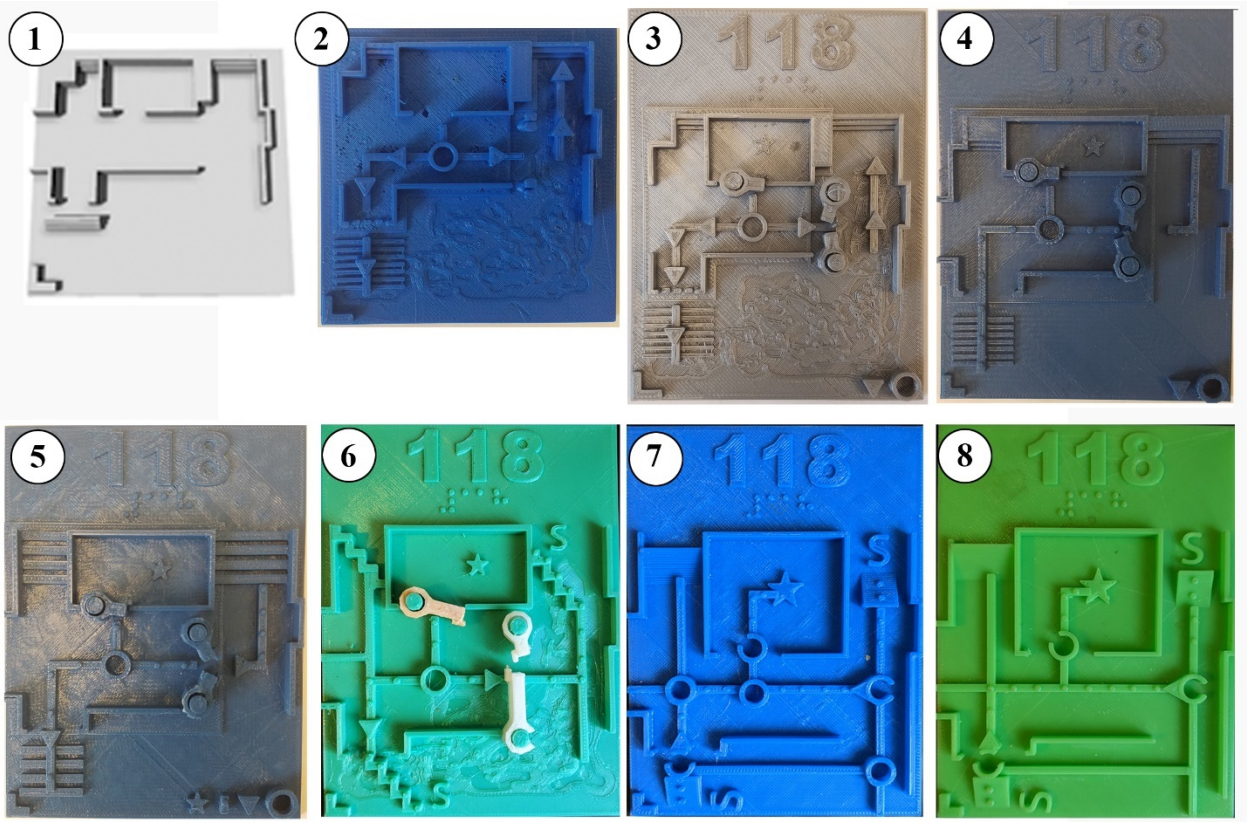
Supporting information

Generations of the maps

Supporting Figure S1 demonstrates 8 generations of a map for the same room. Iterative improvements were conducted for each following generation based on the feedback from the users.



Supporting Figure S1. Eight generations of a tactile map representing the same room.

Blueprint Maps

The first generation of the map was similar to the raised blueprint maps that we tested at the very beginning, however, the wall size and hallway spacing was increased for easier tactile reading. This change was made to allow more room for finger travel and wall identification. The staircases were also designed to mimic actual stairs with steps that were elevated and aligned with the walls.

After that, adjustments were made for the generation 2 based on the participants' feedback. The major change was the introduction of additional tactile encodings, specifically the path and arrows, path split ring, long rectangle stairs, and rough textured exterior surface.

