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Individualization in Spatial Behaviour and Map Reading

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Abstract. For a long time, research has investigated spatial behaviour of people in navigation research and identified different wayfinding strategies. Researchers agree, that the environment with its structure and features influences the wayfinding strategies. The present paper presents a tool to investigate people’s strategies during navigation tasks. GeoGami, an educational geogame fostering navigational map reading skills, can be used to collect trajectories of people navigating through an environment. We developed a semantically annotated representation of the environment and clustered the resulting trajectories according to their spatio-temporal and semantic similarity. The result shows the existence of groups of common spatial patterns along with individual spatial behaviours that cannot be grouped into a cluster.

Keywords. individualization research, navigational map reading, spatial movement patterns, geogame

1 Introduction

When people navigate and use maps for orientation, we can observe similar behaviours, but also differences. These differences might be the result of different map reading and navigation strategies, they might be influenced by differences in the environments or by different spatial information being available leading more or less successful navigation. Navigational map reading can be trained and changes over time. The differences in navigation and map reading can be observed in different spatial behaviour and different paths people follow.

GeoGami is an educational game to train navigational map reading. It is a location-based game for mobile devices: Players receive a map of their environment and different navigation tasks visualized by the target location on the map. The given map as well as the associated tasks can then help users to identify and, with multiple use, improve their map reading skills, orientation and wayfinding strategies. This geotechnology provides support for players to familiarize with maps, localization, orientation and spatial planning.

Each individual has different strategies to read maps and navigate with maps through an environment which result in different trajectories. A trajectory maps a person's path from a starting point to a destination while finding his/her way.

We conducted a test where 96 participants received four navigation tasks in a virtual environment and we collected the trajectories they followed to reach the destination. The analysis of all trajectories revealed several common patterns, but also individual strategies.

The goal of this paper is to (1) present a tool to observe systematically differences in the spatial behaviour during a map-based navigation task and (2) to show how the trajectories resulting from these differences can be analysed to identify individual behaviours.

2 The Educational GeoGame *GeoGami*

GeoGami is a location-based mobile app (Bistron et al. 2023, 2022, Bartoschek et al. 2018, 2013) for testing and training map reading competences. It was designed particularly for children in elementary school. The app allows the user to create map-based rallies to implement navigational map reading trainings or navigational map reading assessment in the real world or in a virtual world.

According to Lobben (2007), navigational map reading can be associated with three competences that we particularly train with GeoGami:

1. Place recognition / Object recognition: the human ability to develop a mental representation of a real object or place and relate it to the representation in the map

2. Self-localization: localizing yourself in the map, i.e. observe objects in the environment (intersections, bridges, buildings) and identify corresponding patterns of objects in the map in order to determine correct location on the map.
3. Map alignment / Direction determination: align the orientation of the map with the orientation of yourself

GeoGami automatically collects data on the participants' movements in space (GPS based trajectory, speed, and cardinal view direction) and on their interaction with the tablet (tapping on the map, panning, and zooming), as well as timestamps (in particular the beginning and the end of each task) and GPS inaccuracy data and stores this in an encrypted data base.

The digital map used in GeoGami is based on standard OpenStreetMap material. Streets and paths are shown as coloured lines, areas of grass, forests or water are coloured in natural colours, houses are shown as polygons in their shape from top view, and objects like trees, statues, benches, bridges, or trash cans are represented with a symbol on the map.

3 The Study

In our study, 96 children aged 6-13 years (M=8.84, SD=1.48), recruited from local schools during summer break, had to solve different wayfinding tasks in a virtual world. The virtual world was projected onto a white wall in front of them. The children could move around in this world using the controller of a games console and at the same time have access to the corresponding map via a tablet (Figure 1).

Figure 1. Playing GeoGami: The virtual world was projected on the wall. With the game controller, participants could move within the virtual world. They saw a map of the virtual world on the GeoGami game on the tablet. Participants received information about their tasks within the GeoGami game.

In the study, the children were first familiarized with the control and orientation in the virtual world. After the training phase, the children had to solve four navigation tasks. They were asked to report on their strategies by thinking aloud. In between the four navigation tasks, the children had to solve several other tasks , such as (i) they had to localize themselves to make sure that they were correctly oriented at the starting location of the navigation task or (ii) they had to follow an arrow guiding them to a new location in the world or (iii) they received information about the current location on the map (Figure 2).

