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Spatial learning using Google Streetview in an online wayfinding task

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The use of navigation applications changed the way people find their way in an unfamiliar environment. A combination of maps, images and textual route instructions shown (or with audio) on one screen guides the user to the destination but may sometimes be overwhelming. This article investigated the spatial knowledge participants acquired after being presented with different types of route instructions, human and computer-generated, in an online wayfinding task using Google Streetview (without the 2D map) of an unfamiliar environment. The results showed a significant difference in the wayfinding performance for deviations from computer-generated instructions, whilst there was no difference in the time spent and the scene recall. Sketch maps revealed both route-like and survey-like characteristics. But most sketch maps are characterised by high route-likeness. Furthermore, this study showed a significant effect of the environmental layout on the participant's performance based on deviations incurred during wayfinding. The results of this study have implications for improving navigation system instructions and design as well as for learning with geospatial technologies.

Keywords: wayfinding; Google Streetview; geospatial learning; route instructions; sketch maps

Introduction

Finding your way in an unfamiliar environment can be challenging. Many people use and depend on navigation applications to get an advanced visualisation of an unfamiliar place before they travel there. Such technology may test a person's geographic knowledge, such as establishing and remembering where things are located to guide spatial decisions (Golledge, 2002), particularly when maintaining orientation during wayfinding. In-vehicle navigation systems are widely available on the market and have shown varying effects on drivers' processing of route information (Jackson, 1998). Today, most people check web mapping platforms like Google Maps, Here Maps and OpenStreetMap, to name a few, before heading to their destination. One popular application is Google Streetview[1], which provides street-level photos in many areas worldwide. For example, a person familiar with the application reads the instructions for going to a hotel in an unfamiliar area and then checks with Google Streetview the route to take. But what do people remember after seeing an unfamiliar place remotely through Google Streetview?

[1]Google Streetview is a technology embedded in Google Maps that provides a 3D panorama of images taken from different positions along the street, providing an 'immersive experience' of the environment.

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Furthermore, Antrobus et al. (2017) compared the type of spatial knowledge the drivers acquired when using SatNav and when navigating collaboratively with the passenger. This current research evaluates different types of route instruction, what people learn during virtual wayfinding in an unfamiliar environment with varied spatial layouts using Google Streetview and how they represent the acquired knowledge on a sketch map. The 2D map was not shown to determine what participants often recall when checking only the Streetview images and spatial descriptions. Evaluating what people learn is often not the intention when developing navigation systems as long as the person reaches the destination. However, the importance of understanding human cognition and technology is to help researchers design an efficient system that involves a multilayer of information to be presented on a specific screen size, such as a map, route instructions and photo amongst others-that will be easy to comprehend, whilst learning about the environment. Route instructions can be easily retrieved from different sources, but the kind of information included may result in different interpretations and knowledge obtained. This study follows previous work comparing different types of route instructions (Krukar et al., 2020) but tests it on virtual wayfinding conducted remotely, following only two general types of route instructions. The first type of description is human-generated instruction, which is like orientation-based wayfinding instruction using relative information with an emphasis on landmarks and providing an idea of the environmental layout or an overview of the place being travelled. The second is computer-generated instructions, which provide absolute information such as street names, cardinal directions and distances. The empirical work aims to investigate these research questions (RQ):

- *RQ1: How do the types of route instruction alongside Google Streetview influence wayfinding performance in an unfamiliar environment?*
- *RQ2: What differences are observed in the characteristics of the sketch maps after the wayfinding task?*

Virtual environment and Google Streetview

There is currently a growing interest from many researchers in the virtual environment (VE) to enhance spatial orientation (Carbonell-Carrera & Saorin, 2018) and spatial training for students (Carbonell-Carrera & Saorín, 2017), where technology is used as a motivational strategy, and many students describe it as an enjoyable activity. Even for older adults, Lokka et al. (2018) investigated the use of VE for memory training, which was beneficial to all groups when following route instructions. In another study, Jansen-Osmann et al. (2007) examined the effect of environmental structure on both adults and children's spatial knowledge.

