# User experience and strategy choices during navigation: A content analysis of navigators using different types of wayfinding devices

**Verena Schnitzler (verena.schnitzler@gess.ethz.ch)**
**Christoph Hölscher (christoph.hoelscher@gess.ethz.ch)**
ETH Zürich, Chair for Cognitive Science, Clausiusstrasse 59, 8092 Zürich, Switzerland

**Abstract**

In this study, we compared navigation through a large, complex, public building a) without any map, b) with a printed map, or c) with a digital map. Participants looked for five different destinations while thinking aloud, filled out questionnaires, and answered open questions about the wayfinding task and about the building and the maps. A content analysis was used in order to identify key factors in the building's and maps' design that facilitated or hindered successful and satisfactory usage. There was a significant search time difference between the no-map group and the two map groups. There were no differences in how efficiently the two map groups found destinations. The analysis of post-experiment questionnaires exhibited a similar pattern, there were no differences in the assessments of map usability. Participants using paper maps significantly reported most often to not have any difficulties with the wayfinding task. The groups did not appear to apply different wayfinding strategies, suggesting that participants' strategy choices were shaped by individual preferences and the building itself with its signage as an additional informative layer.

**Keywords:** design cognition, spatial cognition, user experience

## Introduction

Visitors entering a large, complex, public building (e.g., a conference center or an airport) for the first time might use diverse sources of information to find their destinations. Their personal strategies, the designs of signs and maps, and the building itself shape their navigation decisions. The contentious principle that form follows function, states that design choices are closely connected to the successful usage of products. Scholars have shown that people can judge a building's function by looking at its façade (e.g. Nasar, Stamps, & Hanyu, 2005). Assuming that buildings are potentially intelligible (Al-Sayed, Dalton, & Hölscher, 2010), it seems important to emphasize the significance of well-chosen design elements in order to improve the users' experiences and efficiencies. Although the physical space in which people navigate differs a lot from the metaphorical space of a computer, both share certain characteristics. The real or digital space has to be made usable for the consumer via connecting elements that have deliberately been chosen by the designer. For the computer, graphical user interfaces need to be developed; for the built environment, maps and signs fulfill the same function. To study humans' behavior in design – the designer's as well as the users' - it seems crucial to understand successful versus unsuccessful performance. Successful performance can be a different entity for different products; for a public building, finding an intended destination is crucial. For example, each public building has to be designed in a way that allows at any point to find the next emergency exit in a very small amount of time. Assuming that a building's functions are its intelligibility and usability it seems reasonable to posit that these are moderating factors in the building's design. The usability of a building may also depend (in part) on the devices designed to make it navigable (i.e., signs, printed maps, digital maps). Different navigations aids can induce specific representations of the environment. While signs may induce a representation based largely on landmarks and individual routes, maps allow for a more birds-eye survey representation (e.g. Ishikawa & Montello, 2006; Siegel & White, 1975).

This study investigates the quality of a building's internal layout as well as the quality of particular wayfinding aids. Participants had to find five destinations inside a large, complex public building (the Victoria & Albert Museum, London) with either a) a digital map of the building, b) a customary paper map of the building, or c) the building's signs. The destinations differed in the distance traversed, the number of floors covered, and the overall difficulty of finding them. Our aim was to obtain deeper insights into participants' cognitive processes during wayfinding that were related to building and map design features. We collected and analyzed verbal data with a thinking aloud technique (Ericsson & Simon, 1985) and administered open questions about participants' wayfinding and orientation strategies and experienced difficulties. This inductive and deductive categorization enabled an insight into which design characteristics of the maps and building hindered or facilitated efficient usage. Beyond this content analysis (Krippendorf, 1969) we linked the qualitative data to quantitative data by measuring the time required to find the destinations. For methodological triangulation, we also adapted questionnaires from human-computer-interaction research to check if users' experiences with the building were influenced by the wayfinding devices.