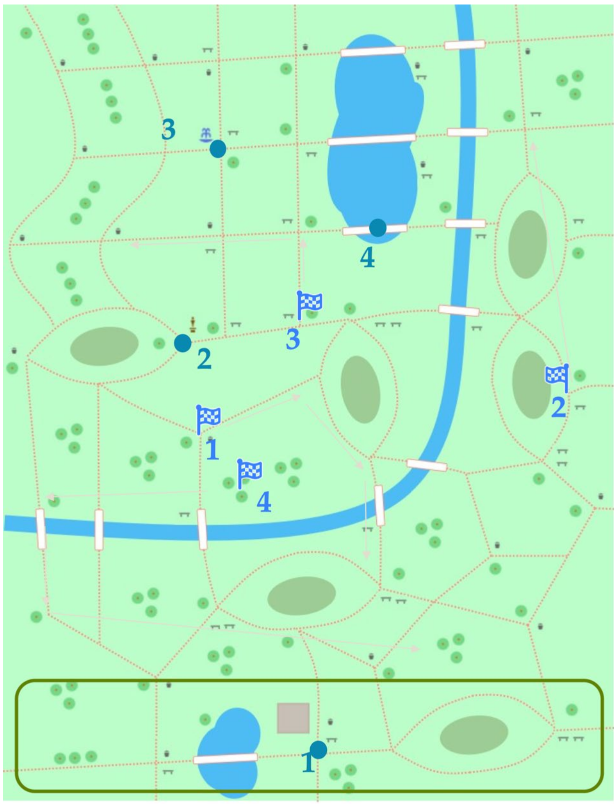

Figure 2. Four navigation tasks in the study: In each navigation task, participants were guided to the starting location (the circle), were informed about the current position and then saw the destination location highlighted on the map with the flag. The green square at the bottom marks the area where the training took place.

The identification of strategies in wayfinding is a non-trivial process that involves a variety of factors: In addition to the spatiotemporal characteristics of the movement patterns, we accounted for various semantic aspects, such as the existence of a path, landmarks, special objects in the environment and their spatial configuration. Based on the thinking aloud statements of the children, we identified important features in the environment that children used for orientation. Figure 3 visualizes some of them.

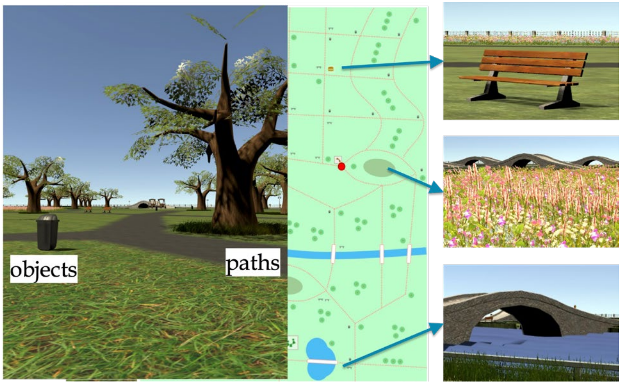

Figure 3. Landmarks used by children to orientate in the virtual world.

4 Detecting Individual Spatial Behaviour based on Trajectories

We recorded the trajectory of the route for each participant for each of the four wayfinding tasks. Furthermore, we collected the location of all landmarks, objects in the virtual world and the paths connecting the different junctions. We annotated the trajectories of the participants with the landmarks and objects related to the current waypoint.

To compare the trajectories, we applied the EFSMClust (Seep 2021), an algorithm that is based on the k-means algorithm (Lloyd 1982) and takes into account the semantic similarity measure EFSMSim, to cluster a set of given semantically annotated trajectories.

The following four figures show some of the clusters and give an explanation what might have been common spatial strategy children applied. The next two figures show two trajectories which were only applied by a single participant.

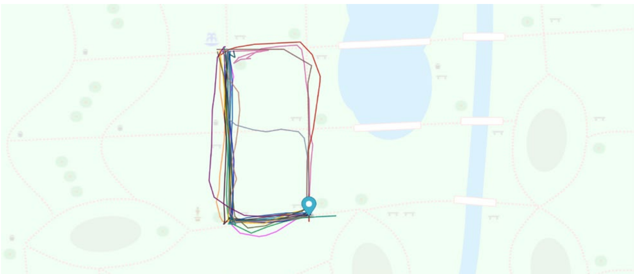

Figure 4. Cluster 1 of trajectories for solving the third wayfinding task in our study.

