The Contribution of Audio-tactile Maps to Spatial Knowledge of Individuals with Visual Impairments

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ABSTRACT

This study aimed at examining the ability of individuals with blindness to create cognitive maps through the use of audio-tactile maps. Twenty adults with blindness (14 males and 6 females) took part in the research. The age ranged from 20 years to 61 years. The visual impairment was congenital for 12 participants and acquired for 8 participants. The procedure was started off by the participants reading the audio-tactile map of an unknown city area which was neither known nor walked down by them in the past and then the participants depicted their cognitive map. The findings of the present study reflect the positive effect of audio-tactile maps on the cognitive map creation and, thus, their effect on the spatial knowledge of people with blindness. More than half of the participants appeared cognitive maps in precision, while the rest performed well with reference to the variables examined.

1. INTRODUCTION

Maps constitute a significant orientation and mobility aid supporting the absolute and relative localization of streets and buildings as well as the estimation of directions and distances between two points [1]. Supporting the relative localization of objects, maps lead to the acquisition of survey knowledge; a knowledge than can be obtained more quickly and with less effort than direct experience either from sighted individuals [2] or from individuals with visual impairments [3]. Especially in the case of individuals with visual impairments, maps contribute to the handling of daily living problems inducing autonomy, independence and a better quality of life [4-5].

Lahav and Mioduser [6] made a review of the aids that people with visual impairments can use to explore and code spatial environment, making a categorization of the aids in two types: passive and active. The former support the spatial learning before an individual's contact with an area, while the latter help an individual during his/her navigation in an area [6]. Tactile maps belong to passive aids and are important for spatial awareness [7] of close or distant places supporting wayfinding [8] and orientation and mobility of individuals with visual impairments [9], as well as improving spatial cognition in the long-term [10].

Researchers have pointed out that raised-line graphics of the spatial environment prepare individuals with visual impairment to travel an unfamiliar space more safely and efficiently than work with a verbal description or a sighted guide [4], demanding a smaller cognitive load than direct experience [11]. Thinus-Blanc and Gaunet [11] stated, also, that when an individual with blindness read a haptic map has the ability to maintain a stable reference point. Using points of reference during spatial learning enables allocentric coding which leads to better spatial performance and knowledge [12-13].

However, there seems to be a series of limitations accompanying tactile maps. Jacobson [5] mentioned that fingertip resolution is lower than eye's resolution, cartographers face the problems of simplification, generalisation, classification and symbolization of the information included to a visual map, extended Braille labelling is required, which leads to overload and is prohibitive for those who do not know Braille reading. The abundance of the information and the complex graphics entail greater memory load [14], while an increased amount of spatial information clearly influences spatial coding and representation [12]. Moreover, separate legends restrict immediacy and interaction with the map.

Verbal assistance can help to overcome many of the obstacles mentioned above by substituting Braille labels and legends, as well as by providing guiding information, such as spatial relations, descriptions of buildings [7] or significant landmarks, for instance, traffic lights with auditory assistance [15]. Information provided through speech in combination with touch can be quite helpful overcoming the restrictions of touch to serial information gathering [15]. Multimodal maps form the context for these solutions and specific audio-haptic devices, such as touch pads represent the tools for using audio-tactile maps.

Touchpad offers at the same time access to the benefits of tactile maps and verbal aids. The combination of auditory and tactile information may result in a more complete concept [16]. Landau and his colleagues [16] found that individuals with visual impairments can enjoy control and independence coming from the ability to make choices between tactile and auditory information used through a touch pad.

Moreover, touch pads give the ability to use environmental auditory cues, incorporating, in a way, the soundscape into the tactile map. Including auditory cues in a map may promote an individual's orientation, since individuals with visual impairments are proved to use auditory cues to determine and maintain orientation within an environment [17-18] and to associate the soundscape with the structural and spatial configuration of the landscape and create cognitive maps [19].

Cognitive mapping refers to the process during which an individual acquires, stores, recalls, and decodes information about the relative locations and attributes of the phenomena in his/her environment [20]. Cognitive map is in effect a mental representation of spatial knowledge [21]. While cognitive mapping of spaces is a prerequisite to develop adequate Orientation and Mobility skills [6], most of the information required for cognitive mapping is gathered through the visual channel [22]. As a result in the case of visual impairment the greater piece of spatial information is missing and the cognitive mapping becomes a very difficult process. Gathering information through compensatory sensorial channels is considered a fundamental way to deal with cognitive mapping [6].