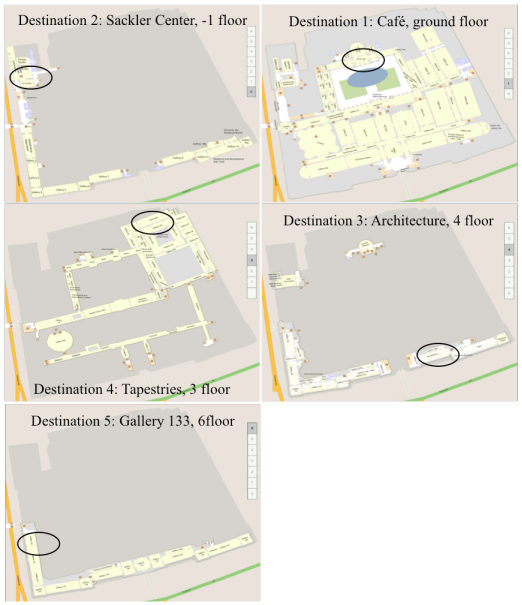
## Method

### The Victoria & Albert Museum

We obtained our data in the Victoria and Albert Museum (V&A) in central London. The building is the world's largest museum of decorative arts and design, built in 1852, and covers 51,000 m2 (5,597,000 ft²) and 145 galleries. As visitors are entering the building through the main entrance, they find themselves in a big entrance hall, which connects several hallways and rooms. Most rooms are interconnected, leading the visitor further into the building with its seven

floors. These rooms surround an atrium and are connected via multiple stairs and elevators, nearly all of which arbitrarily skip floors. Each floor plan looks completely different from the others (Figure 1).

Figure 1: Illustration the floor layout and the map layout (print and digital). The circles indicate the location of the goal destination for the reader (Google Inc., 2013). Floor 2 & 5 are not shown.




## The wayfinding task and the destinations

In order to investigate the building's navigability (and thus intelligibility), we focused on navigators' behaviors in the real environment. Each participant was welcomed and instructed in the same way to find five destinations inside the building, in the same sequence (see Figure 1) starting from the entrance hall. Upon arrival at the last destination they were led back to the starting point. The wayfinding tasks were finished once the participant reach the room. We tested 41 participants (16 male), between 19 and 63 years old (M=30.88, *SD = 9.39*), the groups did not significantly differ regarding the age. The participants were randomly assigned into one of three conditions. They navigated with 1) a customary printed map (n=13), 2) a digital map on a smartphone (n = 14), or 3) no map (i.e., using only the building and its signage for orientation) (n=14). Paper maps were printed on 304 mm x 304 mm of laminated paper with a spiral binding. The digital maps were presented on a Samsung Galaxy Note II with a screen size of 141 mm (5.55 inch) with 720 × 1280 pixels. Paper and digital maps had the same layout and provided the same information (based on the Google Maps display for Android).

The first author extensively walked through the building for several days, visiting each room at least three times, and subsequently selected the destinations. Both authors jointly judged the destinations regarding their difficulty. The destinations were chosen according to distinctive features and so that they differed in terms of the number of floors traversed between destinations. The first destination, a very big, central room in the back of the first floor, can be found by following the main hall and some signs. We expected its function to already reveal some information about its potential location. The second destination was in a much more peripheral corner of the building, but very close to the Café and had very well placed signs. The third destination was located on the fourth floor, which is split into two halves. These could only be crossed by travelling via the third or fifth floor. The fourth destination was a very peripheral destination in the corner of the building, only accessible through other galleries. The last destination was on the highest floor and could be found by following the inconspicuous gallery numbers (see Figure 1).

## I. Performance data: Search times

As stated earlier, it is crucial to study users' behavior in order to understand successful/unsuccessful performance in design. Beyond the mere design process itself, the actual later usage is of equal importance. To address successful usage of the building, we measured the time people needed to find the different locations inside the V&A. A researcher followed participants and captured their start and arrival times at each destination.