Many people find Google Streetview useful for wayfinding and navigation, such as knowing the strategies of international tourists in virtually navigating an unfamiliar area (Nevelsteen, 2013). Chou et al. (2015) used this application to examine the wayfinding performance, and the results were correlated with psychological tests – mental rotation and monkey ladder. This suggests that using such technology can be an alternative to traditional wayfinding involving the real world, which contributes to spatial cognition research. However, problems may occur when there is a mismatch between the photo seen in Streetview and what is seen in the real environment. Liao et al. (2017) compared the navigation performance of the participants using 2D and 3D visualisations. The results indicated that the use of 3D maps resulted in visualisations

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that are both survey and environmental maps for effective wayfinding compared to the 2D map.

Although not the focus of this current research but a possible future work, the eye-tracking approach has been widely explored in cognitive studies and its application in a large-scale indoor environment, such as an airport through the processing of visual information during navigation (Schwarzkopf et al., 2013). Lander et al. (2017) discussed a strategy for choosing the landmark easily through eye-tracking using Google Streetview and proposed this technique to enable automatic landmark extraction. Bruns and Chamberlain (2019) described the role of landmarks in developing spatial memory and cognitive maps through virtual reality (VR). In addition, this study investigates to what extent different urban landmarks help to form spatial memory.

Evaluating spatial learning with sketch maps

Sketch maps have also been used to assess spatial learning after performing a virtual task. For example, to evaluate people's representations after being exposed to a type of map, whether 3D or 2D (Schmidt et al., 2012) and to a large-scale VE (Kraemer et al., 2017). Billinghurst and Weghorst (1995) examined sketch maps as valid tools to measure the cognitive maps of an immersive VE. This study hypothesised that participants who reported being well-orientated with the VE produced accurate sketch maps. Sketch maps were analysed, particularly considering the topological accuracy of the drawn features compared to the metric knowledge. The authors emphasised that topological knowledge is more important than metric knowledge in navigation. However, one disadvantage of the sketch map is the representation of the 3D version to a 2D. The authors highlighted some issues with VEs, such as low image resolution and poor image quality.

Sandamas and Foreman (2007) showed the differences in what active drivers and passengers remember in a virtual tour. Passive passengers recall more landmarks than active drivers. Sketch maps were analysed on their usefulness for navigation, according to the raters. The sketch maps also revealed differences in participants when they experienced more VE tours. The more tours they had, the more the maps resembled the actual layout, which depicted the survey knowledge. In this study, participants will only be asked to go through the route once, but the characteristics of the map will be analysed to determine whether they show both survey-likeness and route-likeness. Bruns and Chamberlain (2019) asked participants to travel in an unfamiliar environment using a head-mounted display and assessed the landmark, route and survey knowledge. Participants were asked to draw the route and landmarks. Sketch maps were digitised, and features that represented the different types of knowledge acquired were extracted. In this study, a more qualitative approach to extracting and analysing features is used.

Savino et al. (2019) compared VR navigation to real-life navigation by measuring the differences in navigation performance, task load and spatial knowledge acquisition. The results suggest that VR cannot completely replace real-life navigation in an experimental setting. Sketch maps were used to measure the route knowledge by counting the correct turns and the directional change. Löwen et al. (2019) evaluated the effect of wayfinding maps emphasising not only local landmarks but also global landmarks through VR driving simulation. The findings suggest that route knowledge and survey knowledge are supported when maps are highlighted with local and global features, respectively. In this study, both the route and survey knowledge are considered.

Method

Participants

A total of 48 adults, mostly students (24 females) 18 years and older (M = 22.13, SD = 5.097), voluntarily participated in the virtual activity. The participants, unfamiliar with the study areas, came from different provinces of the country and were recruited through an online advertisement. Snowball sampling was also used to recruit more participants who met the same criteria. They received monetary compensation for their participation.

Study site

The study sites were the Quezon Memorial Circle (QMC) and the UP Diliman (UPD) Campus. Both sites are in Quezon City, Philippines. The routes had the same number of turns (12) and a distance measuring 2.26 and 1.86 km for the UPD campus and QMC, respectively. The two sites differed in their configurations – a circular layout (QMC, Figure 1A) and a grid-like street pattern (UPD, Figure 1B). Both sites were chosen because of differences in the spatial layout.

Experimental design

During the peak of the COVID-19 pandemic, activity was carried out online using a computer or laptop via the Zoom application. Participants were tested individually, and the experimenter obtained informed consent before starting the activity. Next, they answered the 19-item Questionnaire on Spatial Strategies (Münzer & Hölscher, 2011), which is a self-reported evaluation of how participants rate their global-egocentric orientation ability, preference for survey strategy and knowledge of cardinal directions. This questionnaire is chosen to assess their orientation skills in both known and unknown environments, which are important in wayfinding tasks. Then, the participant proceeded to the main tasks. Each participant performed both the human- and computer-generated instructions. The whole activity lasted around 90 min.

