Analyzing the Design of Tactile Indoor Maps

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Abstract. Tactile maps are feasible to increase the mobility of people with blindness and to achieve spatial information of unknown environments. Exploring tactile maps could be a hard task. Research on the design of tactile maps, especially the design and meaningfulness of tactile symbols, mostly addresses outdoor environments. The design of tactile indoor maps has been studied less frequently, although they differ significantly from outdoor environments. Therefore, in this paper, 58 tactile indoor maps have been investigated in terms of the design of the headline, additional map information, legend, walls and information presentation types used. In addition, the design of common objects for indoor environments, such as doors, entrances and exits, toilets, stairs and elevators, has been examined in more detail and commonly used symbols have been extracted. These findings form the basis for further user studies to gain insights into the effective design of indoor maps.

Keywords: tactile indoor map design · accessible building maps · people with blindness and visual impairments

1 Introduction

The ability to travel is an essential requirement not only for the equal participation of people with impairments in social life, but also in many professional areas. Whether attending workshops, training sessions, networking meetings or conferences - many professions require independent mobility in unfamiliar outdoor and indoor environments. For people with blindness (PB) it is challenging to orient and navigate themselves especially in unknown environments. Tactile mobility and orientation maps are feasible to explore unknown areas and information points as well as to acquire different type of knowledge (landmarks, routes, configurations) [4] and thus support increasing mobility for PB. Tactile maps (TM) consist of raised lines, symbols and textures and can be perceived sequentially by touch. However, reading tactile maps (TM) is a hard task which is why they should be well-designed in regard to the specific requirements of the tactile sense. This requires at least enlargement of symbols and textures as well as the use of Braille letters. Consequently, generalization is an important aspect for the design of TM which implies not least a decision about which details are shown at a specific scale [19]. Still, the usefulness of TM has been shown in prior research. Furthermore, several studies investigated the design of TM (e.g.

[8,16,10] that highly influences the readability. However, TM for outdoor environments are mostly considered, only a few studies have been conducted on the design of TM for indoor environments (e.g. [19,17]) although indoor and outdoor environments differ significantly. Indoor maps of buildings are more complex than outdoor representations and include multiple levels. They are primarily large-scaled indoor maps, showing more details than outdoor and geographical maps. Well-designed tactile maps are also needed for the development of effective audio-tactile applications.
In conclusion, more detailed research on effective design of tactile indoor maps is needed to increase the mobility of PB, even within unfamiliar buildings. Therefore, as a first step in our development process, we investigated existing tactile indoor maps in terms of the applied design. The goal of the analysis was to identify different design characteristics as well as repeating design elements, thus deriving first insights into the design of tactile indoor maps and generating research questions for upcoming user studies.

2 Research on Tactile Maps

The design of TM is influenced by many factors, e.g. the production method [4], the function of the map, the context of use [9] or the experiences and abilities of the user. In order to be able to decrease the amount of data on maps, in recent years, lots of research have been done developing interactive TM for PB (e.g. [6,3,2]). Effective interactive TM require effective tactile map design. For this reason, a number of studies have examined specific design aspects. First, general guidelines for tactile graphics (e.g. [1,15]) recommending minimal distances and sizes, can be applied. However, these guidelines are not sufficient and do not address specific aspects of indoor maps. Although there is no common standard for the use of symbols [11], much research focused on the distinguishability and design of symbols (e.g. [7,11]). Rowell et al. [16] use interviews to investigate which properties are important when designing symbols. The authors identified texture, spacing, type, shape, size, elevation and standardisation as key factors. Other researchers examine the meaningfulness of symbols in maps (e.g. [9,10]). Lambert et al. [9] found out that meaningful symbols are better remembered. According to the authors, the physical characteristics of symbols should help to understand their meaning. Lee et al. [10] investigated the usefulness of visual symbols, collected from visual maps, for use in TM. There is no discussion of how useful it is to assign further meaning to the symbols, for example, the orientation of the symbols. Only Lobben et al. [11] introduce modifiers paired with symbols to expand their meaning (e.g. a triangle to indicate elevation changes). Additionally, a number of papers dealt with increasing availability of TM by proposing an automated creation process (e.g. [18,20,21]).
However, the majority of previous research focused on spatial maps with streets and buildings [3] so their findings can usually be applied specifically to outdoor environments. The orientation strategies, structure, objects, scale and information needs for indoor and outdoor environments differ greatly, so specific