Table 1: Variation of the destinations according to number of floors to be traveled and difficulty to find.

| | | **Number of floors traversed** | | |
|---|---|---|---|---|
| | | No change | One change | Several changes |
| **Difficulty** | Easy | *1. Cafe* | *2. Sackler Centre* | *5. Gallery 133* |
| | Hard | - | *4. Tapestries Exhibition* | *3. Architecture Exhibition* |

## II. Survey Data: User Experience questionnaires

As stated before, an essential part of a building's usability is its intelligibility. If the devices people use for their wayfinding influences their efficiency, they probably also shape their experiences with the building itself. In order to address this matter, we decided to adapt well-established questionnaires from human computer interaction (HCI) to the context of building usage with mobile maps. Although these questionnaires were tailored to the needs of HCI, we decided to use them in order to be able to compare the usage of the digital maps to the printed ones. We administered the questionnaires after the walkthrough to obtain deeper insights into the visitors' impressions of the digital compared to the printed maps.

### II. 1. System Usability

To test if the groups differed in their experiences, we measured the overall perceived usability of the maps and the building with the *System Usability Scale* (Brooke, 1996), which is a validated and well-established, standardized questionnaire consisting of ten items (from *1 = strongly disagree* to *5 = strongly agree*). The items, which were originally designed to assess users' satisfaction with software, were modified so that they could be used to describe the usage of maps and architectural features.

**II. 2. Usefulness and Ease of Use**

Furthermore, we used modified questions taken from the *Perceived Usefulness and Perceived Ease of Use Inventory* (Davis, 1989) to assess the subjectively perceived usefulness and ease of use of the maps and the building (from *1 = likely* to *7 = unlikely*).

**II. 3. Joy of Use**

To assess the satisfaction people encounter while navigating through the building we administered the *AttrakDiff* (Hassenzahl, Burmester, & Koller, 2003). This questionnaire is a semantic differential with 28 bipolar, 7-stage items, eliciting the global positive-negative assessment of a product.

**II. 4. Visual Aesthetics**

Beyond merely focusing on satisfaction measures, we were also interested in how the usage of the different devices might have influenced visitors' impressions of the building. For that purpose, we administered the *Visual Aesthetics of Websites Inventory* (VisAwi; Moshagen & Thielsch, 2010), which is designed to assess the aesthetic of websites, has been experimentally validated, and shows good to very good reliability rates. We used a shorter version with four items (from *1 = strongly* disagree to *7 = strongly agree*) that measures a general aesthetics factor. Although this questionnaire was also originally designed for HCI backgrounds, we decided to use it because the short version's items are applicable to a very broad variety of products. We also administered all four items of the factor *simplicity* taken from the long version because their wording appears to be highly suitable for assessing architecture.

## III. Survey data: Open questions

After looking at navigators' behavior and experiences with the building and navigation devices, we tried to narrow down the design features that might have influenced the building and map usage. After performing the walkthrough and filling out the user experience questionnaires, participants answered three open questions in written form:

1. *Which strategies did you use to find your way?*
2. *Where did you think navigation was difficult?*
3. *How did you orient yourself?*

## IV. Verbal Data: Thinking Aloud protocols

We asked the participants to think aloud, thus uttering their thoughts about the wayfinding process, their navigation choices, the building, the signs, or the maps. While walking, the language was recorded and later transcribed. These transcripts were then abbreviated to 438 task-related statements.

# Results and Discussion

## I. Performance data: Search times

To test our assumption that devices alter navigators' wayfinding performance, we conducted five one-way, between-subjects ANOVAs comparing the effect of navigation devices (i.e., signs, printed map, digital map, independent Variable; IV) on wayfinding efficiency (dependent variable; DV). We obtained a significant effect of navigation devices for the second destination, the fourth destination, and the fifth destination (all $F_{(2, 34)} \geq 3.2$, all $p < .05$). However, there was no significant effect of navigation devices on search time for the first and third destination. Planned contrasts between all three groups indicated that the no-map condition performed significantly better than the map conditions for the second destination, which had very good signage. For the fourth and fifth destination the map groups were significantly faster than the no map group (all $t_{(21.05)} \geq -2.5$, all $p < .05$). However, there were no significant differences between the two map groups. These findings suggest that maps can help people use a building more efficiently. But, there was no result suggesting that the additional medium and design features provided by mobile maps had any benefits or detriments compared to paper maps.

