2001. Supporting the navigation task: Characteristics of "good" landmarks, in: Hanson, M.A. (Ed.), Contemporary Ergonomics 2001. CRC Press, pp. 441–446.

Cheng, B., Wunderlich, A., Gramann, K., Lin, E., Fabrikant, S.I., 2022. The effect of landmark visualization in mobile maps on brain activity during navigation: A virtual reality study. Front. Virtual Real. 3.

Credé, S., Thrash, T., Hölscher, C., Fabrikant, S.I., 2019. The acquisition of survey knowledge for local and global landmark configurations under time pressure. Spat. Cogn. Comput. 19, 190–219. https://doi.org/10.1080/13875868.2019.1569016

Duckham, M., Winter, S., Robinson, M., 2010. Including landmarks in routing instructions. J. Locat. Based Serv. 4, 28–52. https://doi.org/10.1080/17489721003785602

Kapaj, A., Lanini-Maggi, S., Fabrikant, S., 2021. The influence of landmark visualization style on expert wayfinders' visual attention during a real-world navigation task, in: GIScience 2021 Short Paper Proceedings. https://doi.org/10.25436/E2NP44

Keil, J., Edler, D., Kuchinke, L., Dickmann, F., 2020. Effects of visual map complexity on the attentional processing of landmarks. PLOS ONE 15, e0229575. https://doi.org/10.1371/journal.pone.0229575

Lee, Y.C., Kwong, A., Pun, L., Mack, A., 2001. Multi-Media Map for Visual Navigation.

Li, R., 2020. Spatial Learning in Smart Applications: Enhancing Spatial Awareness through Visualized Off-Screen Landmarks on Mobile Devices. Ann. Am. Assoc. Geogr. 110, 421–433. https://doi.org/10.1080/24694452.2019.1670611

Löwen, H., Krukar, J., Schwering, A., 2019. Spatial Learning with Orientation Maps: The Influence of Different Environmental Features on Spatial Knowledge Acquisition. ISPRS Int. J. Geo-Inf. 8. https://doi.org/10.3390/ijgi8030149

Lynch, K., 1960. The Image of City. MIT Press.

Richter, K.-F., Winter, S., 2014. Landmarks: GIScience for intelligent services (No. 978-3-319-05732–3). Springer, Cham.

Siegel, A.W., White, S., 1975. The Development of Spatial Representations of Large-Scale Environments. Adv. Child Dev. Behav. 10.

Sorrows, M.E., Hirtle, S.C., 1999. The Nature of Landmarks for Real and Electronic Spaces, in: Freksa, C., Mark, D.M. (Eds.), Spatial Information Theory. Cognitive and Computational Foundations of Geographic Information Science. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 37–50.

Yesiltepe, D., Conroy Dalton, R., Ozbil Torun, A., 2021. Landmarks in wayfinding: a review of the existing literature. Cogn. Process. 22, 369–410. https://doi.org/10.1007/s10339-021-01012-x