Considering Existing Indoor Navigational Aids in Navigation Services

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Abstract Existing indoor navigational aids such as signs and floor plans are originally designed to assist navigation and to support spatial learning. However, they are often neglected in current navigation services. Integrating such information adequately into indoor navigation services requires a better understanding of their usages. Thus, we conducted an empirical study in two buildings with 28 participants who had to think aloud while performing wayfinding tasks. By analysing the participants' verbal protocols, we distinguished two decision making scenarios and suggested categorizations of their indoor wayfinding tactics. Our results confirmed people's reliance on existing indoor navigational aids and indicated that signs were the most commonly used aids. In addition, the characteristics of targets influenced the choice of aids. Therefore, we recommended that indoor navigation services include signs and present route information adaptively based on distinct destinations.

1 Introduction

Different indoor navigation systems have been designed to support wayfinding (Kargl et al., 2007; Li et al., 2017; Rehman & Cao, 2017). In these systems, floor plans and verbal instructions are the most commonly applied route communication techniques (Huang & Gartner, 2010). However, distance based and turn-by-turn instructions draw too much of users' attention and may raise their cognitive load. Navigating with this kind of indoor navigation systems, users are devoid of inter-

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actions with the environment, thus fail to remember routes travelled and become disoriented easily when the system is not available(Reilly et al., 2008).

Current indoor navigation systems ignore existing navigational aids in buildings (e.g., wall-mounted floor plans, signs, and kiosk maps), which are intended for facilitating indoor wayfinding and supporting spatial learning (Reilly et al., 2008). Navigational aids represent explicit information in the overall configuration and structure of the environment (Conroy, 2001; Vilar et al., 2012). Reilly et al. (2008) demonstrated that using kiosk maps alongside a mobile wayfinding application can help users gain spatial knowledge. Passini (1984) and O'Neill (1991a, 1991b) pointed out that signs, floor plans and architectural features are the key factors affecting human wayfinding. These factors were studied by environmental psychologists in virtual reality (Conroy, 2001; Vilar et al., 2012, 2014). They showed that people rely on signs rather than on architectural features as long as signs are available and that signs are preferred to floor plans in certain situations. However, compared with physical movement, walking virtually lacks important bodily cues (e.g., vestibular information especially during turns), which may lead to inconsistent findings with reality (Meilinger et al., 2008; Klatzky et al., 1998). Therefore, an in situ study is needed to confirm the reliance on existing indoor navigational aids by wayfinders.

To address the above issues, a research project is being carried out, which aims at investigating the possibility of providing indoor navigation services by considering existing navigational aids. During the first part of this research, an experiment was conducted in two buildings with distinct navigational aids to confirm the reliance on existing indoor navigational aids. This paper reports on the methodology and preliminary results of the experiment, which will allow us to answer the following questions:

1. Do people rely on existing indoor navigational aids while navigating? What do they refer to when making indoor wayfinding decisions? What is the most frequently used indoor navigational aid?
2. What environmental features do people employ in indoor route depictions and descriptions?

A follow-up study will then aim to conceptualize indoor navigation services, and integrate existing indoor navigational aids into route planning and communication.

2 Methodology

Unlike in the virtual environment, it is difficult to control and compare existing indoor navigational aids in experiments conducted in the real environment. Consequently, we decided to conduct an exploratory experiment to find out the relevance of existing indoor navigational aids to human wayfinding. Verbal protocols have often been used to obtain a deep insight on human wayfinding behavior. Kevin Lynch (1960) explored the mental representation of city-scale spaces in verbal protocols and sketch maps. Passini (1984) investigated detailed decision making process of

wayfinding by verbal comments of participants. Best (1970) noted that people are more likely to get lost at decision points. Therefore, we employ the thinking aloud method (Ericsson & Simon, 1993) to understand participants' indoor wayfinding decision making in terms of what information they refer to at decision points. Following similar definitions from O'Neill (1991a) and Butler et al. (1993), we define a decision point as a location where people have at least two outgoing options. To represent indoor wayfinding decision making and reasoning process at a decision point, we introduce the term *indoor wayfinding tactic*. This is the process of careful planning of the following action during an indoor wayfinding task, performed at a decision point. Compared with an indoor wayfinding strategy, which is a long-term and overall planning of the whole wayfinding task (Hölscher et al., 2006), it is short-term and specific to the current decision point. We therefore name it as "tactic" (Bates, 1979).