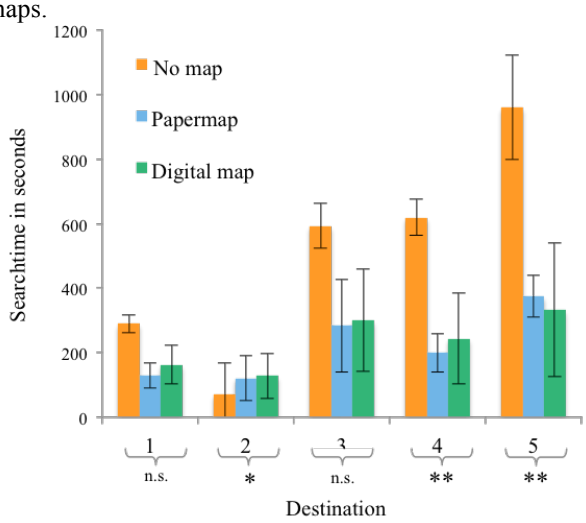



Figure 2: Mean search time (and std. deviation) for the five destinations per group.

## II. Survey Data: User Experience

A one-way, between-subjects ANOVA was conducted to compare the effect of navigation devices (IV) on user experience with the maps (DV). Surprisingly, there were no significant differences, indicating that the two map types did not reliably differ in terms of user experience.

In order to be able to compare the perceived usefulness for the two map types the score for the SUS, the EU and the PU were calculated. The analysis revealed no significant differences regarding the maps' usability (SUS: $F_{(1, 27)} = 0$, n.s.; PU: $F_{(1, 27)} = .04$, n.s.; EU: $F_{(1, 27)} = 1.18$, n.s). SUS scores rank from 0 to 100, where higher scores indicate better usability. The paper maps had a mean SUS score of 68.75 (SD=16.75), the digital maps had a mean SUS score of 57 (SD=20.2). Those values can be interpreted as an appropriate level of usability (values between 52.01 and 72.75) (Bangor, Kortum, & Miller, 2008).

We also conducted a one-way, between subjects ANOVA to compare the effect of navigation devices (IV) on the

users' experiences with the building itself (DV), and again, we could not establish a significant difference between the groups regarding the VisAWI or AttrakDiff. Some of the questionnaires provide researchers with benchmarks to classify if the system reached a sufficient amount of approval by the user. We decided against comparing those benchmarks to our obtained values because the benchmarks were originally designed for core HCI questions, rather than this spatial environment context.

## III. Survey data: Open questions

### III. 1 Which strategies did you use to find your way?

We expected that people would use orientation strategies based on 1) following signage, 2) salient landmarks, 3) cardinal directions, 4) memory, and 5) their intuition and 6) route planning with a map, Additionally, we used findings from previous research that identified path choice strategies navigators use in complex, multi-level buildings: 7) the central point strategy, 8) the floor strategy, 9) the direction strategy, and 10) the route is well known strategy (Hölscher, Büchner, Meilinger, & Strube, 2009). Those deployed wayfinding strategies partly depend on the extend of a building's legibility. The participants' answers were coded if they included a statement that matched one of the developed categories. Krippendorff's α indicated that the coders had a good agreement in the categories of *following signage, route planning with maps, cardinal directions, memory*, and *intuition* (all α's between .82 and .98) (Krippendorff, 2004).

There was a significant association between group and how likely people were to mention using the *signage* ($\chi^2_{(2, N=205)} = 27.62$, $p < .01$). The no-map group reported using the signage significantly more often than the map groups (odds ratio: .16). The map groups did not significantly differ in the number of comments regarding signage. This is in line with the fact that people who did not have access to a map had to rely only on signage for navigation. Furthermore, this demonstrated that people who did have access to maps used information sources beyond the signage alone. We could not find a significant association between which map type people used and how likely they were to plan their route with it.

The groups did not significantly differ in terms of their preference for using memory, intuition, or cardinal directions for their wayfinding. Navigators' orientation behaviors might mainly be shaped either by the building itself or people's individual preferences. The fact that the groups did not significantly differ in their stated strategy choices suggested that having access to one of the map types did not alter the legibility of the building itself.