A B

Figure 1. Study areas with the route.

Source: ArcGIS online

Figure 2. Sample of a route segment (Route 1 showing computer-generated instructions).

Before starting with the major tasks, the experimenter showed Google Streetview and its functions without giving details about the activity. In the first task, the route of one study site is shown to the participant and, thereafter, the other study area. On the screen, the instructions (in MS PowerPoint) and the Google Streetview (without the reference map) were placed side-by-side or in a split-screen mode (see Figure 2). The participant read the directions aloud to the experimenter. Two different types of route instructions were given for each site: computer-generated[2] and human-generated.[3]

The participant was given this scenario without disclosing the next task:

> One of your friends wanted you to virtually visit a place s/he once visited in the real environment. You are given a set of instructions to follow since you are unfamiliar with the area. Try to imagine that you are a passenger who is giving directions to a taxi driver. (The experimenter serves as the driver, who will only follow your directions.). You will tell the driver the route to take based on the set of route instructions you received. You are not allowed to ask the driver questions. Focus your attention on the screen to guide you to the destination. Afterwards, you will be asked to do some tasks.

During the wayfinding task, the experimenter followed the directions dictated by the participant. If the participant deviated from the route, the experimenter leads the participant back to the last correct position along the route. After wayfinding, the participant was asked to draw the route from memory, including other information they thought was important for someone new in the area. The participant took a photo of the sketch map and sent it to the experimenter by email. Subsequently, a recall task was performed to identify whether they saw the photos along the route. There was a debriefing with the participants about the activity, explaining the objectives of the study. Afterward, the experimenter conducted a short interview. Participants were asked to always turn on their cameras during all tasks.

[2]Example for Route 1 computer-generated instruction for the UPD campus: 'Depart from F. Ma. Guerrero St. Head 20 m North on F. Ma. Guerrero St. Arrive at Magsaysay Avenue (less than 1 minute)'.

[3]Example for Route 1 human-generated instruction on UPD campus: 'From the waiting shed on your right, go straight towards the intersection, and immediately turn left. You see Romulo Hall on your right and Bocobo Hall on your left'.

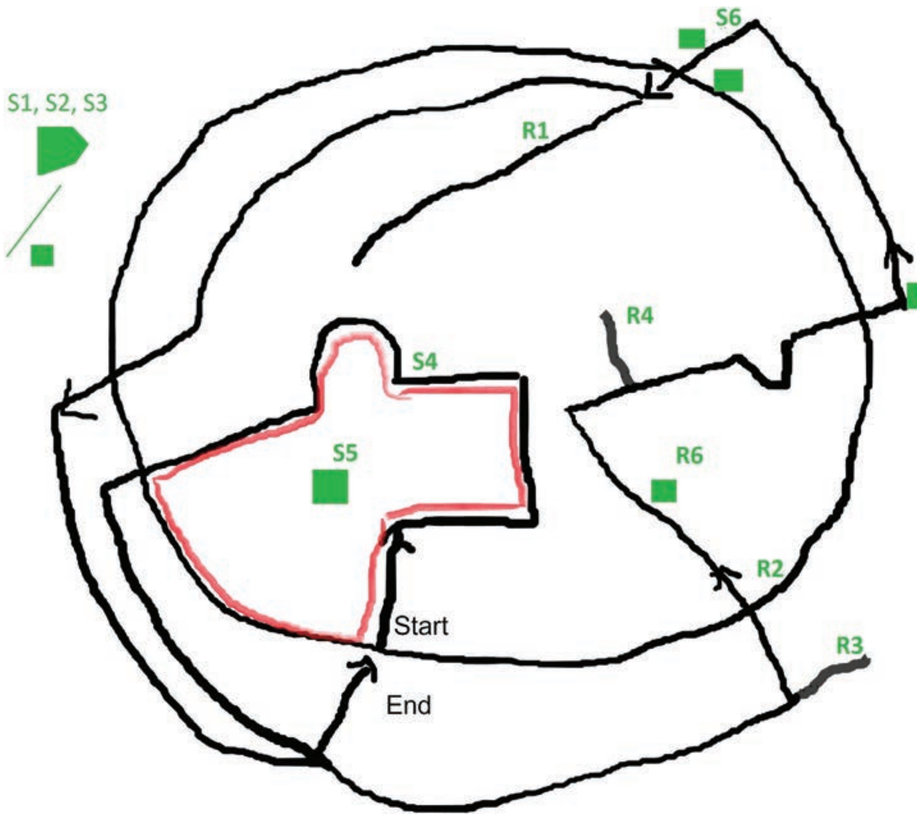

Figure 3. Sketch map criteria after Krukar et al. (2020).