A few of the participants were interested in the type of doors, and if they were manual or automatic. This was especially the case with doors leading from the interior to exterior of the building. The researcher also thought that this information would be important to include in the map since in some instances the automatic doors could malfunction. Starting in generation 2

movable doors representing manual doors and small squares indicating automatic doors were added to the maps.

The participants liked the moveable doors, and thought it was nice how the encoding provided information about the direction the door opened, and whether they were manual or automatic. However, the movable manual door design on the 2nd iteration had multiple issues. First, printing the pegs was difficult because of the small size. The prints would either fail to completely print the pegs, or they would easily break. When the participant moved their fingers along the path to the doors and pushed them open, the pegs would either break or the doors would come off the peg. Additionally, the participants had trouble distinguishing and identifying the room. It was determined that the difficulty was due to the room and hallways being too similar, and that there was not indicator in informing the participant that they were in the room. Therefore, in the 3rd iteration, we included a raised star to indicate being in the room. We also included a raised text and braille room name or number above the map. Adjustments were also made to the movable manual door encodings with a thicker peg and door. A semi-legend was added to the bottom right corner of the map.

3 and 4

Participant feedback and observation showed that the arrows made the map and path hard to follow. The size of the arrows, and other symbols such as the doors contributed to limited spacing for finger travel and increased tactile similarity which confused the participants, making it harder to identify map components. Therefore, for the 4th iteration we eliminated the path arrows and added raised dots instead. When testing one of the participants said, “I like the bumps as it reminds of something urgent, like this is the way.” The automatic door squares were eliminated since the participants could not identify them but were able to determine that there was an opening.

4 and 5

The participants were unable to determine the change from interior to exterior solely on the opening where the automatic doors were. Therefore, in the 5th iteration the arrow encoding was used to represent the transition from an interior to exterior space. It was also determined that even though most participants could with enough time identify the staircase encodings, they were still not optimal and could be adjusted to enable more accurate and efficient map reading. The stairs symbol was made larger.

5 and 6

Between map 5 and 6 we included more travel information by adding paths that did not have dots indicating that these smooth paths were regular hallways, not emergency exit paths. We observed several participants losing their place when the path ended. Some participants also wondered what the empty space at the end of the path. Therefore, it was determined that the paths must be connected and continuous. We also changed the stair encoding to a zig-zag stepped / elevated (each step was slightly raise higher than the previous) representation. The new staircase design was implemented because the participants found it hard to both follow the path and find the stairs and confused the stairs with the path or walls. We also removed the semi-legend in the bottom right corner and provided two separate map legends in both raised text and braille. A new encoding was designed to indicate the end of a path resulting in the location of a Safe Area. This

encoding was introduced to allow the user to quickly identify Safe locations and determine the travel route from the room along the emergency path to a specific safe location.

6 and 7

From iteration 2 through 7 the doors, although liked by most participants, were hard to implement. The moveable doors were complicated to 3D-print, broke easily, fell off the map, required substantial space, and caused other reading issues. Therefore, for the moveable doors were eliminated in the 7th iteration and replaced with rings. The door rings contained two splits indicating an automatic door, or one split for a manual door. A triangle was also attached to these rings when a transition from interior to exterior was present. This change allowed us to increase the room size while still maintaining the path and hallway spacing. The increase room size improved participant readability as it was easier for the participants to move through the map and room and enabled a focal point for the overall map. The path was also connected to the star to eliminated participant confusion and to help participants in determining the location and pathfinding caused by the spacing between the star and path from pervious iterations. Based on participant feedback and other observations the stair encoding was redesigned. One participant's feedback while using the 6th iteration map was, "Maybe just a ramp. We can tell when we get there if they are stairs or a ramp." Another participant said, "All that's important is that I know if there is a change in elevation." Some of the locations mapped also consisted of a set of exterior stairs and a handicapped ramp.

