# App-Free Zone: Paper Maps as Alternative to Electronic Indoor Navigation Aids and Their Empirical Evaluation with Large User Bases

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**Abstract** Nowadays, mobile devices are widely used as navigation aids, e.g., for car navigation. Their greatest advantage is the ability of automatic position tracking. In indoor environments, this feature is often not available, since indoor localization techniques are not ready for the mass-market yet. What remains is a small display with limited space for route visualizations. In contrast, the variable size of paper allows for the representation of additional context information as a means for spatial understanding and orientation in space, rendering it a valuable alternative presentation medium for indoor navigation aids. Independent of the medium used, provided visualizations must meet specific cartographic requirements like clarity, comprehensibility, and expedience. Within a co-operation between geoinformation science and sociology, we develop and investigate cartographic methods for effective route guidance in indoor environments. Our evaluation base comes from user studies conducted with more than 3,000 visitors, of both genders and aged between 4 and 78 years. These user studies were collected during the "Long Nights of Science" in Berlin in 2009, 2010, 2011, and 2012. We used paper as the presentation medium for our experiments, not only for practical reasons but also because we want to confront our participants with a solution which does not align to the current trend. Within this article we put special focus on media characteristics and users' media preferences. Therefore, we

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asked our participants about their opinion on the provided paper maps in contrast to mobile solutions. Based on their answers, we could derive media characteristics relevant from a user's perspective, as well as the affinities of different user groups. One astonishing outcome was that 11–15 year-old teenagers indicate a much higher tendency towards paper maps than towards smartphone apps.

**Keywords** Indoor navigation · Map design · Paper map · Social experiment

## 1 Introduction

Nowadays, mobile devices as navigation aids enjoy great popularity, especially for car navigation. With complete GPS coverage outdoors, the current position can be determined with an accuracy down to a few meters, which is sufficient for car tracking. Reading the map is not meant to be a main task during car driving and travelling at high velocities inevitably requires coarser graphics to reduce stimulus. Therefore, the underlying map typically consists of not much more than the street network plus information about the course of the route. The graph structure of the street network forms the basis for route calculations, which are executed on-the-fly.

The situation is more complex in a pedestrian scenario. Space accessible by pedestrians rarely follows such simple structures. Consequently, pure geometric hints like turn-by-turn instructions or distance values are less useful for pedestrian guidance. What pedestrians need are semantic references, which serve as linking objects between a map and the real world. According to May et al. (2003), landmarks are by far the most popular and effective type of information for pedestrian guidance. Information density of navigation maps for pedestrians is considerably higher than that of higher-velocity applications because of higher perception capacity. Pedestrians want to be informed not only about their current position but also about their surroundings. In outdoor environments one can refer to a broad geographic data base, comprising all object types relevant for pedestrian navigation available in various levels of generalization. In combination with available positioning technology, dynamic approaches may be implemented like video and panorama based virtual environments (Kolbe 2003) or augmented reality as user interface in a mobile computing application (Reitmayr and Schmalstieg 2003).

When it comes to indoor map design, things get even more complicated, since we have to leave the two-dimensional plane. Inside buildings, we usually move between several floors. As basic data for indoor applications, one may rely on existing floor plans, but as the name "plans" already suggests, they typically represent a detailed, non-generalized, CAD-like copy of the floor's architecture. Figure 1 shows a commented example. From a cartographic perspective, such plans are as inappropriate for user guidance as cadastral records in outdoor environments. Another source for indoor geometries along with their thematic
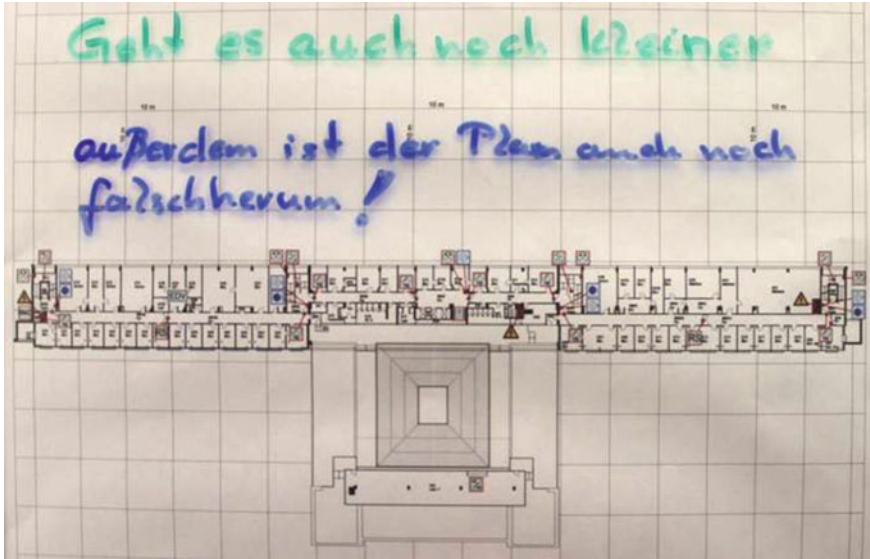
**Fig. 1** Floor plan mounted within the main building of TU Berlin (real size approx. 20 × 30 cm). The comments translate to: "why not printing it even smaller?" (*top*), "the plan is upside-down!" (*bottom*)

meaning are virtual 3D building models following standards like IFC (ISO 2005) or CityGML (Gröger et al. 2008).

Existing data sources allow for the storage of building data, which may only be used as a basis for the creation of indoor navigation maps, since they are not meant to fulfill cartographic requirements themselves. Consequently, issues in the design of existing building data are often mentioned or even criticized. Still, most existing approaches fall back to the available (pseudo-) cartographic material like aforementioned floor plans and superimpose them with additional route information. A rare alternative is the concept of indoor tubes (Nossum 2011), which visualizes accessible building parts in the same fashion as we are used to from subway maps. Unfortunately, *design guidelines* are not widely available. They are mostly byproducts of user studies (e.g., Puikkonen et al. 2009; May et al. 2003; Vinson 1999) and therefore do not allow for the formulation of comprehensive catalogues of design recommendations.

