Verbally Annotated Tactile You-Are-Here Maps

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Abstract: Wayfinding competence is believed to ground on different types of spatial knowledge, on of them is survey knowledge. You-Are-Here (YAH) maps were successfully used in conveying survey knowledge of complex spatial environments. Such visual maps have to be substituted by e.g. tactile maps to accommodate visually impaired people. In such a substitution, we focus on the representational layer of modalities, instead of targeting at the sensory layer. We are interested in how the disadvantages in usage that are introduced by substituting a visual map with a tactile map can be compensated for. As solution we introduce Verbally Annotated Tactile (VAT). VAT maps consist of two components: a verbal annotation system and a tactile map. We show how users could benefit from the cross-modal effects of the interaction of spatial and verbal representations in VAT maps. A first experiment to demonstrate some aspects of the approach is presented and a research agenda on cross-modal interaction of representations with VAT maps is outlined.

Keywords: You-are-here maps, navigation, tactile maps, multimodality

1 Introduction

From the perspective of the cognitive sciences, human knowledge and reasoning processes involve representations, which serve as counterparts to real-world entities in the human cognitive system. Regarding the representations of spatial configurations, there is strong evidence for their analogue nature, i.e. they have intrinsic spatial properties (Kosslyn 1980) and they are believed to be non-propositional (Goldstone & Barsalou 1998; Barsalou 1999). Investigations into internal spatial mental representations have brought forward suggestions about mental images (Kosslyn 1994), mental maps (cf. Weston & Handy 2004) and spatial mental models (cf. Tversky 1991). These internal representations can be induced via different linguistic or perceptual inputs from external (spatial) representations, such as geographic or sketch maps. Maps serve as means for capturing and processing knowledge (Forbus & Usher 2002) and for solving spatial reasoning tasks (Freksa 1991).

Diagrammatic representations, such as maps, have proven to be successful aids in navigation (Freksa 1999) and appear to be a promising aid for visually impaired people as well (Espinosa et al. 1998; Lahav & Mioduser 2008; Loomis, Golledge, Klatzky & Marston 2006; Ungar, Spencer & Blades 1993). To accommodate the special abilities of those users who cannot handle visual sources the change from visual perception to other modalities is mandatory. In the case of visual maps, the substitution of visual perception by tactile perception results in *tactile maps*. Simonnet at al. (2007) point out, that "tactile maps have a clear advantage in facilitating the development of cognitive maps by providing a global perspective on the surrounding geography" (p. 259). They have become an option to supply geographical knowledge to visually impaired persons (Sherman 1975, Gardiner & Perkins 2003).

Due to the low resolution in the tactile modality, tactile maps can only show limited semantic content on an abstract level (see Section 2). This could be compensated for theoretically by using larger maps in which the content is distributed over a large surface. Practically, the size of a any material that is subject to manual handling is limited. The limit is the size of the space where most of the manipulations and interactions human beings perform with their hands take place (the so-called manipulatory or peripersonal space , the "regions that lie within easy reach of one person's hands", Jones & Lederman 2006, p. 92). Instead of pushing the size of maps to the limit as consequence of the requirements from a *sensory substitution,* we proposed to look into a second level of substitution, namely *representational substitution*: whereas maps are *visual-spatial representations* of the environment, verbally annotated maps that provide verbal descriptions are *multimodal representations* integrating *spatial* and *propositional representations* (Habel & Graf 2008). Incorporating spatial and propositional representations, *Verbally Annotated Tactile* (VAT) maps promise to bring an advantage to visually impaired people supporting them in navigating the world. Compared to unimodal tactile maps, VAT maps are multi-modal representations that convey meaning as result from cross-modal interaction of different types of representations. During an exploration of a VAT map, tactile input from the tactile map that contributes to a spatial representation is augmented with verbal input from descriptions that contributes to a propositional representation. Having both, the spatial representation and the propositional representation at the same time, might change the way how the map is interpreted. We want to find out how the disadvantages in usage that are introduced by substituting a visual map with a tactile map can be compensated for by making use of cross-modal interactions of representations.