research is needed for indoor environments [12]. Some approaches already exist that address information needs for orientation in buildings as well as orientation strategies. Rowell et al. [17] investigate in interviews with PB to find out preferences of different map features, characteristics and which types of information to include on a mobility map. The authors point out the usefulness of indoor maps and large scale mapping for mobility purposes. In a recent survey with 106 participants with blindness and visual impairments we investigated [5] the information need in indoor environments, applied orientation strategies, important orientation features and as well specific challenges arising in indoor environments. The study shows the lack of availability of tactile indoor maps, which is due in part to the fact that building data is often not freely available [19]. Till now, it is unclear which information should be included in tactile indoor maps and how to represent the information effectively and highly readable for different purposes. Furthermore, existing studies evaluating the effectiveness of maps often used highly simplified maps without much details (e.g. [4]).
In summary, most of the specific research on design of TM is almost limited to outdoor environments and cannot directly be transferred to indoor environments. Effective design implies the use of meaningful design elements, especially symbols, which must be considered for indoor maps to provide effective design. In addition, the context of use is clearly relevant for the design [14] so it is needed to evaluate symbols and other design characteristics in context of the map [9].

3 Analysing the Design of Tactile Indoor Maps

Due to the lack of studies on specific design aspects for indoor maps, we started our research by analyzing existing indoor maps in terms of design. Therefore, only a few examples of tactile indoor maps are available, which is why we analyzed examples from practice, and extracted the symbols and design approaches used for further user studies.

3.1 Methods and Materials

In total, we collected 58 photos of different tactile indoor maps. As mentioned before, only a few research examples (e.g. [13]) of tactile indoor maps could be used as a basis for the design analysis. Nevertheless, a number of companies produce commercially tactile indoor maps as part of building guidance systems [1]. Many of them reference their projects and the maps created on their websites. Some of these maps were used for the analysis, retrieved from the websites of 12 companies. Three maps come from publications and research projects, four maps have been photographed by ourselves directly in a building, six were provided on the website of a library for the blind (DZB)[2] and few maps were provided by building websites (e.g. website of a university). Due to the corona crisis, it

[1] e.g. `www.schilder-systeme.com`, `https://www.mdsignworx.at`, `www.meng.de` or `www.ilis-leitsysteme.de` (last visited: 09. June 21)
[2] `https://www.dzblesen.de/index.php?site_id=4.2` (last visited: 09. June 21)

was not possible to visit various buildings to search for building maps, so these could only be obtained online. For this reason, we have no further information about most of the maps (e.g. about the expertise of the creators, feedback from users, quality of the maps, exact size, etc.).
The majority of analyzed TM are large UV prints (64 %) that have been set up or hung to a fixed position (74%) in a building for visitors. The physical size of the maps can only be estimated, some companies indicated page lengths of at least 60 cm. Besides using UV printing, 10% of the maps were produced with swellpaper and 12% as foil reliefs. A minority consists of metal or a plastic composition. About 22 % are suitable for the mobile use (maximum size of A3). Furthermore, almost all maps (except three) support both - visual and tactile objects and letters and are therefore feasible for people with and without sights. One map provides further information by adding QR-codes to points-of-interest that can be scanned by mobile devices. The maps come from 11 different countries, with the majority from Germany (60 %) and 17 % from Sweden and just few maps from China. Only one example is represented from each of the other countries (e.g. Great Britain, Czech Republic, Switzerland, USA).

First, we analyzed related work and extracted basic building features that are important for orientation and may be relevant for indoor maps. On that basis, we defined categories that are relevant for indoor map design. We then analyzed the retrieved indoor maps manually in regard to the defined attributes. If maps contain relevant properties that were not previously considered, this category was added and all other maps were also examined in this regard. A descriptive analysis has been applied on the results, followed by an extraction of outlying features and symbols.