### III. 2 Where did you think navigation was difficult?

The two researchers who conducted the testing in the V&A noted where they observed people having difficulties and jointly developed the following categories: 1) *changing floors*, 2) *identifying current floor*, 3) *map properties*, 4) *missing signage*, 5) *layout of the building*, and 6) *no difficulties*. Krippendorff's α indicated a good agreement between the raters on all the categories but 5) layout of the building (α's between 0.72 and 0.91; Krippendorff, 2004). There were some significant associations between experimental group and aspects that caused difficulties in navigation: People without a map reported more difficulties caused by missing signage than those using a map ($\chi^2_{(2, N=205)} = 8.81$, $p < .01$). This corresponds to previously described result and may suggest that people using a map in addition to the signage also used other information sources (Hölscher, Büchner, Brösamle, Meilinger, & Strube, 2007). Interestingly, there was a significant majority of people using the paper map that reported having no difficulties at all ($\chi^2_{(2, N=205)} = 4.22$, $p < .05$). Based on odds ratios, the odds of the paper map group stating that they did not experience any difficulties were 2.11 higher than for the digital map group and 2.08 higher than for the no-map group.

### III. 3 How did you orient yourself?

We specified seven categories in order to obtain further insights into which information sources users chose to successfully navigate the building. Comments were coded regarding the usage of 1) *the map,* 2) *the signage,* 3*) memory*, 4) the *design of the building*, 5) *intuitio*n, 6) *exploration*, and 7) *cardinal directions*. Krippendorff's α indicated that the coders had a good agreement for all seven categories (all α's between 0.72 and 0.91) (Krippendorff, 2004).

Again, the significant association between groups and how likely people were to use *the signage* for orientation could be found ($\chi^2_{(2, N=205)} = 11.7$, $p < .01$). Based on odds ratios, the odds of the map groups reporting using the signage were lower (.3) than in the no-map group. There was no difference between the two map groups. This finding supported our previous observations that people with access to a map used more information sources than the signage alone. None of the map groups gave significantly more comments about the map's design than the other.

Focusing on the differences between the five destinations, revealed an interesting pattern. For the first destination, there was a significant association between group and comments about missing signage as a cause for navigation difficulties ($\chi^2_{(2, N=41)} = 12.26$, $p < .01$; .2 odds ratio for the map groups). The second destination, which had very salient signage, showed the highest number of comments about not experiencing any difficulties in the no-map group ($\chi^2_{(2, N=41)} = 6.95$, $p < .05$). This can be linked to our result that the no-map group also significantly used the least amount of time to find this destination. For the third destination in turn, the paper map group commented most on not experiencing any difficulties ($\chi^2_{(2, N=42)} = 8.25$, $p<.01$). This matched the previous finding that navigating with a paper map was linked to being more likely to report not experiencing any difficulties. This finding, combined with the fact that the paper map group and the digital map group did not show a significant difference in time required to find the destination, suggested that although we could not find a difference between those groups regarding their wayfinding

efficiency, they clearly differed regarding their experiences during wayfinding.

## IV. Verbal Data: Thinking Aloud protocols

The 438 abbreviated statements were coded for whether they included a comment about 1) the *building design*, 2) the *signage design*, and/or 3) the *map design*. Furthermore, the statements were coded if the statement included a comment about 4) a *cognitive process or an orientation strategy* or 5) participants *feeling insecure or puzzled*. The two coders had an excellent agreement for all categories (all Krippendorff's α's between .82 and .97; Krippendorff, 2004). The no-map group gave significantly more comments than the other two groups (50%, see Table 2). The majority of comments were about cognitive processes and orientation strategies (33.1%, see Table 2). There was no significant association between group and whether people commented on their cognitive processes or orientation strategies. There was a significant association of group and noting a *feeling of insecurity or being puzzled* ($\chi^2_{(2,\ N=438)} = 6.69$, $p < .05$). While the map groups had a .86 lower odds ratio than the no-map group, the map groups did not significantly differ.