Compensation could be necessary for at least two problems. First, the tactual sense is—in comparison to the visual sense—relatively coarse, only limited content can be displayed. Conveying complementary content verbally that e.g. has not been encoded in the map due to space constraints could be one option. Another option would be to redundantly present content. Second, the serial nature of tactile exploration results in long exploration times and high cognitive demand for the integration. With touch, there is no such thing as an immediate overview of a map. The tactual features of the map have to be explored serially, demanding a lasting effort and high attention. This is a cognitive burden for the user and takes time. One solution to this problem could be to provide content verbally that is implicitly encoded in the map, e.g. at which destination a street ends. In this way, the map reader does not need to extract this information from the map by exploring it in all detail. Instead she gets the same information via the propositions faster and without an extra effort.

One class of maps has been proven to be used successfully in navigating complex buildings (e.g., malls, hospitals, etc.) and out-door environments (such as, parks, zoos, university campuses, etc.): You-Are-Here (YAH) maps (Levine 1982; O'Neill 1999; Klippel, Freksa & Winter, 2006). They have proven to be successful in facilitating wayfinding for "seeing people" (Richter & Klippel 2002). YAH maps are specifically made to provide an overview of the proximate environment of a location. They have an 'intermediary status' (Habel & Graf 2008, p. 2): Instead of being specialized like a route descriptions, which provides instruction for one single route from *one* location A to *one* destination B, and instead of a being general like a multipurpose city-map, which can be used to navigate from *many* locations to *many* destinations, a YAH map enables navigation from *one* location A, where the map are co-located with the navigator, to *many* destinations. YAH maps are often found at junctions or other main decision points. They enable people to localize themselves in a depictive representation of the environment, namely in the map. These maps are then used to find specific locations they look for and to plan next actions to reach their destinations. In our opinion by providing YAH maps, visually impaired people can be guided in wayfinding and simultaneously be supported in acquiring survey knowledge (cf. Ungar, 2000). In particular in environments visited regularly—as campuses, malls etc.—this would be advantageous for visually impaired people since this could lead to an increase of self-dependency. Supporting the view that maps are useful for navigation even in the time of GPS based systems, Burnett and Lee (2005) and Parush, Ahuvia & Erev (2007) argue that those systems have negative effects on the acquisition of spatial knowledge. This argument can be seen in favour of YAH maps, which are primarily targeted at providing a survey view of the environment at a distinct position instead of supporting the solution of single locomotion or wayfinding problems.

The aim of this paper is to present an agenda for a research project on navigation with verbally annotated tactile YAH maps. Research questions and some results from a first study are presented. Conducting this research, we adopt a cognitive Human-Computer-Interaction (HCI) perspective incorporating aspects of modelling, of designing, of cognitive processes and of technology, which were generally advocated for in the context of maps for visually impaired persons by other authors, e.g. Aldrich (2008).

Through the investigations into the usage of VAT maps in tasks that involve spatial cognition, we want to show that visually impaired people have an advantage when they engage in wayfinding tasks after having consulted a VAT map. The underlying assumption in this project is that the different formats of representations included in multimodal representations can facilitate spatial reasoning. Research by e.g. Kulhavy et al. (1992), Ungar, Blades & Spencer (2002) and Verdi & Kulhavy (1992) on the interaction of text (which is believed to be represented propositionally) in the presence of maps (which are believed to be represented spatially) can be interpreted to support this view. At the end of the project we will look forward to condense some design recommendations for multimodal representation of verbally annotated maps. The goal of the project is to show how to build cognitively adequate representations that helps in navigation without relying on the human visual sensor system.

In the remainder of the paper, in Section 2 we present some background on tactile maps and audio-tactile maps. In Section 3, considerations about a verbal annotation system for tactile maps are presented. In Section 4 we present an experiment with methodology, evaluation and results about how well respondents performed in a wayfinding task with a tactile map. Discussion about the results can be found in Section 5 before we come to a conclusion in Section 6.

2 Tactile Maps and Beyond

In some circumstances the tactile sense can substitute other sensory modalities like vision (Rice, Jacobson & Golledge 2005). Tactile maps seem to support visually impaired people in gaining wayfinding competence (Gardiner & Perkins 2003; Sherman 1975; Simonnet at al. 2007). Tactile maps can be said to be the result from encoding geographical and cartographical entities in a way that they are tactually prominent. In a tactile map entities are represented as raised artefacts on an otherwise flat surface. But tactile maps are not fully equivalent to visual ones in the sense of an isomorphism (Castner 1983; Gardiner & Perkins 2005).