Cognitive maps of individuals with visual impairments appear to contain basic environmental features as streets, buildings, parks, fixed obstacles, bus stops etc. [23] and show that they understand spatial relationships between places when presented on a tactile map [24]. Knowing how individuals with visual impairments understand space and what are the features that their cognitive maps contain could help planning the environment appropriately, make the right information available to them and improve their wayfinding [24].

Kitchin and Jacobson [25], and Jacobson and Kitchin [24] review the techniques used to assess cognitive maps of individuals with visual impairments. A widely used technique to examine configurational knowledge is the reconstruction tasks where the participants are asked to build a model. It has been suggested that specific tasks induce specific cognitive maps [26]. In the present study, the reconstruction technique used to examine the cognitive maps of individuals with visual impairments, which were created after the participants had coded an audio-tactile map for this purpose.

2. STUDY

The aim of the present study was to examine the ability of individuals with blindness to create cognitive maps through the use of audio-tactile maps. Moreover, the degree of precision of the created cognitive maps was also under investigation.

2.1 Participants

Twenty adults with blindness took part in the research. The sample consisted of 14 males and 6 females. The age ranged from 20 years to 61 years (*M* = 37.0, *SD* = 10.96). Seventeen participants were blind or had severe visual impairments and 3 had the ability to detect very large objects. An essential criterion to include a participant in the study was not to have a hearing impairment or other disabilities, apart from visual impairments. The visual impairment was congenital for 12 participants and acquired for the rest 8 participants. With respect to their level of education, 7 participants were university graduates, 4 were university students, 6 had graduated from high school, and 3 had graduated from junior high school.

The participants were asked to indicate the main reading media which they used (i.e., Braille, TtS systems, recorded material), and how often they used TtS systems. The frequency of use was described using a 5-point likert scale: quite often, often, sometimes, rarely, and not at all. Moreover, the participants stated how many years (overall) they had used TtS systems. These descriptive data are presented in Tables 1 and 2. Fourteen out of 20 participants used TtS systems as the basic reading medium.

	Frequency of use				
	not at all	rarely	sometimes	often	quite often
Participants	1	1	3	4	11

Table 1. Frequency of TtS systems use by participants with visual impairments

	Years		
	0-1	2-10	>10
Participants	1	12	7

Table 2. Years of use TtS systems by participants with visual impairments

The participants were asked to state the way of their daily move in outdoor places, by choosing one of the following: a) with the assistance of a sighted guide, b) sometimes myself and sometimes with the assistance of a sighted guide, and c) myself, without any assistance. Moreover, the participants were asked to indicate the frequency of their independent movement using a 5-point likert scale: always, usually, sometimes, seldom, or never. In addition, these two questions were answered from orientation & mobility (O&M) specialists, who were familiar with the participants and could assess the latter's ability of independent movement. Tables 3 and 4 present the answers of the participants and O&M specialists.

	With or without sighted guide		
	with	with & without	without
Participants	1	6	13
Specialists	3	1	16

Table 3. Ability of independent movement according to the answers of participants and O&M specialists - the score represent the number of participants in each group

	Frequency of independent movement			
	seldom	sometimes	usually	always
Participants	0	2	13	5
Specialists	2	4	9	5

Table 4. Frequency of independent movement according to the answers of participants and O&M specialists - the score represent the number of participants in each group

2.2 Instruments

The main research instrument was audio-tactile maps of an unknown city area in Thessaloniki which was neither known nor walked down by the participants in the past. Three audio-tactile maps were created to represent three different routes (itineraries) in the area, respectively. This design satisfies the requirement of variance of the difficulty degree between the routes. The three selected routes were based on the following criteria: a) they had approximately the same length b) they all had the same number of turnings c) they had different shape and d) they were suitable for/accessible to people with visual impairments. In order to achieve the accessibility objective, researchers walked around the areas and examined whether they are accessible to blind people. The main concern was to avoid obstacles which would prevent blind people from passing through. These routes were considered suitable to be selected.

For each route an audio-tactile map was constructed. Initially, three digital tactile maps were constructed, one for each area. Dots were placed on the digital tactile maps at the locations of spatial information (e.g. trees, pillars, stores) and short length vertical lines were placed on the locations where soundscape was recorded.