2.1 Experiment setup

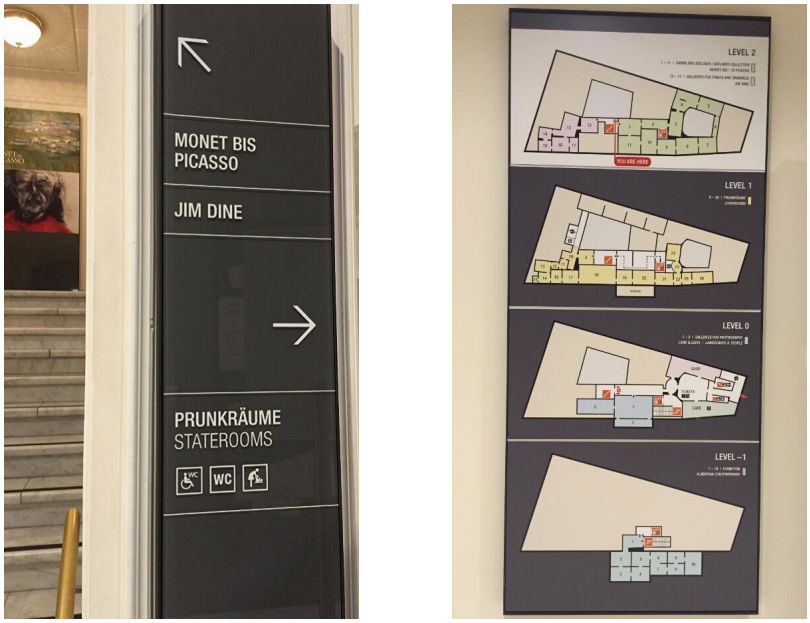
2.1.1 Selection of buildings

In this study, two buildings, the Albertina and the main building of Vienna University of Technology (TU), were selected as our experiment venues. The buildings differ in floor plan configuration complexity, function and signage system used. Built in the 18th century, the Albertina was originally a palace in the Neoclassical style (Albertina, 2017). It has been renovated and transferred into a modern museum. The signage system is well designed (Fig. 1a), with floor plans mounted on the wall (Fig. 1b), as well as printed floor plans freely available at the ticket office.

The main building of Vienna University of Technology was built in the 19th century (TU Wien, 2017). Later, several separate buildings nearby were joined by staircases into a whole complex. Due to its configuration, different sections in this building differ in floor heights and signage systems. The staircases are numbered and utilized as the major wayfinding guidance by local students. Students report getting lost easily inside the building owing to its complexity, a lack of floor plans, and multiple, inconsistent signage systems.

2.1.2 Participants

28 participants (16 female, 12 male, age: M = 29, SD = 6.77) were recruited through our website, social media and flyers posted on other universities' campuses. They hold different professions such as mathematicians, English teachers, musicians, painters, etc. All participants confirmed to have no visiting experience to either building. They were all fluent in English and at least understood basic German. All participants signed the informed consent before participating in the experiment. Each participant received a free entry to the Albertina and a small gift.



(a) (b)

Fig. 1 (a) A sign in the Albertina. (b) A wall-mounted floor plan in the Albertina.

2.1.3 Procedure

An experimenter met a participant in front of one of the test buildings. After a short opening conversation, the participant was lead to the starting point of that building. The experimenter read an introduction informing the participant to find three targets in each building. The participant was then given the first target and asked to describe their strategy to find it. The participant was also told to stop at every decision point on their way to the target. At each decision point, the participant was encouraged to describe their wayfinding options, hints revealing the destinations of these options, to make their decision, and to justify it (Fig. 2). After reaching the first target, the participant was asked to describe the route from the starting point to target one as if someone unfamiliar to the building was asking them for help. The participant was then asked to draw a sketch map. Then, the second target was given. Each target was the starting location of the following task for the verbal description and sketch map. The wayfinding process ended when all the targets were found. The participant was enquired afterwards about their general impression of the existing wayfinding aids in both buildings. Except asking the experimenter, the participant was encouraged to think aloud during the process and to use whatever information available to

help wayfinding. The experimenter followed the participant and recorded the whole process using a head-mounted GoPro Hero 4 Silver[1] and a voice recorder.

Fig. 2 A participant was justifying her decision with a sign at a decision point in the TU.

To avoid learning effects, half of the participants started from the Albertina and the other half from the TU. All participants received the targets in the same order. In the Albertina, the three targets were "The entrance of exhibition *Contemporary Art*", "Room 8 of exhibition *Monet bis Picasso*", and "The toilet close to exhibition *Wege des Pointillismus*". The targets in the TU were a ceremony hall "Festsaal", and two lecture rooms "Hörsaal 15" and "Hörsaal 17".