First, there is limitation in resolution of what humans can sense tactually as consequence of the biological properties of the receptors in the skin. Looking into the psychophysics of touch (Lederman & Browse 1988) reveals a multitude of receptors that make very different types of sensations possible, e.g. the sensation of temperature, deformations, and lateral movements. Certain sensations can be made by passive touch (i.e. touching the material without moving the fingers) others are only possible with active touch (moving the fingers over the material). With these abilities it is possible to discriminate objects by their contours, surface roughness, and materials and others. To clearly feel one entity and separate two entities tactually, the entities and the distance between them have to be wider than between visual entities. As consequence, the distribution of objects in tactile representations is much coarser than in visual ones (if converted to a resolution figure one can find about 20dpi in tactile maps versus at least 300dpi in visual maps). Thus, a reduction in complexity is necessary to represent a world full of details in an abstract, tactile map.

Second, simply abstracting graphical entities does not take into account the limits of tactile perception like minimum distances between entities to clearly understand the separation (see Berla 1982). Michel (1998, 2000) showed that additional transformations are useful to make tactile maps meaningful to users, e.g. widening certain lines to become more prominent than others and guide attention. Distortions in the layout of the map (Michel & Hamel 1998) can bring certain features that would have been misinterpreted otherwise, e.g. that a streets does not run into a junction but just a little off to it, to the attention of the user.

Third, beside the discussed adjustments, which are grounded in sensory differences between vision and touch, there are limitations that affect cognitive processes when using a tactile map. Instead of having an immediate visual impression of a map, the user has to serially explore the surface of a tactile map with his fingertips and integrate the properties and impressions of single points of contact into one compound impression of the map (Révész 1938). Many people who are visually impaired have difficulties accomplishing this task (Ungar, Blades & Spencer 1995a, 1996). They generally read a tactile map slower and can understand it less than sighted people who see a visual representation of the same map (Ungar, Blades & Spencer 1995b). Systematic training of appropriate tactile scanning strategies is needed (for an investigation what constitutes an appropriate scanning strategy, see Perkins & Gardiner 2003) to help blind children to improve their ability to orient themselves on a tactile map (Ungar, Blades & Spencer 1997) or to locate distinctive features on a tactile map (Berla & Butterfield 1977).

In the institutions that produce tactile maps today, there are experts who try to accommodate the limitation found in the human sensory and cognitive system when manually designing a tactile map. To promote some conventions among those map-makers, a multitude of guidelines for the production of tactile graphics exist (American Printing House for the Blind 1988, 1997; Gardiner & Perkins (n.d.); Perkins School of the Blind 2009; for others see e.g. Hasty (n.d.)). This rich body of recommendations is supported by research on assistance in navigation for visually impaired people and how people use tactile maps (Challis & Edwards 2000; Eriksson 1999; Eriksson, Jansson & Strucel 2003; Jehoel et al. 2006; Rowell & Ungar 2003a-c; Ungar, Blades & Spencer 1993).

In contrast to the slow and inflexible production of a tactile map, using a personal computer promises to provide fast, flexible and individual access to spatial information represented in maps. As early as 1966, Linvill & Bliss proposed a device that translated graphical image into a tactile image that was presented by a dense array of pins (Linvill & Bliss 1966). That direct conversation approach addressed the challenge of substituting the visual sensory channel to provide some content in tactile form. It did not address the challenge of changing the content itself to be adequate for visually impaired persons. Way & Barner (1996) proposed an automatic transformation of images via image processing algorithms into an abstract graphical form. In their approach the content itself was abstracted. Nevertheless, it was not checked if the concepts used in the abstracted image were cognitively adequate for the particular impairment of the reader (see Heller (2002), Heller & Kennedy (1990) and Heller et al. (1995) for details about the challenge that e.g. congenitally blind people face when interpreting tactile images). For a review of sensory substitution technologies see Pun et al. (2007).

Aside from enabling sensory substitution, computer technology has been employed to provide blind people with naturalistic and intuitive devices dedicated to the acquisition of spatial knowledge. Virtual reality was proposed, e.g. virtual tactile maps which are explored with a computer controlled, motorized device move with the hand. When a user virtually touches a virtual object in the simulation space (the virtual world), such a device produces a real force against the movement of the user ("force-feedback"). An impression as if a real object was hit is produced. Force feedback interfaces can be viewed as having two basic functions: to measure the positions and contact forces of the user's hand, and to display contact forces and positions to the user (Tan et al. 1994). This concept can be used to explore virtual objects, as well as virtual geographic environments or virtual tactile maps of real environments (e.g. Golledge, Rice & Jacobson 2005). It can be extended to be an audio-tactile system that links touch with sound. For example, audio labels are attached to certain points and if those points are virtually touched the corresponding sound label is triggered.