The cluster shown in Figure 4 was the largest cluster. It is characterized by direct paths from the origin to the destination, either first south then west, or first west then south or a combination of south-west-south. Although the spatio-temporal path differs, all participants in this cluster

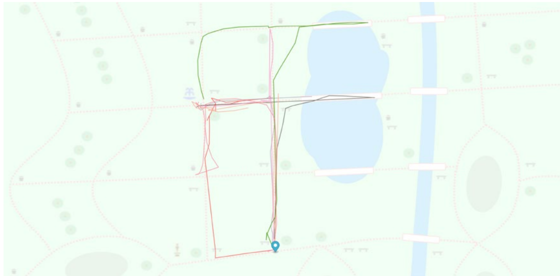

Figure 5. Cluster 2 of trajectories for solving the third wayfinding task in our study.

share the same strategy using the grid-structure of the paths navigating on the direct path to the destination.

The cluster shown in Figure 5 is characterized by an initial detour to the bridge. The two bridges are a distinctive and striking object to localize yourself in the environment. Afterwards, children went on the direct way to the destination.

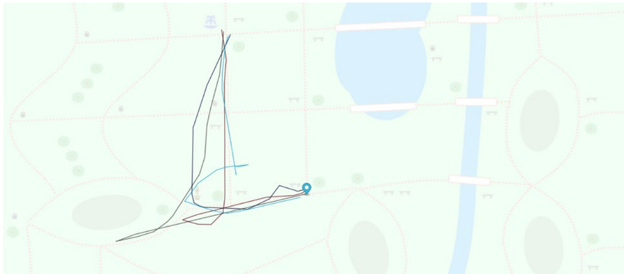

Figure 6. Cluster 3 of trajectories for solving the third wayfinding task in our study.

The cluster shown in Figure 6 is characterized by the detour to the east to a unique landmark (a statue) nearby the flower field. From there, children navigated on the direct path to the destination.

The cluster in Figure 7 is characterized by a direct path to the destination (first south then west), but an overshot at the destination.

Figure 7. Cluster 4 of trajectories for solving the third wayfinding task in our study.

Some trajectories could not be clustered with others. They remained as individual solutions to the wayfinding task. The child in Figure 8, for example, spend a lot of time familiarizing himself/herself with the starting location. Only afterwards, when he/she was spatially orientated, he/she decided to navigate to the destination.

Figure 8. Individual spatial behaviour pattern 2 for solving the third wayfinding task in our study.

Figure 9 gives another example for an individual spatial behaviour pattern. On this route, the participant navigated first to a landmark to the south (a unique building) which they got to know during the training phase and thus were very familiar with. Only afterwards, once he/she reached this landmark, he/she navigated to the final destination. This strategy can be compared to the central point strategy that is well-known from indoor navigation (Hölscher 2006).

5 Conclusion

This paper presents an educational location-based GeoGame GeoGami. People playing GeoGami receive navigation tasks in the real world or the virtual world. In our study, we asked children aged 6-13 years (learning how to read maps in elementary school) to solve a series of wayfinding tasks in the virtual environment and collected their trajectories.

Our set-up with the educational GeoGam *GeoGami* was suitable to collect trajectories of participants. Afterwards, we used semantic criteria for clustering similar trajectories.

We analysed the trajectories for spatial and semantic similarities. The semantic clustering revieled many similar spatio-temporal trajectories, hover, some participants do have a very individual trajectory. We identified individual spatial behaviours of some participants whose trajectories cannot be clustered with others.

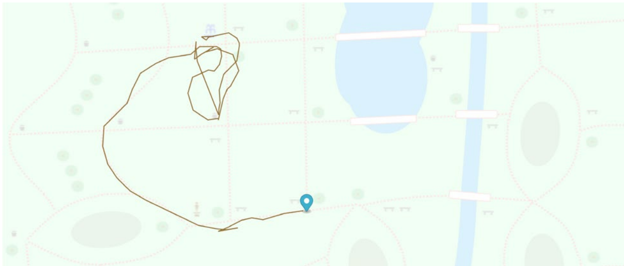

Figure 9. Individual spatial behaviour pattern 1 for solving the third wayfinding task in our study.

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