In order to evaluate different design aspects, we have conducted annual user studies since 2009. We have the chance to use the "Lange Nacht der Wissenschaften" ("Long Nights of Science"; LNDW[1]) as a framework for our experiment, which frees us up from a lot of organizational effort. At the same time it provides us with up to 1,100 participants per year, allowing for detailed examinations of the influence of various user characteristic parameters (e.g., cultural background, age,

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[1] LNDW, Lange Nacht der Wissenschaften. http://www.lndw.tu-berlin.de/

education, personal abilities, interests, familiarity with the study area) and context issues (e.g., route complexity, abstraction of the map, influence of other participants). Statistical analyses and results are published in (Lorenz and Thierbach 2012; Thierbach 2011; Lorenz et al. 2010).

This article shifts the focus from map design variations, towards using paper as a presentation medium for indoor navigation aids. The sheer size of our user base prevents the use of mobile devices as presentation medium. So we dare to go against the current trend with using paper as the output medium for the resulting maps. In this article, we analyse the opinions on the use of this medium among our user base and identify reasons for users preferring paper over mobile devices and vice versa.

## 2 Paper Versus Mobile Devices

Both, paper and mobile devices have their advantages and disadvantages regarding their suitability as presentation medium for personal indoor navigation maps. In the following we will present two comparative literature analyses which later on will be opposed with results from our survey. One obvious drawback of mobile devices, which is always stressed, is their typically very small sized device displays. They "have not been particularly designed for map applications. Hence, the maps had to adjust to the conditions of the device that has been designed to be preferably compact" (Pauschert et al. 2011). We will refer to several studies, which have demonstrated that small displays negatively influence the user's orientation and spatial understanding. The reason for this lies in the strong segmentation of space, caused by the big ratio between screen size and displayed area. "Despite advances in small-screen cartography, the limitations due to size and display technology will remain for the foreseeable future. Interactivity can be a key benefit but a large percentage of user actions is typically concerned with control interaction to address the limitations of the devices used" (Paelke and Sester 2010). The insertion of the current location, using positioning methods, helps with this. Through automatic user tracking, orientation becomes easier and users may find their way without full awareness of their environment. Unfortunately, positioning methods are not as ubiquitous for indoor environments as they are for outdoor environments. We will outline the state of the art of indoor positioning methods and their implementation in mobile navigation aids at the end of this section.

### 2.1 Comparative Analyses of Presentation Media for Navigation Maps

Pauschert et al. (2011) compare paper maps and electronic devices. For their analysis, they refer to the concept of affordances, which goes back to the

**Table 1** Affordances of paper maps and electronic devices (Pauschert et al. 2011)

| Affordances of paper maps, guides | Affordances of electronic devices |
|---|---|
| Flick through several pages (guide) | Access larger amounts of information |
| Read across several documents at once | Access and display multimedia content |
| Make annotations on the document | Modify documents and create new ones |
| Get an overview of an area of interest (map) | Get additional information linked to a document |
| Grasp, fold the map | Use computational resources for services like navigation, route guiding |
| Work collaboratively on one document | Remote communication with other users |
| Source of static information | Access dynamic information |
| Independent, easily accessible | Dependant on battery power, network connection, familiarity of the user with the technology |

ecological psychologist Gibson (1979). Contrary to objective media characteristics, affordances of media express their subjective relation to people, i.e., what they can use them for. Table 1 shows several affordances of paper maps and compares them to the affordances of electronic mobile devices.

Paelke and Sester (2010) compare paper maps and maps on electronic handheld mobile devices, analysing general features, content presentation, as well as use and interaction properties (Table 2). Several aspects are rated for both media, underlining their complementary strengths and weaknesses.

## 2.2 Impact of Display Size

Several studies examined the impact of display size on way-finding behavior and spatial knowledge acquisition. Dillemuth (2009) tested 80 undergraduate students, aged between 17 and 41. They had to solve navigation tasks with the help of scrollable maps of a fictitious town with different extents. Those participants viewing the full extent of the map had the advantage of direct perception, whilst participants with the small-window conditions had to rely on mental representations held in memory. For the estimation of relative distances and relative directions, the crucial point seems to be whether all landmarks necessary for orientation are located within a single view. If they are not, zooming to a smaller scale could be beneficial, but this might introduce new issues concerning the estimation of absolute distances. Another serious insight is the mismatch of confidence and accuracy regarding relative distances and relative direction estimates. Participants are often unaware of their incorrect judgements, which could lead to wrong