Using audio-tactile devices to navigate and access non-textual, spatially distributed content was first presented in the work of Parkes (1988) and Lötzsch (1995). During the last two decades, there has been a lot of work on computer driven audio-tactile devices (cf. Parente and Bischop 2003; Wall and Brewster 2006; Wells and Landau 2003) and on computer driven virtual audio-tactile maps, i.e. maps that are equipped with sound (e.g. Droumeva, Antle & Wakkary 2007; Nasir, Canterbury, Roberts 2007; Zhao, Plaisant & Shneiderman 2005) and verbal labels (Jacobson 1998; Miele, Landai & Gilden 2006). For example, Jacobson et al. (2002) used a force-feedback mouse and auditory labels to give directions in a mixed modal interface. This multimodal approach turned out to be more comprehensive (Golledge et al. 2005) than the unimodal approach that combined a tactile matrix (a device with an array of controllable pins that penetrate the skin) and a virtual map (Jansson & Pedersen 2005). Similar effects for the combination of animations and narrations have been reported (Mayer and Anderson 1991).

The multimodal approach is realized in Verbally Annotated Tactile maps as well. VAT maps are multi-modal representations that make use of cross-modal interactions of different types of representations. In VAT maps, tactile input from a tactile map, which contributes to a spatial representation, is augmented with verbal input from descriptions, which contributes to a propositional representation, i.e. a VAT incorporates spatial and propositional representations. For example, when reaching an intersection (which is felt tactually) the user might hear the announcement, what points of interest are in the vicinity and where the departing streets lead to. The content of the announcement will be probably more than what can be interpreted from the ad-hoc sensation of the tactile stimulus. Compared to a simple tactile map, a VAT map is a representation that promises to bring an advantage to visually impaired people supporting them in gaining survey knowledge of the world for successful navigation.

This chapter has provided a background on tactile and audio-tactile maps, how they could be simulated and how they relate to VAT maps. The next chapter will present some details on the verbal annotations system that is part of a VAT map.

3 A Verbal Annotation System for Tactile Maps

We are investigating the opportunities that multimodal representations provide to level the disadvantages that emerge when using tactile maps. Our interest is in cross-modal interaction of propositional representations, such as speech or text, and spatial representations, such as tactile maps. Our goal is not to demonstrate the feasibility of the technological solution. Instead we want to investigate how the interaction of different types of representations can be modelled and used for the successful engagement between visually-impaired map-readers and maps.

The integration of verbal descriptions into tactile maps was described in previous work e.g. b, Holmes & Jansson (1997), Parente & Bischop (2003), and Siekierska & Müller (2003). In the NOMAD system (Parkes 1988) a touch-sensitive pad provided raised features as an analogue to map features and verbal descriptions of the location that was touched. The descriptions contained information about what the user was touching and where this point was. Heller et al. (1996) examined the influence of categorical information and visual experience on the identification of tangible pictures. Providing categorical information before the exploration of the pictures or before identifying objects had a positive influence on the identification result (Heller at al. 1996).

The presented literature can be interpreted such, that combining propositional and spatial representation can possibly benefit from cross-modal effects. None of the work reviewed so far has investigated the interaction of propositional representation and spatial representation when exploring a verbally annotated tactile map. We hypothesise that the comprehension of concepts encoded in a tactile map is facilitated by concepts encoded in the verbal description accompanying that map. Pre-conceptualisation of map characteristics through concepts that were activated when listening to the verbal content may help the map-reader to better understand what is displayed in the map and how entities relate to each other. For example, linguistic information as part of a map should not only hold local information about what the entity represents (e.g. to identify the stippled line as railroad track) but what relationships the represented object has in the world (e.g. the start and the end of the railroad track, stations on it and where they are). Semantic information about the global relation of the represented object to other objects promises to be helpful to the map-reader. By assessing map exploration times, survey knowledge, and subjective measures like user satisfaction the appropriateness of VAT maps to be used for spatial tasks can be evaluated. If people can handle such maps and have an advantage from it, then this will be an argument for making use of both external spatial and propositional representation to facilitate navigation with VAT maps.