4 Results of the Design Analysis

We examined the design with regard to design of symbols, textures, lines, legend as well as Braille labels. We paid particular attention to the different design characteristics as well as the common features and differences of the maps. The majority of maps were made for public buildings, with the exception of shopping centers and hotels. Most indoor maps were made for museums or theaters as well as universities (26 %). About 10 % also represent sports or swimming halls. Building types that are typically frequently visited by people with disabilities, such as health centers or train stations, are less frequently represented. However, it cannot be assumed that the frequency with which building types are represented in the sample reflects the population of available TM. It is also possible that additional indoor maps are not publicly available.
Headline. The headline of a map is very important for orientation and understanding the map's content. Most maps provide a headline, at least representing the building name or the name or number of the most common level (see Table 1). 25 % of the analyzed maps provide the type of the map (e.g. orientation or evacuation plan). A description of the shown area is given for 12 % of the

Table 1. The first value column shows the percentage of maps containing basic elements like Headline, Legend, Walls, Symbols etc. The second column contains additional characteristics that frequently occur in relation to the first column values (average value calculation without 0).

	Available	Frequent Characteristics
Headline	81%	Building name (50%), level number (45%)
Legend	88%	Position above map (31%)
Walls	95%	all walls same width (57%)
Symbols	95%	6 per map in average (SD= 3.3)
Textures	59%	3.1 per map in average (SD=2.6)
Line Styles	98%	1.6 per map in average (SD= 0.6)
Labels	54%	6 per map in average (5.1)
Keys	40%	8.2 per map in average (SD= 6.9)
Doors	86%	gap in the wall (76%)
Entries/ Exits	81%	shown as symbol (76%)
Elevator	66%	shown as symbol (62%)
Stairs	83%	shown as symbol (79%)
Toilets	76%	shown as symbol (43%), indicators for gender (64%)
Location	65%	shown as symbol (65%)

TM (e.g. exhibit name, building wing). 25 % of the headlines provide multiple information types (e.g. building name and level name).

Further Information. Overall, most maps do not include further information about the map. In particular, no map makes use of a grid for orientation, just five maps provide a visual or labelled marker for scale and four present a marker to indicate north direction. Only two maps support a schematic overview specifying the location of the map shown in the building.

Legend. The majority of maps comes with a legend, that is most often placed directly above the map and quite often on the right side (26 %), followed by the left side (21 %). Two maps (handheld ones) provide the legend on a separated sheet. The design of the legend is mostly similar, with a reference on the left (e.g. key, texture, symbol used in the map) and an explanation on the right. The legend is essential for the comprehension of almost all maps and mostly describes all elements on the map. Some maps do not reference the stair symbol in the legend.

Walls. The structure of the building is represented by the floor plan and, if necessary, by the labeling of rooms and areas. When exploring TM, lines are followed to identify the dimensions of the building and its layout. Most of all analyzed maps support the representation of inner and outer walls. While most maps present walls with same width, about 30 % support line tracing and thus recognition of the outline, by designing outer walls thicker than inner walls. 14 % of the TM represent the wall thicknesses in the building very differently, as they correspond to the real thickness of walls. Only 19 % reference the line style for walls in the legend.