**Table 2** Comparison of paper maps and maps on electronic handheld devices (Paelke and Sester 2010)

|          |                                              | **Paper Maps**                                                  | **Hand-held eMaps**                                                      |
|----------|----------------------------------------------|----------------------------------------------------------------|-------------------------------------------------------------------------|
| Features | size                                         | small to large, foldable, flexible                             | small, fixed                                                            |
|          | power consumption                            | none                                                           | significant; endurance hours to days                                    |
|          | weight                                       | low                                                            | wide range; typically several 100g's                                    |
|          | price                                        | low                                                            | high                                                                    |
|          | reliability                                  | very high                                                      | limited                                                                 |
| Content  | resolution (spatial)                         | very high                                                      | low                                                                     |
|          | resolution (temporal)                        | very limited (static depictions)                               | potentially high (animation)                                            |
|          | flexibility of content                       | no adaptation, difficult update                                | easy if supported by software                                           |
|          | content dimensions                           | fixed, limited                                                 | flexible, potentially unlimited                                         |
|          | coverage                                     | fixed                                                          | potentially unlimited                                                   |
|          | level-of-detail                              | fixed, typically high (use specific)                           | lower due to display resolution, flexible                               |
| Use and interaction | readability                       | very high                                                      | lower                                                                   |
|          | information access                           | mostly push; serendipitous discovery common                    | mostly pull; often lack of overview for discoveries if not explicitly supported |
|          | use, interaction                             | well known interaction with paper; but learned map skills required | special mechanisms, devices specific, only tasks supported by the software |
|          | accessibility                                | high, but no support for visual impaired                       | lower, but special mechanisms for target groups can be implemented in software |
|          | flexibility of use / adaptation to other uses | very easy, common                                             | only if supported by the implementation, typically limited              |
|          | annotation                                   | simple with pens, post-its etc.                                | only if supported by the software                                       |
|          | query, search                                | only pre-designed indices                                      | full support possible in software                                       |
|          | integration of GPS                           | none                                                           | full support possible in software                                       |
|          | multi-user interaction                       | very easy, common                                              | difficult due to device size                                            |

decisions in a real world navigation scenario. Correlating the results of spatial ability tests with general performance in all navigation tasks, suggests that people with good spatial abilities even perform well with small-window conditions, whereas people with lower abilities do not and therefore may benefit from efficiently designed maps. Gartner and Hiller (2008) tested 30 persons who had to find a route and solve navigation tasks with the help of either a paper map or a small display mobile device with scrolling and panning functionality. Evaluation results show that paper map users performed better in all navigation tasks, including the estimation of absolute directions, topological understanding expressed by sketch maps, and spatial action, i.e., find the way back to a prior destination. Ishikawa et al. (2008) came up with similar results when they tested 66 college students, aged 18–28, in a slightly modified scenario. Using GPS-based navigation systems, paper maps, or direct experience, participants had to follow six routes and solve navigation tasks at the end of each route. Results for the estimation of absolute directions and topological understanding, confirm the strength of bigger displays, primarily their potential in displaying large amounts of context information. Another interesting issue mentioned by Ishikawa et al. (2008) is the interference between local focus of attention, in the case of a small display size, and global processing of spatial information, which is required for getting oriented in space by interrelating the surrounding space, the user, and the map.

## 2.3 State of the Art Indoor Positioning Methods and Their Implementation in Mobile Navigation Aids

In short, indoor positioning methods are not yet ready for the mass-market (Wirola et al. 2010). Suitable methods need an acceptable level of accuracy, along with availability indoors and low installation and maintenance costs. Unfortunately, existing families of positioning methods only partially fulfill these requirements. Satellite based methods are very cost-effective since satellite positioning systems like GPS are globally available and can be received and interpreted by almost every modern smartphone. But there is one considerable drawback in that GPS signals are shielded by building walls resulting in low positioning accuracy indoors. Cellular network based methods also have accuracy challenges, since positions may be determined with an accuracy of around 20 m (UMTS). WiFi and short range methods require new infrastructure in terms of tags, beacons, or markers as well as corresponding radios or cameras. This allows for higher positioning accuracy, but also implies higher costs. For that reason, such methods are only affordable within small-scale realizations.

Such small-scale realizations differ in terms of positioning technology, kind of representation, user adaptation, and interactivity. Often they are hybrid (outdoor and indoor) systems, relying on GPS outdoors and sensor techniques like WLAN or Bluetooth indoors (e.g., Krüger et al. 2004; Rehrl et al. 2007). For better results, different sensor techniques may be combined like in the NAVIO project (Gartner et al. 2004), where WLAN is combined with other wireless techniques like Bluetooth or ZigBee. In contrast, the following approaches use alternative positioning and/or presentation solutions. Müller et al. (2006) propose an approach where a mobile phone is used as a magic lens which is swept over existing georeferenced floor plans. This allows for position verification without the necessity to track the user and forms the basis for augmenting the route on the camera image of the floor plan. Hide and Botterill (2010) developed a system integrating measurements from a foot-mounted IMU with position and orientation updates from computer vision techniques. It can be applied indoors and outdoors, providing position accuracies better than 10 m (typically 1–5 m). Another concept, which has only been tested outdoors so far, but could (in a slightly adapted version) also be deployed indoors, is the Rotating Compass. This is an advanced kind of signage which individually indicates the direction to a specific destination (Rukzio et al. 2009). Becker et al. (2009) provide a conceptual framework for indoor navigation introducing a multilayer space model for the representation of both topographic and sensor space. Nagel et al. (2010) proposed formal requirements for an indoor navigation standard which the multilayer space model meets. Such a standard should support different navigation contexts which are constituted by three main factors: the mode of locomotion of the moving subject or object, the logical context representing pre-knowledge or navigation constraints, which result from various application domains, and the localization infrastructure used. For the modelling of indoor environments, a navigation standard should be compatible to

existing 3D building models and employ a hierarchical aggregation concept for the grouping of spaces.

A lot of research efforts are dedicated to indoor navigation using mobile devices and automatic positioning. Nevertheless, we must not loose sight of conventional paper maps for indoor navigation. If they were designed adequately, they could be a valuable alternative, because not everyone appreciates the use of mobile devices for navigation tasks.

## 3 User Tests

In order to evaluate different design aspects, we have conducted annual user studies since 2009, within a collaboration between geoinformation science and sociology. This allows us to bundle experience and know-how in cartographic methods and social research. The user studies take the form of a social field experiment (factorial design without control group) conducted with visitors of the LNDW at the Technische Universität Berlin's main building. Due to its complex architectural structure, consisting of two components with different floor heights and an intricate system of staircases, the university's main building is well suited for the purpose of developing and testing design guidelines for indoor navigation maps. Most user studies in this domain are typically conducted with a small number of participants with similar age and social background, such as students. In contrast, a total of more than 3,000 persons participated in our experiments, to date. In 2011 (the date for which all results presented in this paper are based upon), 1,140 persons aged between 4 and 78 years had tested our maps, 54 % of which were male and 46 % female.