Navigation support with VAT maps can be seen (on a high level) as support through an integrated system of tactile maps with verbal annotation. On the low level VAT maps are composed from two components: (A) the tactile map, and (B) the verbal annotation system.

(A) The tactile map could be simulated or be real: In the first case, the tactile map could be entirely virtual and then would be virtually explored with a force-feedback device, which works as actuator to allow experiencing real forces when hitting a virtual object (see Chapter 2). In the second case, the tactile map could be real and could be explored with some device that allows sensing the current position of the point(s) of contact, e.g. an electronic tablet that is overlayed with the tactile map and equipped with a stylus.

(B) The verbal annotations system is connected to the tactile map through references that link certain point-of-interest (POI) or areas-of-interest (AOI) on the tactile map with some entity in the verbal annotation system. If the map-reader is in the vicinity of a POI or AOI, the verbal description is presented (the concept of 'vicinity' will be detailed later). In the simplest case, the verbal descriptions are pre-recorded but in a more advanced system they could be generated on the fly from some (dynamic) database that provides the propositional content.

The verbal annotation system does not merely contain a set of propositions for a specific tactile map but it encompasses the rules how and when to use the propositions in conjunction with that map. Two aspects constitute the main questions to be answered to conceptually realize VAT maps.

1. "Which": Which content can be conveyed verbally without exhausting the map reader cognitively? Which content should be selected to be conveyed verbally to ensure a significant gain for the map reader?
2. "How": How is the content best brought to the listener (e.g. at what point in time, for how much time)? How must the content be structured with respect to the salience of object in the environment; what comes first, what next etc.? How much does the structure of the content influence map exploration behaviour?

Each topic relates to one distinct part of the verbal annotation system. The first one concerns the content of the propositions; the second one concerns the process of conveying content verbally. The following research agenda and the experiment reported were set up to help answering these questions.

4 Research Agenda for Verbally Annotated Tactile Maps

The goal of investigating multimodal verbally-annotated tactile YAH maps providing natural language descriptions and instructions cannot be achieved without knowing what constitutes a successful tactile YAH map. Therefore, we were initially interested in the two research questions: What sensor modalities and representational modalities can be used to substitute visual perception in realizing YAH maps? How can tactile YAH maps of different types of physical realization as well as of different graphical inventories and representation conventions be implemented? This investigation provided the opportunity to learn how people extract meaning from that type of tactile map that we are going to use in subsequent experiments. This investigation into the feasibility of coding the unimodal external spatial representations (a tactile YAH map) into an internal representation, which can be used to solve spatial cognition tasks, serves as baseline for further research into multimodal representations, such as VAT maps.

First Experiment

Research Questions

As we could not rely on previous work on tactile YAH maps, we firstly had to answer the question if the tactile representation we use to run experiments with is really useful to convey spatial knowledge to the user. Secondly, we wanted to find out, which type of (tactile) reference to the You-Are-Here symbol in the map results in the smallest search time when looking for the YAH point. Thirdly, we wanted to assess quantitatively and qualitatively which type of annotation was the least hindering in exploring the map after the YAH point was found. The combination of the last two objectives should demonstrate if the objective assessment of the ease-of-use of the tactile annotation corresponds with the subjective assessment.

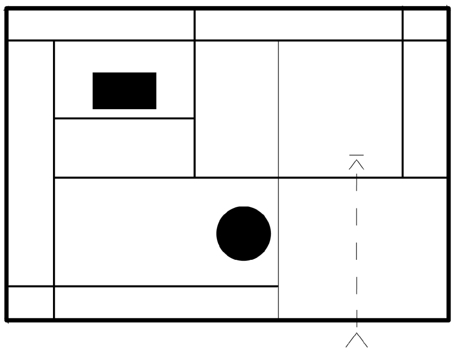
Experimental Design

The experiment had a within-subject design with three conditions. The order of the conditions was systematically varied.

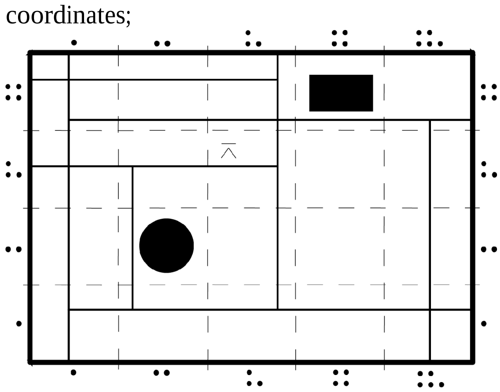
Experimental Conditions

There were three experimental conditions. They differed in how finding the YAH symbol was supported.