Encoding of Information. Information on maps can be provided using Braille

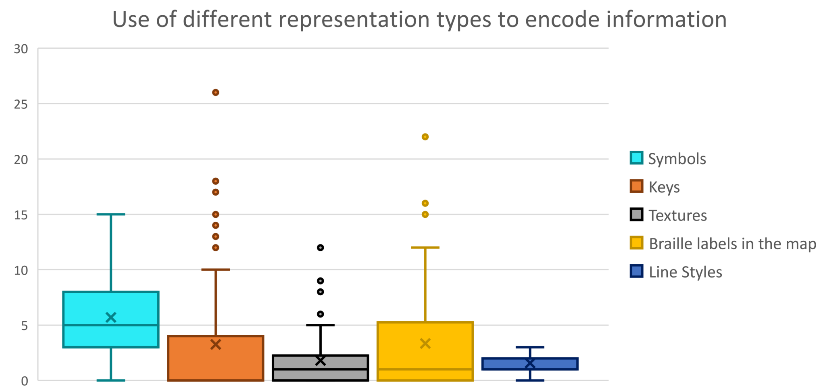

Fig. 1. Box plot that shows how many different symbols, keys, textures, Braille labels and line styles were used on average on one map to provide information (maps without occurrence included as 0 value) .

labels, textures, line styles, and point symbols. It is up to the author's decision which information the map should contain and which of these encoding types are used. The main focus was on analyzing which representations occur in the maps and how many different elements of an object class (e.g. symbols) were represented. Almost all maps make use of different symbols to represent relevant information (see Fig. 1). An amount of 5 to 8 different symbols on the map is very common, where the maximum number of different symbols per map is 15. While some maps provide only a few basic symbols, others use them as the main information carriers. Textures, line styles (at least one to represent walls), and braille labels in the map are used less consistently, but still by the majority of maps (see Table 1). According to this, there is partly a high variance in the number of objects used. For example, while 46 % do not provide any braille label in the map for areas and objects, the number of labels used varies greatly for the remaining maps. Most of the maps use less than 10 different keys. Textures and line styles were used relatively rarely to encode information. Textures were often used to determine restricted areas or to indicate functions of areas (e.g. corridors, exhibition areas). Filled areas occurred most frequently. Areas are often visually separated with colors, but not filled with raised textures. A maximum of three different line styles (5 %) were used on a map, with solid lines assigned to walls. Most maps present only two different line styles to distinguish walls and routes. About 45 % of the maps show either a route (e.g. escape route) or a guidance system, which is mainly represented with dotted or dashed lines.

Labels and Keys. Visual and tactile labels were equally supported in most of all TM. Most maps placed Braille letters directly under the visual counterpart. Visual letters are also raised on most maps. It is more common to provide Braille labels just in the legend (about 50 %) than in the map only (14 %). 12 maps use numeric indicators for keys, two maps use letters and numbers to separate keys in two categories, and seven maps use abbreviations with single letters.

Doors. Doors are important for orientation for many PB (e.g. by counting the doors). The majority of the maps show at least the positions of doors. The majority represent normal doors with a gap in the wall, the remaining representations use symbols. These indicate not only the position of doors, but also their opening direction. The different symbols appearing in the maps are shown in Fig. 2. The symbols used are very similar to those applied for visual indoor maps. Many maps explicitly identify entrances or exits of the building by special symbols, Braille labels (5 %) or both (9 %). A total of 38 % identify emergency exits separately, although some maps also distinguish between normal exits and emergency exits. Most entries (56 %) can be identified by a filled triangle or arrowhead (see Fig. 2 Entrance (a) to (d)), while 22 % apply an arrow that points in the direction of the entry. One map indicates a revolving door with an unfilled circle with a gap (Fig. 2 Doors (f)). Exits or emergency exits were often represented with the same symbol (Fig. 2 (Emergency) Exit (a) and (b)). Three times, a combination of an arrow and a further symbol (e.g. wheelchair or iconic person) was given for this purpose.

Stairs and Elevators. Stairs and elevators are an important orientation feature and can be found in almost all buildings. The majority of maps include stairs and elevators and represent it with a symbol. 69 % of the stair symbols consist of parallel lines in different variations (e.g. with or without border). About 40 % of the represented stairs have indicators for their direction, for example, an open side of a rectangle indicates the bottom (13 %), decreasing width of steps from top to bottom (8 %), an arrow pointing to the top (6 %), applying three elevation levels (8 %), or a point on the highest step (6 %), as shown in Fig, 2. Symbols for elevators mostly represent variations of a square with (47 % of all symbols for elevators) or without an open site indicating the entry, whereby some contain a cross (24 %), two arrows (18.4 %) or a key/ label (8 %). The elevator symbol most often used is a rectangle with one side open and an arrow pointing in (29 %, Fig. 2 Elevators (c)).