We applied a mixed-method research design with both qualitative and quantitative data. In order to grasp familiarity with the test location, orientation behavior, prior experience, and personal characteristics, participants were asked to answer an a priori survey before being assigned a map/route. The experiment itself was organized as a race, so that two parties (single persons or groups) compete against each other, one using the Eastern route and one the Western route (see Fig. 2). Both routes start in front of the main auditorium, within the entrance area of the main building of TU Berlin, and lead to the Geodätenstand, a geodetic laboratory on the roof of the building. Participants have to ascend seven floors using four to five different staircases, but no elevators. Along the route, they pass seven critical decision points. The average walking time for people who are not familiar with the route is about 10 min. The simpler, but longer Eastern route is characterized by fewer turns, one long corridor without visual cues, and fewer changeovers between building parts. In contrast, the more complex, but shorter Western route, features much more changeovers, route parts within and outside the building and a more winding route, complicating route visualization. After having arrived at the (same) destination, participants were asked to answer an a posteriori survey and open-ended questions in order to assess the participants' navigational

approach, their motivation for participation, as well as their experience with the route and especially with the provided map. In addition, we conducted a focused ethnography (Knoblauch 2005) along the route, i.e., coworkers observed the participants (Lamnek 2005) during navigation in order to see how they oriented within the building. This gives us the opportunity to get to know and analyze unexpected effects during the navigation task, as for example group dynamics and reasons for delays, for outstanding quick runs, or for leaving the recommended route (Thierbach 2011).

The maps are based on existing floor plans, which are generalized for the final representation scale. This involves the selection of relevant architectural structures, geometric simplification, exaggeration of important details, as well as amalgamation of building parts according to their function. For the purpose of navigation, we decided to only distinguish indoor hallways, rooms, outdoor paths, and roof areas, with each colored appropriately. For each floor, we cut out the relevant parts of the produced maps and arranged them accordingly. Stairs and pillars were inserted and connecting elements were added as means for orientation.

In addition, we systematically varied map design aspects for each route. The active, controlled variation of map design variables in the social experiment gives us the chance of systematically analyzing their suitability with respect to specific user groups and context settings. In 2011, we developed eight maps, focusing on two map design issues: representational perspectives (2D and 3D) and different types of landmark representation (natural versus artificial landmarks represented as symbols along the Western route and natural landmarks represented as symbols versus text along the Eastern route). Figure 2 visualizes one of the maps tested in 2011, showing an oblique view (referred to as 3D) of the Western route including natural and artificial landmarks. In this context, natural landmarks are distinctive objects that one can find in the building, e.g., fire extinguishers, garbage cans, or restrooms. Artificial landmarks are not naturally there, but have to be placed artificially. We chose zodiac signs as artificial landmarks and installed them along the Western route at difficult parts and decision points where no natural landmark supports navigation.

## 4 Results

In 2011, we tested navigational success based on representational perspective as well as different types and amounts of integrated landmarks. Our data shows that generally 3D maps perform better as they strongly enhance spatial understanding. However, a surprising detail was that, for the representation of vertical structures, 2D maps are almost as good as 3D maps, if additional textual information like navigation hints and floor numbers are included. Landmarks are only regarded as being helpful if the connection between landmark and route is obvious. In our survey, both statements receive similar amounts of positive user feedback, implying that the alignments seem to be well done, are understood by users, and
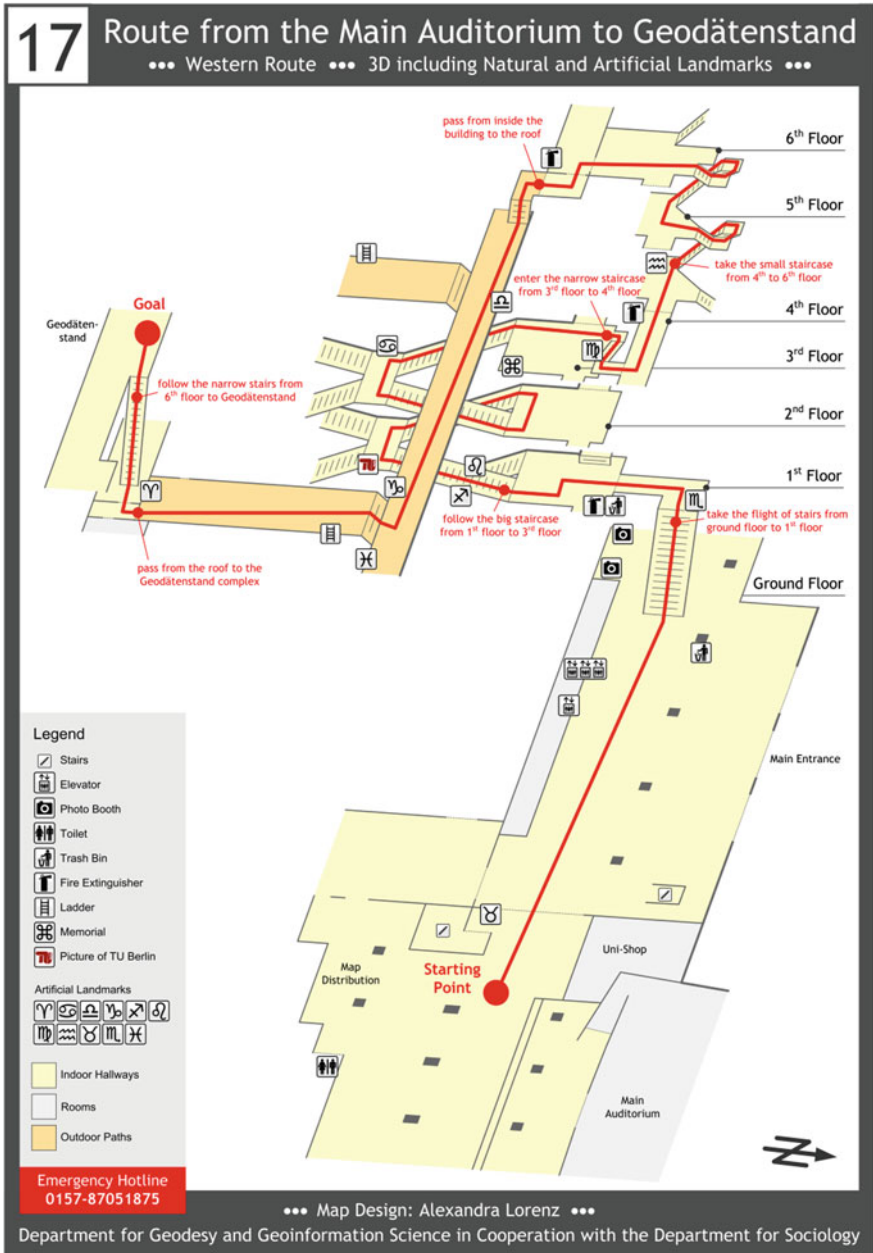
**Fig. 2** Sample map: western 3D route including natural and artificial landmarks. All maps tested within our user studies can be accessed online at: http://www.gis.tu-berlin.de/menue/projekte/laufende_projekte/das_entwirrte_labyrinth/