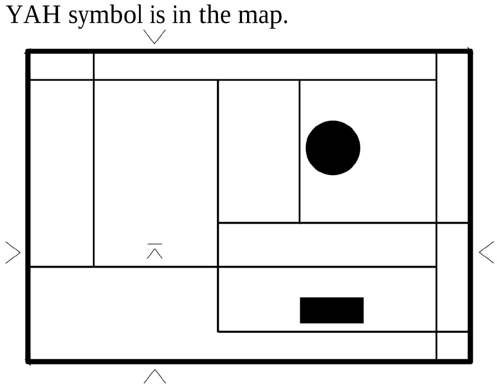
(A) Condition “FL”: A specific meta-line led the user from a prominent entrance point on the frame of the map to the position of the YAH symbol in the map;



(B) Condition “GI”: A grid of meta-lines partitions the map into regions that are addressable by coordinates and the position of the YAH symbol is given in coordinates;



(C) Condition “RM”: Four marks, two at the vertical and horizontal border of the map, gave an idea to the map user at which horizontal and vertical position the YAH symbol is in the map.



Materials

The tactile maps of format A4 were made with a ViewPlus® Emprint SpotDot™ Braille Embosser based on the TIGER® technology (Gardner & Bulatov 2004; Sahyun, Gardner & Gardner 1998; Walsh & Gardner 2001) that embosses tactile pixels (following the convention in literature we call this entity a ‘taxel’) into a paper surface of size A4 (29.7 x 21 cm) with a resolution of 20 taxels per inch. Assembling single taxels beside each other can compose objects like lines, figures and regions. The displayed maps were of uniformly large scale and presented an artificial world with three landmarks. The topology of the maps was the same in two of them, a third was different as one line segment was accidentally missing (this resulted in one missing region and a change of +1 in the cardinality of one region). All tactile objects on the maps had the same surface structure and the same prominence in terms of height above the base paper.

Respondents

The respondents in all experiments reported here were 12 sighted individuals (all students, 4 male & 8 female, mean 28years (SD: 5years) with no impairment to the visual, tactile or motor system and no experience in solving task solely with their hands without visual feedback. The respondents showed a reasonably high self-confidence in their abilities to read maps (Mean: 0.72, SD: 0.17) and to successfully solve tasks with maps (Mean: 0.79, SD: 0.07).

Procedure

The respondents sat in front of a curtain to exclude vision and put their hand and arms beneath the curtain to reach the tactile map on the other side. In the beginning, respondents were individually trained on sensing and interpreting tactile sensor (for the efficiency of short-time practice see Jansson & Ivs, 2001). Each concept that was used in the experiment was introduced in the training. In the experimental, the first task in each map was to find the YAH point as fast as possible. The time was taken. Then the respondent was asked to explore the map in such way that she could explain routes on the area later on. The task was to gain an understanding of the entire area without any target route being announced before the map was read (cf. Brambring & Weber 1981). After the exploration of a map, respondents were confronted with two questions concerning the spatial properties of the area represented in the map. Thus a basic understanding of the map was checked. Then, respondents should explain two routes to check if they could infer some route knowledge from the map. Lastly, respondents were asked to produce a copy of the map as complete as possible on a graphic tablet to test their survey knowledge (following the methodology of Ungar, Blades & Spencer 1997). The whole experiment lasted about 2 hours (Mean: 2:02:55h, Standard Deviation [SD]: 15:06min). The route descriptions were analysed regarding the question if the route could be found following the description. The maps were analysed how many segments were missing or have to be deleted to result in a correct map.

Preliminary Results

The sketches that the respondents produced after the exploration of the tactile map (in total 12x3=36 sketches) were analyzed regarding the questions if a person that is unknown to the area would have a chance to navigate there successfully. Grade 1 was awarded for a perfect map that showed the landmarks and streets in correct relation to each other (let alone minor flaws in geometric details), grade 6 was given for a map if there was no resemblance with the structure of the tactile map at all. In total 6 sketches were very good or good, 26 acceptable or moderate and only 4 not interpretable for the task. Together 32 of 36 sketches (>88%) were at least of moderate quality and showed that the drawer did build up an internal representation of the spatial configuration, i.e. the tactile map. The first research question, if the tactile representations we use to run experiments with conveyed spatial knowledge to the respondents of the experiment can most likely be affirmed.