Note: This map is redrawn from the original sketch map of a participant, which contains no features and indicates only the start and end of the route. The landmarks were placed purposely by the author to visualise the criteria used. The arrow shows the route direction.

Sketch map analysis

The classification by Krukar et al. (2020) was used in the analysis. The sketch maps were classified as showing *route-likeness or survey-likeness*. For route-likeness, the criteria are (R1) a non-fragmented route; (R2) explicit turns; (R3) side streets at decision points; (R4) side streets at non-decision points; (R5) local landmarks and street names at decision points; and (R6) local landmarks and street names at non-decision points. For the survey-likeness criteria, they are (S1) global landmarks (point), (S2) global landmarks (linear), (S3) global landmarks (regional), (S4) network or linked street, (S5) containment or hierarchy and (S6) spatial relations between two or more separate elements (refer to Figure 3 for the visualisation).

In the scoring, one point was given to each of the criteria that a map satisfied based on its characteristics – route-likeness or survey-likeness. This will address the research question of what the sketch maps reveal after a certain type of instruction on different routes. This also evaluates how they mentally represent the route shown remotely. The sketch map analysis did not investigate the accuracy of the route taken.

Results

Wayfinding performance

Deviations

There were more deviations in the computer-generated instructions (M = 1.13, SD = 1.196) with 54 errors than in the human-generated ones (M = 0.48, SD = 0.652) with 23 errors, showing a significant difference based on a repeated-measures ANOVA, F (1, 46) = 9.699, $p < 0.05$. Table 1 presents the mean and standard deviations of the errors made when comparing both types of instruction.

Another analysis looked at how the deviations differed according to the study area. The results indicated that there were more deviations at the UPD campus (M = 1.21, SD = 1.148) with 58 errors than at the QMC (M =0.40, SD = 0.644) with 19 errors. This showed a significant difference between the means of the site type as shown in the repeated-measures ANOVA, F (1, 46) = 16.635, $p < 0.001$, demonstrating that there were more deviations in the grid-like street.

Time spent

The maximum time spent on the wayfinding task was around 20 min. In general, it took participants longer to follow the human-generated instructions (M = 11.11, SD = 3.15) than the computer-generated instructions (M = 10.19, SD = 2.54), but the difference was not significant. No significant effect on the time spent for both computer-generated and human-generated instructions in recalling scenes and sketch mapping was found.

Scene recall

There was no significant difference in the scenes recalled for computer-generated (M = 4.31, SD = 1.095) or human-generated instructions (M = 4.528, SD = 0.989). This showed that participants paid attention to Google Streetview apart from the route directions presented on the same screen, with more recall of the human-generated instructions than the computer-generated instructions. The results demonstrated that participants could recall landmarks or scenes even if the instructions appeared more detailed, especially for human-generated type.

Table 1. Mean and standard deviations of the wayfinding performance indicators and the characteristics of the sketch map.

Type of instructions	Computer-generated		Human-generated	
	Mean	SD	Mean	SD
Deviations	1.13	1.196	0.48	0.652
Scene recall	4.31	1.095	4.52	0.989
Time spent wayfinding	10.19	2.54	11.11	3.15
Sketch map route-likeness	2.96	1.110	3.27	1.144
Sketch map survey-likeness	2.67	1.419	2.81	1.439

Sketch maps characteristics

In analysing the sketch maps, the method of Krukar et al. (2020) was used to classify the maps based on their survey-likeness and route-likeness. A rater was asked to score the sketch maps according to the criteria used, with no further explanation given. There was a positive association between survey-likeness and route-likeness in human-generated instructions, $r(48) = 0.419$, $p < 0.05$ as well as in computer-generated instructions, $r(48) = 0.423$, $p < 0.05$. This means that the types of instruction showed both characteristics in the participants' sketch maps. It also illustrated that sketch maps after computer-generated instructions characterised high route-likeness (M = 2.96, SD = 1.110) compared to survey-likeness (M = 2.67, SD = 1.419), but the difference was not significant. Concerning human-generated instructions, these also showed more route-likeness (M = 3.27, SD = 1.144) than survey-likeness (M = 2.81, SD = 1.439), showing a significant difference, $F(1, 47) = 5.046$, $p < 0.05$.