are seen as being very helpful. The importance of landmarks for navigation maps is confirmed by the fact that both benefit and alignment of landmarks strongly correlate with overall users' satisfaction.

In order to relate users' map satisfaction with different aspects like user characteristics, route complexity, and map design, we conducted a series of analyses of variance (ANOVA; Baur 2012). The results show that although often humorously stressed, gender and age are not significant indicators of users' likely satisfaction with maps. The properties of the route are much more important, explaining 5.6 % of users' satisfaction with maps, whereas map design issues like variation of landmark representation and representational perspective are of utmost importance, as they explain 29.2 % of differences in user satisfaction with maps. More details regarding the evaluation of the results from our user studies can be found in Lorenz and Thierbach (2012), Thierbach (2011) Lorenz et al. (2010).

## 4.1 Media Preferences: Who Prefers Paper Maps Over Apps?

Within this chapter, we concentrate on our findings on users' preferences for different presentation media. In order to get a feel for the public opinion on this topic, we inserted the following question into the 2011 a posteriori questionnaire: "You used a printed map for this experiment. If you had the choice, would you prefer to use such a printed map or a mobile phone app?" Our participants are surprisingly decisive on this issue: 54 % prefer paper maps, only 19 % prefer electronic solutions, and 27 % do not show any preference.

An insight from sociology is that very often, there are typical patterns in social preferences and actions. This means that we expect that different types of people prefer different types of media. In order to assess who prefers printed paper maps over apps, we conducted a series of multiple linear regression analyses (see Table 3; Fromm 2010). First, bivariate analyses show the correlation (Pearson's r) between single variables/factors and media preference. Factors in this context are sets of variables with similar response tendencies, formed on the basis of a factor analysis. Models 1–4 investigate different categories of variables, which might influence people's affinity for paper maps or apps: sociodemographics, media experience, other experience helping orientation, and orientation praxis. They form the basis for the complete and the final model, which explain all or the most important variables/factors respectively. The regression coefficients (Beta) express the expected change of media preference in relation to single variable changes. Variables are only relevant if they have a low significance value (Sig.), which defines the linear relation between variable and media preference. S.E. describes the standard error of variables in the linear regression. Finally, R-Square measures the ratio of the explained variance for the applied models.

Model 1 shows that sociodemographic variables (gender and age) together explain about 5 % of the differences between respondents. In the case of women, we observed a strong tendency towards paper maps (61 % paper map, 16 %

**Table 3** Who prefers paper maps over apps? Results of a multiple linear regression analysis (Fromm 2010) explaining the relation between sets of different independent variables (models 1–6) and users' media preference

| | presen-tation medium | ratio | sub categories | n° of entries | analogies to Pauschert et al.'s affordances of paper maps and electronic devices | analogies to Paelke & Sester's comparison of paper maps and maps on electronic devices |
|---|---|---|---|---|---|---|
| smartphones / mobile devices | paper map | 10% | no or seldom usage of mobile phone | 9 | | |
| | | | only for phone calls | 1 | | |
| | | | not app capable | 39 | | |
| | app/ e-map | 8% | always available | 11 | | |
| user characteristics | paper map | 27% | familarity with paper maps | 31 | familarity of the user with the technology (switched) | well known interaction with paper, but learned map skills required |
| | | | advanced age | 6 | | |
| | | | old fashioned | 13 | | |
| | | | anti-smartphone | 19 | | |
| | | | affinity for paper | 38 | | |
| | app/ e-map | 11% | familarity with apps/e-maps | 3 | | |
| | | | modern | 5 | | |
| | | | pro-smartphone | 3 | | |
| | | | affinity for technology | 4 | | |
| presentation medium | paper map | 32% | always ready to use | 37 | easily accessible; independent of battery power and network connection (switched) | no power consumption; high accessibility; very high reliability |
| | | | customizable, foldable | 6 | make annotations on the docu-ment; grasp and fold the map | simple annotation with pens, post-its etc.; foldable |
| | app/ e-map | 8% | all-in-one solution | 4 | remote communication with other users; access larger amounts of information | |
| | | | eco-friendly | 7 | | |
| usability | paper map | 7% | usability | 20 | | flexible; adaptable to other uses |
| | | | free adjustment of map orientation | 8 | | |
| | app/ e-map | 30% | usability | 37 | | |
| | | | automatic adjustment of map orientation | 4 | | |
| graphics | paper map | 40% | big display size | 60 | | flexible size |
| | | | readability, comprehensibility | 20 | | very high display resolution and readability |
| | | | overview | 80 | get an overview of an area of interest | typically high level-of-detail |
| | app/e-map | 15% | compact display size | 8 | | |
| | | | readability | 4 | | |
| | | | overview | 9 | | flexible; flexible level-of-detail; potentially unlimited content dimensions and coverage |
| (no) interaction | paper map | 5% | no undesirable dynamics | 21 | source of static information | information access mostly by pull |
| | | | multi-user interaction | 0 | work collaboratively on one document | very easy multi-user interaction |
| | app/e-map | 14% | desirable dynamics | 13 | access dynamic information | information access mostly by push; potentially high temporal resolution |
| | | | adaptiveness, additional information | 4 | get additional information linked to a document; access and display multimedia content | easy adaptation if supported by software; full support of search & query possible |
| | | | additional functionality | 2 | | special mechanisms for target groups can be implemented |
| routing capability | app/e-map | 13% | tracking of user location display of course direction | 17 | | full support of GPS possible in software |
| | | | route calculation | 1 | use computational resources for services like navigation; route guiding | |