There was a significant association of group and comments on the *building's design* ($\chi^2_{(2,\ N=438)} = 46.95$, $p < .01$). The odds ratio of the paper map group to comment on the building's design had a 6.7 higher odds ratio than the no map group and had a .2 odds ratio for the digital map group. Many participants confirmed the V&A to be a confusing building. This could also be found in the verbal data: "It's a really confusing building." (Condition: no-map, Destination: 5) / "I can't understand (how) stairs can miss a level." (Condition: no-map, Destination: 5) / "Ok, we could just go around and round in this thing. It feels like a labyrinth." (Condition: paper map, Destination: 3) / "I'm not really sure where I am right now. (laughter)" (Condition: digital map, Destination: 3).

Furthermore there was a significant association of group and comments on *the signage's design* ($\chi^2_{(2,\ N=438)} = 16.78$, $p < .01$) with an odds ratio of .24 for the map groups to comment on the signage compared to the no map groups. And a 2.25 higher odds ratio for the digital map group than the paper map group.

There was also a significant difference between the map groups in commenting on the *maps' designs* ($\chi^2_{(2,\ N=209)} = 14.6$, $p < .01$); the odds ratio of the digital map group commenting on the *map's design* was significantly (4.31) higher than in the paper map group. All those statements ranged from neutral descriptions to comments about design shortcomings and potential improvements.

## Summary and Conclusion

We found robust wayfinding efficiency advantages for navigators using a map, both digital and printed, over navigators only relying on signage. These findings confirm that maps can improve a people building's legibility and support finding goals faster. However, there was no result suggesting that the additional medium and design features provided by mobile maps were more (or less) beneficial than paper maps when it comes to wayfinding efficiency. Furthermore the efficiency advantages of maps appear to be moderated by destination characteristics. This leaves room to speculate about the possibility of shaping wayfinding not only with devices, but also with architectural design and signage (Hölscher et al., 2007). Further testing would require an experimental control of building features to detect connections between characteristics of the build environment and wayfinding decisions.

The user experience questionnaires did not reveal a significant difference between people using a digital or printed map. There were also no significant differences between the three groups regarding the building's assessment. Participants might have been suffering from fatigue after the potentially tiring wayfinding tasks that were administered without a break. This might have influenced their experience ratings in general and caused a floor effect.

The open questions about navigation difficulties, orientation, and wayfinding strategies added to the pattern revealed by the efficiency measures. The three groups did not reliably differ in their reported navigation strategies. Navigators without a map reported significantly more often to use signage for orientation, and to experience difficulties caused by missing signage. This might be explained with the fact that they were not able to form a survey representation of the building and therefore had to focus more on information in their local surrounds than on their knowledge about the building. However, navigating with a paper map was linked to reporting most frequently on not experiencing any difficulties. This suggests that navigation appeared easier to navigators with a paper map than in the two other conditions. Despite the two map groups not

Table 2: Frequencies of comments per group and category. The percentages within condition are shown in parentheses.

| **Commenting on** | No map | | Paper map | | Digital map | | ***Total*** | |
|---|---|---|---|---|---|---|---|---|
| Cognitive process /orientation strategy | 81 | *(55.9)* | 32 | *(31.7)* | 32 | *(27.1)* | ***145*** | *(33.1)* |
| Insecurity / feeling puzzled | 53 | *(61.6)* | 18 | *(20.9)* | 15 | *(17.4)* | ***86*** | *(10.0)* |
| Building design | 17 | *(25.8)* | 37 | *(56.1)* | 12 | *(18.2)* | ***66*** | *(15.1)* |
| Signage design | 63 | *(64.9)* | 9 | *(9.3)* | 25 | *(25.8)* | ***97*** | *(22.1)* |
| Map design | - | - | 9 | *(20.5)* | 35 | *(79.5)* | ***49*** | *(10)* |
| ***Total*** | ***214*** | *(48.9)* | ***105*** | *(24)* | ***118*** | *(27.2)* | ***438*** | |

significantly differing regarding the time required to find the destinations, they seem to have experienced a different ease in wayfinding. This could also be supported with the Thinking Aloud data. The digital map group provided more comments about irritating or missing features of the map design. In addition the no-map group gave significantly more comments about the signage design and reported more often about a feeling of being insecure or puzzled by their wayfinding tasks, while the paper map group gave significantly most comments about the building's design. We believe that the signage group and the digital map group were primarily involved with the available navigation information, while the paper map group's attention was less absorbed by the map, and therefore had free capacity to pay attention to the surrounding environment. The verbal protocols did not show a difference between groups regarding cognitive processes or orientation strategies, which supports the finding from the open questions.