Regarding the correlation with Spatial Strategies (Münzer & Hölscher, 2011), only the Knowledge of Cardinal Directions scale correlates with the score in wayfinding performance after human-generated instructions, $r(48) = -0.306$, $p < 0.05$, using the Pearson's correlation measure. This implies that those participants who prefer cardinal directions easily follow more detailed human route instructions concerning landmarks since they did not incur many deviations when following human-generated instructions. The results of the self-assessment on each scale with a 7-point rating are: global self-confidence, related to egocentric strategies (M = 4.498, SD = 1.12), using the survey strategy (M = 4.27, SD = 1.185) and knowledge of the cardinal directions (M = 3.1313, SD = 1.832). No correlation was found between self-reported measures and the characteristics of the sketch map, as well as scene recall.

Discussion

Wayfinding performance

In this study, the results showed that participants can follow both types of instruction at different sites through online wayfinding. The deviation was referring to the wrong or missed turns. It showed more errors on the UPD campus. Most participants find the UPD route more complex due to the series of turns compared to the QMC route. They mentioned that the similarity of houses in the residential area of the UPD campus was also disorienting for some of them. The computer-generated instructions made it even more complicated due to the detailed distances and the street names, which were difficult to recall. This is what Liao et al. (2017) emphasised: Too much precise information is overwhelming, and the knowledge gained is less useful and less effective.

There was an effect of the environmental structure on the number of deviations. Many participants find the QMC route easier to follow for both computer- and human-generated instructions. They incurred more errors when wayfinding in UPD than QMC. The grid-like street network was a more confusing layout and required effort to follow the route. It differs from the findings of Jansen-Osmann et al. (2007), who described no influence of environmental layout on people's spatial knowledge. This can be explained by a different experimental design and complexity of tasks, where participants in the current study had to follow a set of instructions with a longer route. According to most participants, they prefer human-generated instructions, even if the instructions are longer. But some suggest that fewer details and only

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important landmarks should be included. One participant mentioned that instructions could also be a mix of both computer-generated (no distances, only street names) and human-generated (with landmarks) instructions. Since most of the participants use Google Maps for navigation, they often give visible landmarks to people who ask for directions, as these are more helpful information.

There was no huge time difference in most activities, although it took time for participants to follow the human-generated instructions. It could be the many details included compared with the computer-generated ones since they must read the instructions whilst also checking the Google Streetview.

Although they were able to follow the route instructions, particularly human-generated instructions, it was also evident that none of the participants correctly recalled the route taken. Participants mentioned the difficulty, especially since it was shown only once and without reference to any map. The two modes of presentation – visual and verbal – may have been complex for the participants to represent the route on the map. However, if shown to the participants many times, their maps may illustrate the route better and provide a more survey-like representation of the unfamiliar environment similar to the study of Sandamas and Foreman (2007). Other factors that may explain the findings include the lack of concentration of participants and some distractions during the virtual task, getting disconnected during the activity and the difficulty of the route, which can be more appropriate in the real environment. This is what Savino et al. (2019) also observed, and VR may not completely replace navigation experiments in the real world. Some issues with image quality, like the findings of Billinghurst and Weghorst (1995), were also a concern in this current study due to poor internet connection.

Scene recall

In the recall task, participants were presented with some scenes, whether they recalled them or not after the wayfinding task. The results showed participants recalled more correct photos of the UPD campus despite the detailed instructions, suggesting that they are still paying attention to Google Streetview in split-screen mode. This can be attributed to the presence of landmarks. Landmarks identified in verbal descriptions are useful for remembering such features (Kraemer et al., 2017). This corresponds to Bruns and Chamberlain's (2019) study, in which landmarks play a role in people's spatial memory in their study of the VE.

In the interview, participants were asked about their experience whilst doing the activity. Many considered Google Streetview to be helpful, especially for those unfamiliar with the environment. Some participants became familiar with the place without being physically present. So, when they are already in the actual place, it becomes easier for them to find the destination. A participant also mentioned that this activity is suitable during the pandemic because they can learn about an unfamiliar area. However, using Google Streetview for first-time users seems a bit disorienting, especially when navigating the route, and the map was disabled.