For this analysis, the sample size reduces to 613, since not all participants responded to all relevant questions (variables/factors)

*Data Base* LNDW Survey 2011. n = 613. *Significance Levels* $+ \alpha = 0.1$; $* \alpha = 0.05$; $** \alpha = 0.01$; $*** \alpha = 0.001$
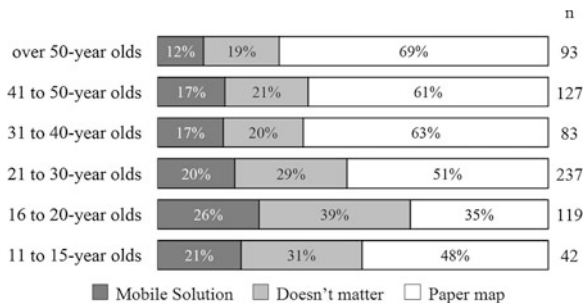
electronic solution), whereas men's preference for paper maps is not as clear (47 % paper map, 22 % electronic solution). The main reason for this gender difference seems to be that men have a stronger affinity for technology and other practices relevant for orientation. This means that we suspect that women who have an affinity for technology and are good at orientating themselves, are more similar to men in their media preferences than to other women. Our data suggest that this is true, as gender differences become insignificant when controlling for orientation practices and prior experience with technology relevant for orientation (Model 5).

Another factor which significantly affects preferences for presentation media is age. Figure 3 gives an overview of the preferences of different age groups. As presumed, with increasing age users' affinity for paper maps gets stronger. Older people even indicate their age as a reason for their paper preference, e.g., "I'm 59 years old and prefer to orientate myself on paper maps." or "I'm old school". However, not only adults strongly tend towards paper maps. Within the group of 11–15 year-olds, only 21 % prefer electronic maps. This may be due to smartphones not frequently being used by persons within this age group. The peak for electronic maps is reached within the age group of 16–20 year-olds, but still here, paper maps are preferred. In contrast to gender, age remains significant when controlling for other variables.

People are prone to habits. Therefore, they might simply prefer media that they are used to, as this is more convenient. In fact, our data shows that *prior media experience* (Model 2) is the single most important factor for media preference, explaining 13 % of the variance between respondents. Not surprisingly, people who currently often use paper maps prefer using paper maps in the future, while a large number of people who often use maps on the internet, GPS, and other electronic maps would prefer an app. All these effects remain significant when controlling for other variables. Interestingly, frequently using floor plans or engineering drawings privately or professionally (which would be the case for engineers and cartographers) does not influence media preference.

Whilst prior media experience influences the specific experience a user has with different types of maps, users might also gain general experience in orientation itself. In turn, good orientation skills might include knowledge on how to orient best in a practical way and which media to use best for orientation tasks. Model 3



**Fig. 3** Preferences for a presentation medium (by age)

| | | | | n |
|---|---|---|---|---|
| over 50-year olds | 12% | 19% | 69% | 93 |
| 41 to 50-year olds | 17% | 21% | 61% | 127 |
| 31 to 40-year olds | 17% | 20% | 63% | 83 |
| 21 to 30-year olds | 20% | 29% | 51% | 237 |
| 16 to 20-year olds | 26% | 39% | 35% | 119 |
| 11 to 15-year olds | 21% | 31% | 48% | 42 |

■ Mobile Solution   ▨ Doesn't matter   □ Paper map

shows that these *other experiences potentially relevant for orientation* do have an effect, although it is small, explaining 3 % of the variance between respondents. However, the effect is not much smaller than that of sociodemographics. The first thing we tested, is how people typically are moving around in space on an everyday basis. We found that some people tend to use cars, while others tend to walk or use public transport. However, neither seems to be relevant for preference of a specific media type. Furthermore, we examined people who are forced to orientate themselves in new environments very often: They travel a lot to new cities or countries, go often to airports and to buildings unknown to them (such as houses, shopping malls, cinemas, hospitals, or government buildings). As a front-seat passenger, they often help the driver of a car finding her way by reading road signs and maps and by giving directions. Those people typically prefer apps. Very likely this has to do with the fact that apps provide the functionality of automatic localisation using GPS, as this effect looses significance when controlling for other variables. Finally, we observed gaming practices: Some people do not play at all, whilst others love playing games such as strategy games, logic games, various kinds of role plays, shooting games, outdoor orienteering games, and second life. While almost no person plays *all* these games, typically people have a tendency towards playing several or none. This seems to be important for media preference, as people who play a lot of games strongly prefer apps—regardless of other experiences.