Researchers visited each area, recorded the spatial information (as far as absolute location and kind of information are concerned) and selected 30 of them to be mapped out. The selection was based criteria: a) the existence of information on every street of the route, and b) the existence of all tactile, audio, and olfactory information. So, an attempt was made in order to exclude the possibility of error in case of a specific type of information is stored more easily or more difficultly on the cognitive map of individuals with blindness.

Moreover, soundscape recording for each route was made at a certain time, during evening hours and for 20 seconds at each point. Soundscape was recorded at the beginning and the end of each route, at all intersections and at some places with special auditory information, such school, café, car wash etc. For the recording a Telinga Stereo Dat-Microphone was used with the recording system Zoom H4n-Handy Recorder. Finally, a speech synthesizer was used for the presentation of spatial information and street names.

In the next phase the digital tactile maps were installed on the touchpads and all audio information (street names, information, and soundscape) were added to them. The software application Iveo Creator pro 2.0 together with the device touchpad, were used to develop the audio-tactile maps. Both of them are products of “ViewPlus® Technologies” company. The Iveo Creator pro 2.0 is a WYSIWYG editor [27] and has the potential to create and/or edit any type of image format. The files produced by the software are saved in Scalable Vector Graphics (SVG) format. The touchpad device is a pointing device consisting of specialized surface that can translate the position of a user’s fingers to a relative position on the computer screen. When used in combination with a tactile image, this device has the potential to offer tactile, kinaesthetic and auditory information at same time [28].

Adobe Illustrator CS6 was used for the creation of digital tactile maps. These maps were then printed in microcapsule paper and were placed on the surface of the touchpad device.

A laptop, a touchpad device and headphones through which they listened to audio information (street names, information and soundscape) were used for the purposes of the experiment.

Each participant read via touch the tactile map that was placed on the surface of the touchpad device, and by tapping the streets he/she listened to their name, by tapping the dots he/she listened to the information they represent, and finally by tapping the small vertical lines he/she heard the soundscape of the particular area.

In the phase where their cognitive map was depicted, a range of different materials were used by the participants. The materials included a kappa fix carton on which an A3 sheet was fastened. Moreover, a string was placed in the position of roads, thumbtacks to fasten the laces and twist them when there were turnings were used, and different type of thumbtacks were placed in the position of obstacles.

2.3 Procedures

The examination procedure was carried out individually in a quiet environment. The examination consisted of reading the tactile map through the touchpad device and then the participants depicted their cognitive map.

Initially, participants were informed about the procedure of the experiment and the model they should create at the end i.e. their cognitive map. The tactile map was placed on the touchpad device and a familiarization process using the tactile map with the touchpad device, took place. Then the audio-tactile map reading phase followed. The maximum time that was offered for the map reading was 15 minutes, in which participants had to learn the route, street names and 30 pieces of information. They could refer to the map and listen to the information as many times as they wish during the 15 minutes, while they could stop reading earlier if they wished to. A five- minute pause followed. Then the participants used the materials given by the researcher to create their cognitive map. In practice, the participants created a haptic model representing their cognitive map. There was no time limit for the creation of the haptic model. Each time a participant touched an item on the haptic model, the researchers pointed out what this item stood for so that he/she could make a review. Times of audio-tactile map reading and creation of the haptic model were recorded. After the completion of the haptic model, the researchers were drawing the cognitive maps, by drafting the outline of the materials of the haptic model on the A3 sheet. The recording of the data on the cognitive maps and their analysis followed.

During the processing of the cognitive maps, the following variables were recorded and calculated by the researchers as to their accuracy: number, names, and length of the streets, the number and direction of turnings and the number of information participants placed on the haptic model. Specifically, with respect to streets, variables that were examined included how many streets participants placed properly and how many wrong (placed wrong, placed in abundance or were missed). It was also measured how many names of streets were indentified right and how many wrong (indentified wrong, placed in abundance or were missed). Regarding he road turns, two variables were measured. One for the number of turns placed correctly and one for the right turns that were placed wrong (placed wrong, placed additionally or forgotten).