Regarding the route instructions, almost all participants preferred the human-generated type due to the presence of landmarks. The landmarks are the most important orientation information in the route instructions. However, some also preferred less information in the human-generated instructions, but salient landmarks should be included. It would be helpful to refer to some buildings in the environment to maintain orientation. Few participants preferred the computer-generated instructions only when they were driving and unfamiliar with the area. For future work, using eye-tracking (Lander et al., 2017; Nevelsteen, 2013; Schwarzkopf et al., 2013) can be applied to a similar virtual wayfinding task with a focus on the kind of landmarks people pay much attention to. This technique will also help detect participants' fixation on route instructions or the image. Most participants concentrated more on the route instructions since it was the first time to see the places. This is an important observation because it implies that navigation route instructions must be well-structured so that they are easy to comprehend and recall. Most of the participants preferred to ask people for directions, particularly in unfamiliar areas. Hence, the information needed in the route instructions should help a person become oriented in the environment, with landmarks as the common feature often mentioned.

Characteristics of sketch maps

In the qualitative analysis of the sketch maps, a set of criteria determined the characteristics shown based on the presence of landmarks and street configurations without considering the correctness of the drawn route. Taking all of the sketch maps together, the results revealed that the sketch maps showed both route-likeness and survey-likeness. Figure 4 shows some examples of sketch maps drawn by participants. This showed that the sketch maps contained both survey-like and route-like features. This echoed the findings of Krukar et al. (2020) that sketch maps can show both characteristics. But route-likeness was more distinct for both types of instruction, which can be attributed to the less frequent inclusion of global landmarks and the experiment design conducted through a remote virtual set-up. However, even though the 2D map from Google Streetview was not shown, participants can still learn the layout of the environment. After the wayfinding task, most of them realised that they had come back to where the starting point was. Hence, some sketch maps showed a survey-like representation. Montello (2009) stated that when a person is new to an environment, one can learn the area with landmark, route and survey knowledge. It is worth knowing how a person understands the spatial layout of the surroundings whilst navigating an unfamiliar environment, as this is helpful to maintain orientation. According to Löwen et al. (2019), the most desirable wayfinding maps that help maintain orientation in space and support the acquisition of spatial knowledge should highlight local and global landmarks. Antrobus et al. (2017) also emphasised that navigation systems must use route instructions that incorporate landmarks for better interaction between the driver and the environment. Hence, navigation systems should adapt to people's natural way of travelling, particularly in an unfamiliar environment. Jackson (1998) even considered the importance of designing navigation aids for the specific needs of the drivers. This pertains to the relevant information that contributes to building one's cognitive map. Figure 4 shows examples of participants' sketch maps based on the type of instructions.

Poor internet connection causing video delay and disconnection is a limitation of this study, but the findings suggest this online learning activity creates awareness about an unfamiliar environment. This could be useful during a pandemic as an alternative activity for students that can be interactive and induce learning. This can also be an exercise during a fieldwork course, where the class is unable to visit the field site for familiarisation. In general, participants find the activity helpful and fun, as observed by Hagge (2021), since most of them have not yet explored Google Streetview. But many of them considered that actual wayfinding is better than virtual type. They also realised the difficulty of following a certain type of route instruction and