The question concerning the efficiency of the different (tactile) references to the You-Are-Here symbol was assessed through the measurement of search times for the YAH symbol. All respondents except from one in the RM condition found the YAH symbol. This resulted in a total of 35 valid runs (12 in FL condition, 12 in the GI condition, 11 in the RM condition). A descriptive analysis of search times, exploration times and drawing times is given in Table 1 below.

	Time to find the YAH symbol	Time for exploring the map	Time for drawing the sketch	
FL	0:22	4:11	1:27	
RM	0:16	5:59	1:23	
GI	1:46	7:56	1:37	
	0:48	*6:02*	*1:27*	*Mean*
	0:50	*1:53*	*0:07*	*SD*

Table 1: The three main quantitative variables recorded during the experiment.

In the RM condition map user find the YAH symbol the fastest, in the GI condition it takes the most time. An ANOVA test reveals that for searching the YAH symbol the conditions differ highly significantly ($p=0.00008 << 0.05$).

To answer the third research question about which reference to the YAH point is least hindering in a tactile map, we need to look into the table again. It seems that the FL condition is best suited for exploration. After having removed three outliers from the GI dataset, an ANOVA test confirms a strong trend to significant difference between the conditions ($p=0.053 > 0.05$).

Having demonstrated that the experimental conditions have an strong effect on searching time as well as a moderate on exploration time it was checked if there is any difference between the conditions in the times needed to sketch a map. No such effect was found ($p=0.91$).

To support the results with qualitative data, we were interested in the respondents' opinions. They were asked to rank the three reference types on the background of two different tasks that are performed with the map: (1) how much does the particular reference supports the finding of the YAH symbol, and (2) how much does it hinder the exploration process after the YAH symbol was found? The ranks for the reference types in the two tasks can be found in Table 2.

Task	Searching the YAH Point			Exploring the map		
Condition	FL	RM	GI	FL	RM	GI
Average Rank	1.50	1.25	3.00	2.00	3.00	1.00

Table 2: Respondents ranked the types of references when used in different contexts.

The border marks ("RM") are ranked first for both task the meta-line ("FL") is second and the grid ("GI") is last. This is somehow in-line with the quantitative results (GI condition is always worst) but not in all cases (people can objectively handle the FL faster than RM but they subjectively rank it lower).

Discussion

Testing sighted people instead of blind people in this experiment might be questioned as blind people seem to be so much better than sighted when asked to solve tasked on the basis of touch. Indeed, on the sensory level, blind and sighted people depend on the same bodily sensor system. For example, for judgments of smoothness, Heller (1989) found no differences by sighted and blind respondents, neither for passive touch (in which a stimulus is applied to a static skin surface) nor for active touch (in which a stimulus is engaged with by a moving skin surface). Jehoel et al. (2005) reassessed those findings and concluded that there are mostly preference differences in both the blind as well as the sighted people when it comes to touch. When it comes to basic cognitive tasks like object matching, which includes e.g. shape processing and recognition, visually impaired people outperform sighted people in the beginning but loose their gain fast (Postma et al. 2008). It seems that haptic experience increases the speed of identification of abstract, simple schapes, but blind people do not perform as well when active elaboration is required (Vecchi 1998). In contrast to sensing and object matching, the experiment reported here depend more on higher cognitive abilities that demand the tacit and procedural knowledge how to interpret a map. Therefore sighted people instead of blind people were our test persons.

During the experiments we could observe that respondents reported tactile illusions, namely shortening of lines when comparing horizontal and vertical lines at a T-junction shape. That length-distorting effect resembles the Müller-Lyer illusion in vision and was reported before for congenitally blind people (cf. Millar & Al-Attar 2001). In this experiment, respondents did not suffer from any kind of blindness but showed the same effects.