Toilets. The location of toilets is a very important feature for many people, especially those with disabilities. Most maps show the location of toilets, represented by a single symbol in more than half of the maps or just by labels (26 %). While 21 % of the toilets do not distinguish between different types of toilet rooms, 64 % use indicators for male, female, and accessible toilets, with more than half illustrating these with iconic stick figures. The label "WC" was commonly used (33 %).

Infopoints and Current Location. Especially for mobility maps it is essential to know the current location. However, in the case of static maps, this is only meaningful when maps were permanently installed. More than 50 % of the symbols represent a filled circle and 23 % a filled triangle, similar to many visual maps. In particular, PB also have great interest in the location of information points or personal contacts in the building. This information is rarely given: just 10 % of the maps provide information on receptions or info points, mostly marked with an "I" symbol.

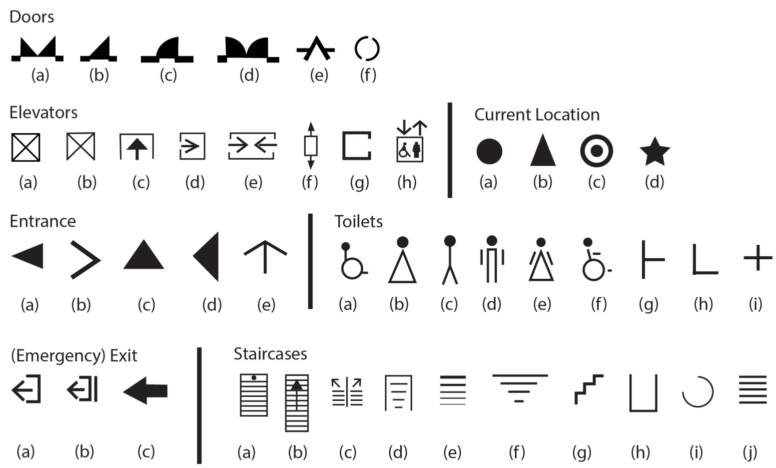

Fig. 2. Different types of symbols extracted from the analyzed maps

5 Discussion and Outlook

We analyzed a wide range of different indoor maps in regard to the representation of important building information as well as design concepts and spaces for the design of tactile building maps. The results show that although the design of the maps is very heterogeneous and not standardized, some design aspects are very similar. For example, there seems to be a consensus on the design of some symbols as the applied symbols were often similar and meaningful relating to the represented feature, e.g. symbols for stairs, elevators and exits. In contrast, different line styles and textures play a minor role for the analyzed indoor maps. Symbols were more often used than Braille labels to encode information. We could also identify important building objects that were represented with the majority of maps. Consequently, a headline, walls, stairs and elevators, toilets, doors and exits/ entries as well as the current location (in case of fixed or dynamic maps) should be provided by the map. We extracted the different types of symbols for individual objects from the maps, traced them and adapted the size to at least 6 mm per site (according to guidelines). Based on our many years of experience, we will adapt the most common symbols according to guideline requirements to evaluate their readability and meaningfulness with PB in well-designed indoor maps. For example, it would be interesting to find out whether encoding of additional information with symbols, such as the opening direction of elevators or the direction of staircases, can be represented and understood by PB. In addition, the choice of symbols should be made not only in terms of readability but also concerning their meaningfullness and consistency with outdoor map symbols. In particular, the level-of-detail of tactile indoor maps still needs to be investigated.