2.2 Data processing and analysing

The videos and the audios were synchronized and merged using a video editor[2]. Afterwards, the merged videos were transcribed into verbal protocols and both were analysed qualitatively. In order to analyse indoor wayfinding tactics and the relevance of existing indoor navigational aids to human wayfinding, we focused on participants' justifications of their decisions. In this study, we only considered the verbal justifications expressed at decision points.

We applied the structuring method of qualitative content analysis to code the verbal protocols. This is a content-analysis method that starts with a defined category system from existing theory, and keeps revising these categories while coding (Mayring 2014). Passini's (1984) categorization of wayfinding strategies and tactics for decision making served as our initial category system.

[1] https://gopro.com/

[2] http://www.videosoftdev.com/

3 Categorization of indoor wayfinding tactics

Prior to categorizing indoor wayfinding tactics, we distinguish two scenarios at a decision point encountered by a wayfinder: (1) when relevant wayfinding support information is explicitly accessible and perceived, and (2) when *no* relevant wayfinding support information is perceived.

Based on Passini's (1984) wayfinding decision making theory and our analysis, we propose the following categorization of indoor wayfinding tactics, which will be iteratively evaluated and eventually adopted.

1. Tactics used when relevant wayfinding support information is explicitly accessible and perceived:
   - Sign: Wayfinders make a decision based on identification signs, directional signs, and floor directories without a graphical floor plan, e.g., "*There is a sign straight ahead for HS 17, so I'll follow that.*"
   - Floor plan: Wayfinders make a decision based on floor plans, e.g., "*That will be on level 2 according to this plan.*"
   - External help: Wayfinders make a decision based on external help from other people or electronic devices, e.g., "*He said that I need to go this way to find the 4th.*"
2. Tactics used when no relevant wayfinding support information is perceived:
   - Memory: Wayfinders make a decision based on certain information they memorized about the setting or similar settings, e.g., "*Now I'm going out of the bridge. And with my memory then I should go right.*"
   - Inference: Wayfinders make a decision based on their mental manipulation and reasoning without relevant information available, e.g., "*I'm going to decide to go up another floor because 14 and 15 are on this floor and a higher number should be on the floor above.*"
   - Searching: Wayfinders make a decision because they wish to find signs, floor plans, someone to ask or any relevant information on the option they choose, e.g., "*I'm going to come down to see if there is some signage out here.* "
   - Preference
     - Architectural feature: Wayfinders make a decision based on corridor width, room size, brightness, color, and their preferred direction, e.g., "*I took this side because I think this room is bigger. That attracts me to go inside.*"
     - Non-spatial related preference: Wayfinders make a decision based on cultural and personal preferences, e.g., "*Don't want to go through this crowd.*"
   - Random: Wayfinders make a decision randomly, without specifying any reasons, e.g., "*This is just a sort of random decision to get my bearings.*"

4 Preliminary results and discussion

4.1 Indoor wayfinding tactics in the Albertina and the TU

The frequency and proportion of different indoor wayfinding tactics used in the Albertina and the TU are shown in Table 1. In both buildings, referring to signs was the most frequently used tactic, despite the inadequate signage system in the TU. Comparing the two scenarios, we discovered that in the Albertina, 62% of the decisions were made in Scenario 1, while in the TU, the proportion dropped to 55%, due to the limited availability of existing navigational aids in the building.

Table 1 Indoor wayfinding tactics and their frequency and proportion in the Albertina and the TU

Scenarios	Indoor wayfinding tactics	Frequency (n)		Proportion (%)	
		Albertina	TU	Albertina	TU
Scenario 1	Sign	121	189	39	47
	Floor plan	58	0	19	0
	External help	14	34	5	8
Scenario 2	Memory	4	8	1	2
	Inference	80	80	26	20
	Searching	26	80	8	20
	Architectural feature	1	0	0	0
	Non-spatial related preference	3	1	1	0
	Random	3	10	1	2

Considering the first scenario, in the Albertina, although both wall-mounted and paper-printed floor plans were available, the usage of sign tactic (63%) was twice as much as floor plan tactic (30%). This is probably due to a higher cognitive load of using floor plans comparing to using signs (Passini 1984). Since the TU did not offer floor plans to its visitors, no floor plan tactic was employed in the TU. As the sole information source other than asking other people or checking mobile phones, the sign tactic dominated in the TU with a percentage of 85%. The tactic of seeking external help was not popular in either building.