The size and height of the star encoding was increased to allow for better identifiability,

7 and 8

Though the participants could easily identify and liked the Path Split ring encoding it was eliminated since it was also used for the door encoding. The design of the connected paths also enabled participants to easily follow and determine when a path split and changed directions. It was also determined that since we added the additional pathways (non-emergency) that the users could follow the path quicker without the split then with it regardless of the type of path (regular or emergency). The ramp stair ending provided improved readability, ease of use, and was agreed upon by participants to be a better representation since it was easily identifiable and provided the necessary change in elevation information.

Details of the study protocol

Tactile Maps and Symbol Plate Studies were conducted 1 participant at a time, with 2 researchers and occasionally a staff member from a relevant organization. The study was conducted by following these steps:

1) Participants were provided information from the IRB protocol and then asked general questions about Braille and/or raised text reading / preference, age of blindness, mobility device, previous experience with tactile resources, current age,

2) Participants were given the symbol plate, and then a map that they could freely explore prior to the beginning of the interview. During that step the participants were given a symbol plate (3D-print) containing a specific object, such as a door or stairway and asked the Readability and Representation questions. Then participants were given a map with combined encodings and

asked the Readability and Representation questions. Participants could still use the map during the question session.

3) After the Readability and Representation questions for both the symbol plate(s) and map(s) Participants were asked to complete a series of tasks using the map. The tasks were, use the map to:

- Find the room using the travel path encoding from the main / primary entrance.
- From the room find the emergency exit
- Count doors in the map. What kind of doors (manual or automatic – when applicable based on map design)
- How many stairways / ramps in the map
- Are there any other paths? Where do they lead (if applicable)

4) Difficulty Level survey. A five-point Likert survey was given to each of the participants after the map tasks.

Participants repeated steps 2-3 during a single session for multiple symbol plates and map designs. Symbol plates were different for each physical component such as a door, or travel path. Map designs with differing combinations of the encoding designs.

Function of the experimenter:

During the experiments, the Experimenter recorded observation data, such as map reading strategy, map reading issues, participant comments. Video and audio also recorded.

As newer designs were created, they were added to the symbol plates. Older designs were eliminated according to participant feedback of both the symbol readability and representation, as well as Experimenter observation data collected. Some of the symbols on the plate were duplicated and scaled up or down to determine the most appropriate size.

During the field studies the Experimenters observed the whole experiment, recorded data and kept track of time, lead the process (determined when to start and stop the field test tasks based on the protocol). However even time required for the navigation was tracked, it was observed that many factors could have contributed to travel time including walking speed and distractions. Overall, we were not interested in travel speed, but in navigation accuracy and understanding of the map, as determined by task completion.

Field Tests:

The field tests were conducted with one participant at a time and 2 experimenters who recorded data, and provided safety / support, if needed. A local organization staff member was also present.

1. At the location experimenters gave the participant the map and discussed the study tasks. Then the participant was told when to start the first tasks of travelling to the room location, and data collection began.
2. Experimenter and participants started at the main entrance of the location.
3. The participant was given the 3D-printed map and asked to travel to the specified room (star location).
4. Once in the room the participants were asked to exit the building using an emergency route and go to the safe area.

Choice of locations for field tests:

1. Field Testing locations were chosen followed by the discussion between the researchers and the organization, (Southeastern Guide Dogs, Tampa Lighthouse, and Conklin Center for the Blind,) taking into consideration their needs for the maps.
2. USF testing locations were determined by the Students with Disability Services Department together with the researchers.
3. Room locations were determined by organization based on the needs of the people with blindness (e.g. dorm rooms, and classrooms).
4. All of the participants had never been to the location or room, except in the USF field test the participants navigated two locations. One of them they had previously visited and another location was new. This was done to collect information from the participant on how they felt about the representation of the tactile map based on a location that they were familiar with.

    a. All the USF participants strongly agreed with the representation of the space, including travel paths and encodings of the map.

    b. The field test in the previously visited location was done prior to the field test in unfamiliar area.

Data Collected:

Experimenters did not help any of the participant's during the field test. None of the participants asked for help.

Documented: Map use, - how many times participants referred and/or used the map during, navigation, issues, stops, doorway interaction, any questions or remarks made during the test, travel time.