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References

1. Braille Authority of North America and Canadian Braille Authority: Guidelines and standards for tactile graphics (2010), http://www.brailleauthority.org/tg
2. Brock, A., Oriola, B., Truillet, P., Jouffrais, C., Picard, D.: Map design for visually impaired people: past, present, and future research. MEI-Médiation et information pp. 117–129 (2013)
3. Brock, A.M.: Touch the map! designing interactive maps for visually impaired people. SIGACCESS Access. Comput. (105), 9–14 (Jan 2013). https://doi.org/10.1145/2444800.2444802, https://doi.org/10.1145/2444800.2444802
4. Brock, A.M., Truillet, P., Oriola, B., Picard, D., Jouffrais, C.: Interactivity improves usability of geographic maps for visually impaired people. Human–Computer Interaction **30**(2), 156–194 (2015)
5. Engel, C., Müller, K., Constantinescu, A., Loitsch, C., Petrausch, V., Weber, G., Stiefelhagen, R.: Travelling more independently: A requirements analysis for accessible journeys to unknown buildings for people with visual impairments. In: The 22nd International ACM SIGACCESS Conference on Computers and Accessibility. ASSETS '20, Association for Computing Machinery, New York, NY, USA (2020). https://doi.org/10.1145/3373625.3417022, https://doi.org/10.1145/3373625.3417022
6. Götzelmann, T.: Lucentmaps: 3d printed audiovisual tactile maps for blind and visually impaired people. In: Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility. p. 81–90. ASSETS '16, Association for Computing Machinery, New York, NY, USA (2016). https://doi.org/10.1145/2982142.2982163, https://doi.org/10.1145/2982142.2982163
7. James, G.: A kit for making raised maps. The Cartographic Journal **12**(1), 50–52 (1975)
8. Lambert, L., Lederman, S.: An evaluation of the legibility and meaningfulness of potential map symbols. Journal of Visual Impairment & Blindness **83**(8), 397–403 (1989)
9. Lambert, L., Lederman, S.: An evaluation of the legibility and meaningfulness of potential map symbols. Journal of Visual Impairment & Blindness **83**(8), 397–403 (1989). https://doi.org/10.1177/0145482X8908300808, https://doi.org/10.1177/0145482X8908300808
10. Lee, C.L.: An evaluation of tactile symbols in public environment for the visually impaired. Applied ergonomics **75**, 193–200 (2019)
11. Lobben, A., Lawrence, M.: The use of environmental features on tactile maps by navigators who are blind. The Professional Geographer **64**(1), 95–108 (2012). https://doi.org/10.1080/00330124.2011.595619, https://doi.org/10.1080/00330124.2011.595619
12. Loitsch, C., Müller, K., Engel, C., Weber, G., Stiefelhagen, R.: Accessiblemaps: Addressing gaps in maps for people with visual and mobility impairments. In: International Conference on Computers Helping People with Special Needs. pp. 286–296. Springer (2020)
13. Papadopoulos, K., Barouti, M., Charitakis, K.: A university indoors audio-tactile mobility aid for individuals with blindness. In: International Conference on Computers for Handicapped Persons. pp. 108–115. Springer (2014)

14. Perkins, C.: Cartography: progress in tactile mapping. Progress in Human Geography **26**(4), 521–530 (2002)
15. on Information Access for People with Print Disabilities Inc., R.T.: Guidelines on Conveying Visual Information (2005)
16. Rowell, J., Ongar, S.: The world of touch: an international survey of tactile maps. part 2: design. British Journal of Visual Impairment **21**(3), 105–110 (2003)
17. Rowell, J., Ungar, S.: Feeling our way: tactile map user requirements-a survey. In: International Cartographic Conference, La Coruna (2005)
18. Štampach, R., Mulíčková, E.: Automated generation of tactile maps. Journal of Maps **12**(sup1), 532–540 (2016)
19. Trinh, V., Manduchi, R.: A multi-scale embossed map authoring tool for indoor environments. In: International Conference on Computers Helping People with Special Needs. pp. 459–466. Springer (2020)
20. Wabiński, J., Mościcka, A.: Automatic (tactile) map generation—a systematic literature review. ISPRS International Journal of Geo-Information **8**(7), 293 (2019)
21. Watanabe, T., Yamaguchi, T., Koda, S., Minatani, K.: Tactile map automated creation system using openstreetmap. In: International Conference on Computers for Handicapped Persons. pp. 42–49. Springer (2014)