In the second scenario, compared to other tactics, the inference and the searching tactics were more regularly employed by our participants in both buildings. However, the distribution of the inference tactic and the searching tactic differed dramatically between the two buildings. In the Albertina, 68% of the decisions were made by inference, while 22% of the decisions were made because participants wished to search for information in the chosen route. This can be explained by the simple structure of the Albertina and its well-designed guiding system that wayfinding support information is available at almost all possible decision points. A different situation was found in the TU. The usage of the inference tactic and the searching tactic were similar. Participants searched for wayfinding support information more frequently owing to the absence of floor plans and the sparsely placed signs in the

TU. The complexity of the building and a lack of overview that could be provided by floor plans made it very hard to build a mental map of the building on first exposure. Hence, the decisions made by inference sometimes led participants to disorientation, which in turn contributed to the high rate of the searching tactic.

4.2 The choice of indoor wayfinding tactics among tasks

The choice of tactics is influenced not only by the architecture and the existing navigational aids of the buildings but also by the tasks. Distinct targets evoke the distinct sense of the corresponding tasks, thus affect the selection of the tactics.

Table 2 Indoor wayfinding tactics and their frequency and proportion among tasks in the Albertina

Indoor wayfinding tactics	Frequency (n)			Proportion (%)		
	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3
Sign	39	46	36	52	40	30
Floor plan	4	23	31	5	20	26
External help	8	1	5	11	1	4
Memory	0	2	2	0	2	2
Inference	21	32	27	28	28	22
Searching	3	9	14	4	8	12
Architectural feature	0	1	0	0	1	0
Non-spatial related preference	0	1	2	0	1	2
Random	0	0	3	0	0	2

In the Albertina, the tactics used in different scenarios have almost identical distributions among different tasks, according to Table 2. However, the ratio of using signs to floor plans varies substantially among tasks. In the Task 1, participants were required to find the entrance of an exhibition. There was no wall-mounted floor plan before finishing this task. The sign tactic was therefore applied extensively. While the targets became more specific and wall-mounted floor plans started to appear from the Task 2 on, the ratio of using signs to floor plans decreased. There were two decision points with signs and floor plans, which could be passed by the participants during both Task 2 and Task 3. By analysing the tactics used at these decision points, we discovered that the only situation more floor plan tactics were employed was at the landing of Level 2 during the Task 3. In that situation, the participants just left the Exhibition *Monet bis Picasso* and were to find the toilet close to Exhibition *Wege des Pointillismus*. Since the description of the Target 3 contained spatial relation, the participants preferred floor plans to signs to get an overview of the spatial structure. Once the spatial information was acquired, participants would tend to refer to signs for the immediate directions at later decision points.

In the TU, the tactics used in different scenarios were greatly influenced by the tasks (Table 3). The use of signs dropped considerably from the Task 1 to the Task

Table 3 Indoor wayfinding tactics and their frequency and proportion among tasks in the TU

Indoor wayfinding tactics	Frequency (n)			Proportion (%)		
	Task 1	Task 2	Task 3	Task 1	Task 2	Task 3
Sign	56	95	38	75	49	28
Floor plan	0	0	0	0	0	0
External help	0	20	14	0	10	10
Memory	0	4	4	0	2	3
Inference	17	28	35	23	15	26
Searching	2	42	36	3	22	27
Architectural feature	0	0	0	0	0	0
Non-spatial related preference	0	0	1	0	0	1
Random	0	3	7	0	2	5

3, while the proportion of applying the searching tactics grew, as a result of the insufficient existing navigational aids in the building. The Target 3 was spatially close to the Target 2, but there was no direct sign from the Target 2 to the Target 3. Hence, there was a high possibility that the participants would not be able to find the Target 3 without enough inference and searching.

5 Conclusion and outlook

In summary, after preliminary interpretation of the experimental data, we reflect on our first research question and draw an initial conclusion that people rely on existing indoor navigational aids, in spite of their quality. Although the preference of existing indoor navigational aids varies individually, signs are the most commonly used.

Different tasks influence the choice of indoor wayfinding tactics. The requirements of survey knowledge provided by floor plans increase while the targets become more specific, especially when spatial relations are contained in the targets. In designing navigation systems, this is worth considering for presenting route information adaptively, according to distinct destinations.

We are currently investigating on the impact of different types of decision points on the choice of indoor wayfinding tactics. The relevance of individual sense of direction to the tactics is another direction we are working towards. To address the second research question, the verbal descriptions and the sketch maps are also being analysed.

Based on the findings from the experiment, we are going to include signs in indoor route planning and to generate route instructions accordingly. One example is, rather than providing turn-by-turn instructions, navigating users to a certain sign which displays the destination and instructing them to follow the succeeding signs. An appropriate visualization of the indoor environment with relevant signs highlighted is a further direction for research.

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