Knowing how to orient themselves and how to use maps does not automatically mean that people apply that knowledge or rely on it. In fact, one of the things we found in our ethnography was that most people prefer to walk in groups—they strongly rely on others for finding their way. However, actual *orientation praxis* (Model 4) explains only 2 % of variance and thus only has a small effect on media preference. Again, there are typical patterns in how people orient themselves. While some people are very self-reliable, other people have a strong tendency to use external help (regardless, if they have a map or not): Whenever they visit someone they have never visited before, they let someone describe the way orally before they leave or ask for a written description of the way. On the way, they use the step-by-step written description and ask other people for help. During our experiment, they additionally used other maps (e.g., escape plans and floor plans) and like that sometimes found other ways to the goal than the one described on our maps. In tendency, these people had more problems than others in spatially visualizing the whole route and did not use the landmark information in the maps. Nevertheless, these orientation habits do not affect media preference at all.

Regardless of how much external help people use, there are map-readers and followers: Some people believe that they are very good at orientating themselves and reading maps. They very often use classical printed road maps, town maps, floor plans, and/or engineering drawings, but also maps on the internet. This reflects in their orientation practices: Whenever they visit someone they have never visited before, they look at a map (e.g. a traditional paper map or a map on the internet) before they leave. On the way, they make use of the full range of possibilities for orientating themselves: They use maps, road signs, buildings,

other landmarks, and finally rely on their spatial sense. In contrast, other people find it more convenient to let others do the orientation work: Whenever they visit someone, they have never visited before, someone else tries to find out how to get there before and during the trip—they only walk along. This pattern is important when analyzing media preference, as map-readers, i.e., people who always read maps themselves and typically do the actual orientation work, would prefer paper maps.

Our *final model* (Model 6) compiles all factors tested that are significant when controlling for other variables. As can be seen, older people and people experienced in using paper maps and people using maps themselves (in contrast to relying on other people) prefer paper maps. Only people playing games a lot, frequently using maps on the internet, GPS and other electronic maps would prefer apps. These six factors together explain 16 % of variance between respondents.

## 4.2 Why do People Prefer Specific Media?

Our quantitative analysis gives us insights into *who* prefers which medium. In order to get deeper insights on *why* people prefer specific media, we analyzed the reasons given by participants, provided as free text in the questionnaire. Since we did not suggest any response categories, this method resembles a brainstorming, allowing for a broad range of answers, but giving only rough estimates of de facto percentages. The resulting aspects (see Table 4) are impulsive ideas to which the user presumably attaches particular importance.

The classification of answers results in seven main categories: smartphones/mobile devices, user characteristics, presentation medium, usability, graphics, (no) interaction, and routing capabilities. According to user responses, all categories split into several aspects regarding paper maps and app/e-maps. In order to visualize the relevance of different categories and aspects, we inserted percentual values for all main categories as well as the amount of entries for individual aspects. e.g., 40 % in case of paper map graphics means that 40 % of all paper map supporters mentioned graphic issues like big display size, readability, comprehensibility, or overview as one reason for their affinity. Since each user might have mentioned more than one aspect, the total number of entries is not equal to the total number of participants, just like ratios for one presentation medium (paper map or app/e-map) do not sum up to 100 %. Comparing user support, we can state that paper maps score highly with their graphics, but also regarding user characteristics. They show minor advantages when it comes to the characteristics of the presentation medium as well as the necessity of mobile devices capable of displaying apps/e-maps. Mobile devices exhibit good usability and routing capabilities. Furthermore, they surpass paper maps regarding possible interaction.

As already mentioned, we compared findings from literature, namely the two comparative analyses of presentation media, with results from our survey. For this purpose, we tried to draw parallels between the three investigations. Accordingly,

**Table 4** Reasons for preferring a specific presentation medium based on results from our survey and parallels to comparative analyses from literature (Pauschert et al. 2011; Paelke and Sester 2010)

| | presentation medium | ratio | sub categories | n° of entries | analogies to Pauschert et al.'s affordances of paper maps and electronic devices | analogies to Paelke & Sester's comparison of paper maps and maps on electronic devices |
|---|---|---|---|---|---|---|
| smartphones / mobile devices | paper map | 10% | no or seldom usage of mobile phone | 9 | | |
| | | | only for phone calls | 1 | | |
| | | | not app capable | 39 | | |
| | app/ e-map | 8% | always available | 11 | | |
| user characteristics | paper map | 27% | familarity with paper maps | 31 | familarity of the user with the technology (switched) | well known interaction with paper, but learned map skills required |
| | | | advanced age | 6 | | |
| | | | old fashioned | 13 | | |
| | | | anti-smartphone | 19 | | |
| | | | affinity for paper | 38 | | |
| | app/ e-map | 11% | familiarity with apps/e-maps | 3 | | |
| | | | modern | 5 | | |
| | | | pro-smartphone | 3 | | |
| | | | affinity for technology | 4 | | |
| presentation medium | paper map | 32% | always ready to use | 37 | easily accessible; independent of battery power and network connection (switched) | no power consumption; high accessibility; very high reliability |
| | | | customizable, foldable | 6 | make annotations on the document; grasp and fold the map | simple annotation with pens, post-its etc.; foldable |
| | app/ e-map | 8% | all-in-one solution | 4 | remote communication with other users; access larger amounts of information | |
| | | | eco-friendly | 7 | | |
| usability | paper map | 7% | usability | 20 | | flexible; adaptable to other uses |
| | | | free adjustment of map orientation | 8 | | |
| | app/ e-map | 30% | usability | 37 | | |
| | | | automatic adjustment of map orientation | 4 | | |
| graphics | paper map | 40% | big display size | 60 | | flexible size |
| | | | readability, comprehensibility | 20 | | very high display resolution and readability |
| | | | overview | 80 | get an overview of an area of interest | typically high level-of-detail |
| | app/e-map | 15% | compact display size | 8 | | |
| | | | readability | 4 | | |
| | | | overview | 9 | | flexible; flexible level-of-detail; potentially unlimited content dimensions and coverage |
| (no) interaction | paper map | 5% | no undesirable dynamics | 21 | source of static information | information access mostly by pull |
| | | | multi-user interaction | 0 | work collaboratively on one document | very easy multi-user interaction |
| | app/e-map | 14% | desirable dynamics | 13 | access dynamic information | information access mostly by push; potentially high temporal resolution |
| | | | adaptiveness, additional information | 4 | get additional information linked to a document; access and display multimedia content | easy adaptation if supported by software; full support of search & query possible |
| | | | additional functionality | 2 | | special mechanisms for target groups can be implemented |
| routing capability | app/e-map | 13% | tracking of user location display of course direction | 17 | | full support of GPS possible in software |
| | | | route calculation | 1 | use computational resources for services like navigation; route guiding | |