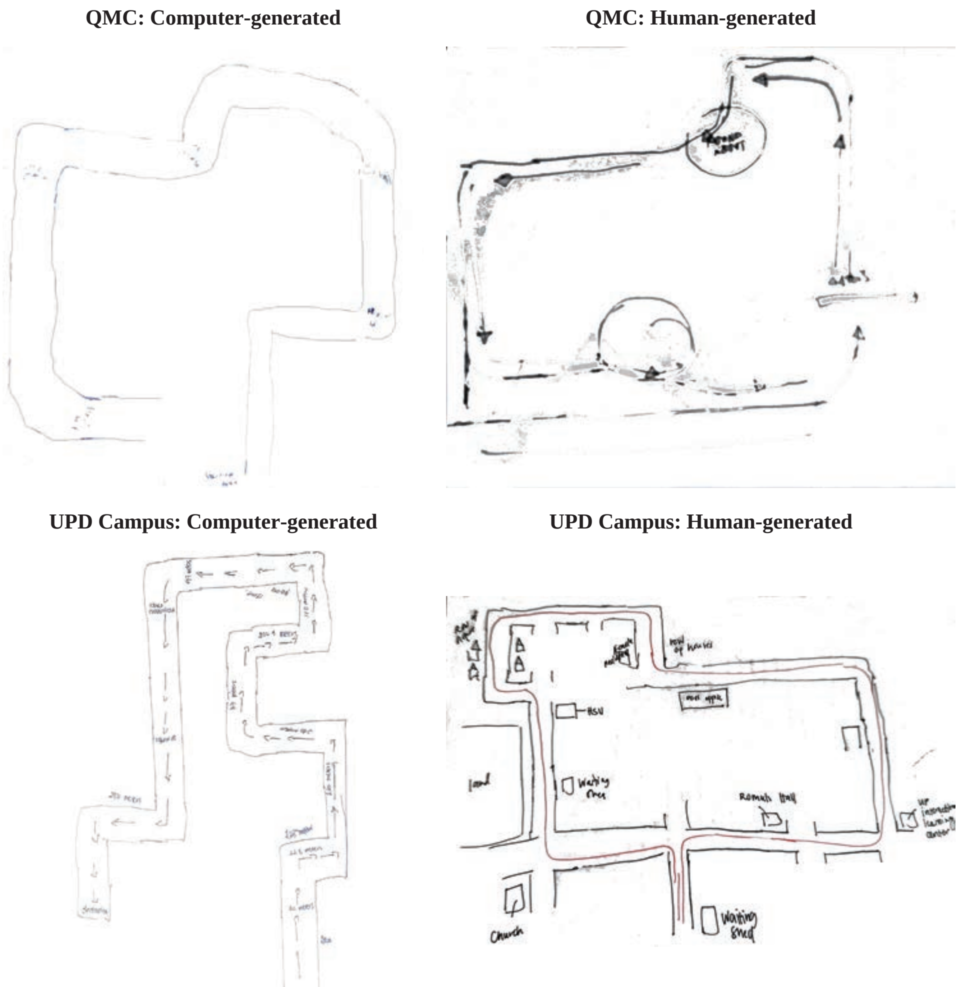

Figure 4. Example of participants' sketch maps.

the challenge of visualising the route through a sketch map after the virtual activity, as well as assessing their spatial strategies. As Carbonell-Carrera and Saorin (2017, 2018) highlighted, this kind of activity can encourage student learning and may be used for spatial training. It can contribute to spatial cognition research (Chou et al., 2015) that focuses on geospatial learning. Nowadays, there are navigation applications that integrate different sources of information or different modes of presentation. Montello and Frendschuh (2005) emphasised that through cognitive research, one would have an idea of how much information people need and can comprehend, as well as the kind of presentation format that can guide researchers in developing effective tools for visualising geographic information.

Conclusion

This study showed that acquiring spatial knowledge is possible in an online wayfinding task. Although there were differences in the wayfinding performance, participants had more deviations from computer-generated instructions and more time spent on human-generated instructions. However, participants were able to recall scenes from the route for both types of instructions. The wayfinding task exposed participants to the technology and helped them better understand what people learn, particularly those who heavily use navigation applications incorporating Google Streetview.

The effect of environmental structure on wayfinding is one interesting observation of this research, which can be further investigated to determine whether a certain type of instruction works best for a specific environmental layout. This study showed that some participants had difficulty with the grid-like structure. This may be attributed to the type of instructions, the environmental features and the route that consisted of many turns. Sketch maps of participants are characterised by both route-likeness and survey-likeness, even if the instructions are stated more in a route-like form. Although most sketch maps showed high route-likeness, people could still develop survey knowledge of an unfamiliar place through virtual wayfinding even without a 2D map.

The activity highlighted how recallable landmarks are than street names and distances found in computer-generated instructions. People are now exposed to procedural route directions from many online mapping services; however, most users do not always remember the details. This study has implications for learning with geospatial technologies and for the design of current navigation systems containing verbal and visual information that people easily remember as viewed on screen. For future work, the application can be tested with a mobile device in a real environment. This can determine the kind of instructions that are difficult to follow and the site that may appear complex to the participants. The findings contribute to existing studies on attempts to improve computer-generated instructions and visualisation that help humans better understand and learn the environment.

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