A closer analysis at the ratings of the sketches reveals that the sketches graded with 4 or worse were the only ones that showed clear route orientated encoding schemata. In those sketches, only one route or part of a route was drawn, no other structures like streets that encircle the area or that go from one end of the map to the other was displayed. All the sketches with grade 5 and 6 were effected and over one third of the sketches with grade 4. This could be interpreted in such way that route concepts were activated, not so much survey concepts. The final investigation into the verbal description will shed more light on this controversy. Analysing the verbal protocols has not been finished yet and will complement the results reported here. A more formal analysis of the sketches could foster the idea that with complex tactile maps, which put high cognitive load on the reader, map readers employ strategies to focus on the part of the map with a lot of semantic content, i.e. the area where landmarks are positioned and the routes between them.

From a cognitive perspective some interesting observations were made during the respondents navigated mentally: Segments that were part of a route before are most likely to be chosen again, even if other routes would be shorter. Another behaviour could be observed many times: long segments are used to traverse wide parts of the map to reach the next waypoint even if they are not included in the shortest route, and even this does not mean fewer turns. Respondents explained that they could remember a route made of multiple of these long segments more easily, even if the number of turns they had to take in total to reach the destination was more. In some extreme cases respondents described routes that went along three edges of the map to reach a point that was “just around the corner” (on the map) from the location where they started.

Future Development

The experiment that was reported here serves as kind of baseline for future experiments to develop an understanding of what the effects of cross-modal interaction are and how they can be employed to ease cognition for humans, especially those that have a natural disadvantage from visual-impairment.

Although there has been extensive work on visual-impairment (see Chapter 1 & 2), there is only limited account for work that investigates cognition in blind people at the representational level. We know very little about the practical aspect of the interaction of propositional representations and spatial representations, e.g. what the threshold of unimodal spatial exploration is, i.e. which types of representation that are conveyed tactually can humans process easily, which not? This would open the opportunity to support the human with customized multimodal representations, e.g. VAT maps, that make deliberate use of different cognitive subsystems to convey (spatial) meaning.

Thinking of the verbal annotation system as concept for VAT maps there need to be some initial guideline which content is selected to be represented. We assume that the combination of verbal presentation in conjunction with a tactile map might have an influence on the behaviour of the map reader. It’s most likely a question of timing, granularity of presented content and context. We would like to investigate in what way the map reader is influenced when presenting verbal material about (1) the direct surroundings so that she is accommodated in her current situation, or (2) the adjacent areas that she might wander into in some minutes, or (3) the survey perspective that makes more distant landmarks accessible. We hypothesise that people who consume many pieces of “local content” will more likely build a mental model from connected representations of local phenomena. It will hold many details that can be asked for but not so much survey knowledge. As result tasks that build on survey knowledge should take longer to accomplish, other cognitive task that need detailed knowledge should be served faster. Conversely, people who consume many pieces of “survey content” will more likely build a survey like representation and will probably be good in querying it, but not so well with questions for details.

These experiments (and others) will tell us more about how a concept of a verbal annotation system should look like to accommodate different types of uses or contexts.

Conclusion

We have learnt from an initial literature review that some researchers favour a multi-modal approach to convey spatial knowledge to visually impaired people. Even if Jansson, Juhasz & Cammilton (2006) concluded that in their particular experiment, there was no interaction between tactile and verbal channel, others have shown that reading of tactile maps is improved with the combined auditory and haptic information (e.g. Holmes, Jansson and Jansson 1996; Holmes, Michel and Raab 1995). We interpreted the inconsistent results in the area of sensory modalities as background to our own work. Our research goes beyond these approaches in the sense that we are looking at the *representational modalities* rather than purely at the *sensory modalities*.

In this paper we introduced the concept of a Verbally Annotated Tactile map that integrates *spatial* and *propositional representations* and thus is a *multimodal representation*. We chose the class of You-Are-Here maps to exemplify how such a multimodal representation could be structured and what cognitive advantages can be gained from that structure. We developed research questions that need to be answered to fully gain from the potential of VAT maps. To lay ground for further work on VAT maps we presented preliminary results from an experiment we did on tactile YAH maps. The central research questions left to be answered relate to the questions, which granularity of content supports in navigation with a VAT map, which content should be verbalized in a VAT map as opposed to being represented in the map, and how should this content be structured to best support the activities of the map reader.

With the Verbally Annotated Tactile map we proposed a new type of multimodal map that might circumvent the bottleneck of low-detailed and hard to interpret maps for visually impaired people. Using VAT maps, inefficient navigation strategies might be avoided as people could build a richer model of what surrounds them through cross-modal interaction of propositional and spatial representations.

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