aspects from Pauschert et al. (2011)'s affordances as well as Paelke and Sester (2010)'s comparison are added to Table 4: aspects which match with user entries from our survey are inserted into the respective row; new aspects are assigned one of the main categories and provided with a new row, e.g., multi-user interaction is added as an additional aspect of the category (no) interaction. We ignored three affordances listed in Table 1 (Flick through several pages [guides], Read across several documents at once, Modify documents and create new ones) since they did not fit into our user case of a single-sheet paper map and an app respectively. The comparison in Table 2 considers aspects in terms of both media, underlining their contrasting nature. We picked out only beneficial ratings, i.e., typically each aspect is taken up for one presentation medium.

Table 4 also reveals various aspects mentioned by our participants, which have not been investigated by Pauschert et al. (2011) or Paelke and Sester (2010). Above all, this concerns the usage of smartphones/mobile devices, user characteristics (except for familiarity) and many usability aspects. In detail, we detected the following very beneficial aspects of paper maps: no necessity of a mobile phone capable of apps, many people just like paper maps (because of being a bit old fashioned, detesting smartphones in general, or having an affinity for paper), paper has no breakdowns, and interactions like zooming and panning are not necessary for coarse orientation. Comments like "I'm a boyscout. We do not always have to use technology.", "I hate iPhones and apps. Old is just as good!", "The haptics of a paper map are sexy.", "Technology often leads to even more irritations.", and "I feel uncomfortable with digital maps if they change during navigation." support these advantages. Furthermore, we found the following positive aspects of mobile devices: many participants are equipped with a smartphone anyway and are eager to use it, mobile devices are eco-friendly (no paper is wasted for throwaway maps) and show good usability (they are easy to use, good to handle, or practical). Some users even like their compact display size. Again, various comments underline the benefits: "I've got my mobile with me anyway—other paper stuff often gets lost!", "No idea, paper maps are too complicated.", and "There is no room for an A4 map within my pockets.". In order to refine our estimates for user preferences, we are going to introduce multiple-choice response categories within 2012's questionnaire.

## 5 Conclusions

Within this chapter we concentrated on our findings regarding users' preferences on different presentation media. Based on a series of multiple linear regression analyses, we assessed who prefers printed paper maps over apps. Expecting that different types of people prefer different types of media, we investigated the influence of the sociodemographic variable, prior media experience, other experiences potentially relevant for orientation, and orientation praxis on participants' media preferences. Our analyses show that women have a slightly stronger

tendency towards paper maps than men. Additionally, all age groups prefer paper maps with stronger affinity as age increases. The peak for electronic maps is reached within the group of 16–20 year-olds, but still here, paper maps are preferred. From all factors, prior media experience is the single most important one, explaining 13 % of variance between media preferences of respondents. The reason might be that people are prone to habits and therefore simply prefer media that they are used to. Interestingly, frequent usage of floor plans and engineering drawings does not influence media preference at all. Other experiences possibly relevant for orientation such as being forced to orient oneself and playing a lot of games have a small influence on media preference. The effect of actual orientation praxis is very small, with only people who always read maps themselves having a significant tendency towards paper maps.

In order to get deeper insights into why people prefer specific media, we analyzed reasons participants provided for their media preferences. They could be classified into: usage of smartphones/mobile devices, user characteristics, presentation medium, usability, graphics, (no) interaction, and routing capabilities. Paper maps score highly with their graphics, but also regarding user characteristics, while mobile devices exhibit good usability and routing capabilities. We drew parallels between the findings of our survey and existing comparative analyses on this topic, revealing some new aspects only mentioned by our participants. They include beneficial aspects of paper maps, i.e., no necessity for a mobile phone capable of supporting apps, an affinity for paper, and no breakdowns, as well as advantages of mobile devices, i.e., various usability facets. In summary, paper maps and mobile devices support different user needs: Whereas the size and presentational perspective of paper maps allows for a better overview and therefore better spatial understanding of the environment, mobile devices may interactively accompany the user along a route, facilitating position verification and map alignment.

Our investigations are based on navigation experiments carried out within a cooperation between geoinformation science and sociology. The large number of participants allows for statistically significant statements. Although visitors of the LNDW might not include people from all social backgrounds, we can make the assumption that our sample is quite representative of the total population. Experience acquired during the past three years has shown that paper maps constitute a serious alternative to mobile devices as navigation aids for indoor environments. Provided that map design follows cartographic principles, they are most suitable for guiding a user to a desired destination. As importantly, people just like paper maps. This was not clear to us when we started our experiments. Initially, we took the decision to use paper maps simply because of pragmatic reasons. Only later, positive user feedback confirmed our choice. In the future, one of the biggest challenges will be to find out which indoor configurations influence user needs regarding map design. This will support the automatic derivation of optimal maps for individual routes which will also be beneficial for LBS using apps.

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