Concerning the amount of information apart from the variable "correct information" the variable "wrong information", was created which corresponds to the information each participant placed wrong and includes the following nine categories of errors: 1) information placed didn't actually exist, 2) wrong position on the same road, 3) the wrong position on the opposite road, 4) the combination of wrong position and opposite road, 5) error placement, i.e. in the correct position some other information was used, 6) a combination of error location and replacement, 7) combination of replacement and installation on the opposite side of the street, 8) combination of wrong position, replacement and placement across the street, and 9) could not remember the kind of information but only its existence in that location. Regarding the street length the average error of the length of the roads placed in the haptic model was measured. To make this measurement, the following procedure was followed for each participant: 1) the actual map of the area was printed, 2) a change of scale of the cognitive map in the scale of the actual map was implemented, 3) for each road the participant placed, the error length was measured; this is the divergence between the length of the actual and the length of the cognitive road (after scaling), and 4) the average error length for all the roads included in the cognitive map was calculated.

3. RESULTS

Initially, the scores of the following 9 variables were calculated: "number of streets-correct," "number of streets-wrong", "streets names-correct", "streets names-wrong", "turnings-correct", "turnings-wrong", "information-correct", "information-wrong", and "streets length- error". The minimum, maximum, mean, and standard deviation (SD) of scores, are presented in Table 5. Each correct or wrong answer was scored to 1. Concerning the number of streets and streets names, if any participant had placed all the streets and streets names correctly, his/her score would be equal to 8. Regarding the turnings if any participant had placed all the turnings correctly, his/her score would be equal to 7. Moreover, concerning the information, if any participant had placed all the information correctly, his/her score would be equal to 30.

	Min	Max	Mean	SD
number of streets-correct	4	8	7.35	1.09
number of streets-wrong	0	6	.90	1.71
streets names-correct	1	8	6.30	2.39
streets names-wrong	0	7	1.70	2.39
turnings-correct	3	7	6.35	1.09
turnings-wrong	0	5	.80	1.44
information-correct	0	25	6.45	8.11
information-wrong	1	11	4.83	3.29
streets length-error	.80	4.08	2.24	.77

Table 5. Minimum, maximum, mean, and standard deviation (SD), of correct and wrong answers regarding the number of streets, streets names, turnings, and information.

Moreover, the lot of participants in relation to the lot of correct and wrong answers for each variable separate, was calculated (see Table 6). As it is presented on table, 13 (65%) participants hadn't made any mistakes in the number of streets and the turnings, whereas 10 (50%) participants hadn't made any mistakes in streets names.

	Lot of correct/ wrong answers								
	0	1	2	3	4	5	6	7	8
	Lot of participants								
streets-correct					1		3	3	13
streets-wrong	13	3	2			1	1		
streets names-correct		2	1			2	3	2	10
streets names-wrong	10	2	3	2			1	2	
turnings-correct				1		3	3	13	
turnings-wrong	13	3	2		1	1			
information-correct									
information-wrong									

Table 6. Lot of participants for the lot of correct/ wrong answers.

Regarding the placement of information, 2 out of 20 participants placed correctly 25 information, 1 placed 19 information, 1 placed 15, 5 placed 5-10 information, 6 placed 1-4, and 5 didn't placed any information.

The mean reading time of audio-tactile map was 643 (SD = 200.67) seconds (min = 370 sec and max = 960 sec). Moreover, the mean time of haptic model creation was 382 (SD = 160.83) seconds (min = 192 sec and max = 660 sec).

Finally, it was investigated if there was any relation between the performance of individuals and the following variables: gender, age, and age at onset of visual impairment. The t-tests revealed no significant differences between males and females. Moreover, the correlation analysis showed no significant correlations between scores and: a) age, b) age at onset.

4. CONCLUSIONS

The findings of the present study reflect the positive effect of audio-tactile maps on the cognitive maps creation, and thus, their effect on the spatial knowledge of people with blindness. More than half of the participants appeared cognitive maps in precision, while the rest participants performed well at all the variables which were examined. The only exception was the poor appearance of the information in participants' cognitive maps. However, this should not be accounted a disadvantage of the aid, considering the large amount of information that a participant had to memorize (30 pieces of information) in a relatively short time span available for studying the audio- tactile map.

Probably, the repeated use of the aid i.e. the usage experience could result in the improvement of individuals with blindness regarding the coding of information in cognitive maps. This should constitute a future research objective.

The findings of the present study contribute to the understanding of issues that concern the development of cognitive maps in individuals with blindness through the use of audio-tactile aids. Thus, the results of the study have implications for both educators and orientation & mobility specialists.

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