Efficiently guiding visitors to a desired destination may not be seen as the V&A's core function, since museums are also a place for exploration. To provide participants with an adequate scenario, we framed the visit as a wayfinding task with a focus on efficiency differences and experience differences between the groups. Because none of the navigators stopped or detoured to look at exhibitions we believe the fact that they were traveling through a museum did not influence our participants' wayfinding behavior. On the one hand the museum is a realistic testing environment and allowed us to get insight into people's experiences as they are in everyday life, instead of merely testing complexity-reduced reactions in the lab (Brunswik, 1956). But on the other hand, testing in realistic settings does not allow for easy experimental variations (e.g. altering signage, enlarging windows, fitting in atriums), the specification of key factors that alter visitors' experience with the building and maps, and the improvement of their effectiveness and satisfaction. Those questions can be answered in virtual reality scenarios and provide fruitful ideas for further research focusing on those key factors. This case study was a valuable opportunity to look at indoor map users' navigation through a multilevel, complex building and provided further ideas regarding which factors to take into account for subsequent studies. A further step could include mobile eyetracking in order to focus on the users' attentional processes, and including architects analyzing building properties to get a deeper insight into the designers' perspectives and to prospectively aim to identify key factors that alter users' cognition and behavior.

## Acknowledgements

We thank Google Inc. for the Google Faculty Research Award that supported this research project. We also thank Thora Tenbrink and the SFB/TR8 Spatial Cognition for helping us with transcribing the verbal data and Carina Hoppenz for her help with conducting the experiment.

## References

Al-Sayed, K., Dalton, R. C., & Hölscher, C. (2010). Discursive design thinking: The role of explicit knowledge in creative architectural design reasoning. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *24*(02), 211.

Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An Empirical Evaluation of the System Usability Scale. *International Journal of Human-Computer Interaction*, *24*(6), 574–594. Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability Evaluation in Industry*, *189*, 194.

Brunswik, E. (1956). *Perception and the representative design of psychological experiments*. Univ of California Press.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 319–340.

Ericsson, K. A., & Simon, H. A. (1985). *Protocol analysis*. MIT press.

Google Inc. (2013). *Google Maps Mobile*. Mountain View, CA, USA: Google Inc.

Hassenzahl, M., Burmester, M., & Koller, F. (2003). AttrakDiff: A questionnaire to measure perceived hedonic and pragmatic quality. In *Mensch & Computer* (pp. 187–196).

Hölscher, C., Büchner, S., Brösamle, M., Meilinger, T., & Strube, G. (2007). Signs and Maps – Cognitive Economy in the Use of External Aids for Indoor Navigation. In *Proceedings of the 29th Annual Cognitive Science Society* (pp. 377–382). Austin, TX: Cognitive Science Society.

Hölscher, C., Büchner, S. J., Meilinger, T., & Strube, G. (2009). Adaptivity of wayfinding strategies in a multi-building ensemble: The effects of spatial structure, task requirements, and metric information. *Journal of Environmental Psychology*, *29*(2), 208–219.

Ishikawa, T., & Montello, D. R. (2006). Spatial knowledge acquisition from direct experience in the environment: Individual differences in the development of metric knowledge and the integration of separately learned places. *Cognitive Psychology*, *52*(2), 93–129.

Krippendorff, K. (2004). Reliability in Content Analysis. *Human Communication Research*, *30*(3), 411–433. Krippendorf, S. (1969). Content analysis: history and critical issues. *Unpubl. Doctors Diss. Univ. of Pensylvania*.

Moshagen, M., & Thielsch, M. T. (2010). Facets of visual aesthetics. *International Journal of Human-Computer Studies*, *68*(10), 689–709.

Nasar, J. L., Stamps, A. E., & Hanyu, K. (2005). Form and function in public buildings. *Journal of Environmental Psychology*, *25*(2), 159–165.

Siegel, A. W., & White, S. H. (1975). The development of spatial representations of large-scale environments. *Advances in Child Development and Behavior*, *10*, 9–55.