SOCIETY. INTEGRATION. EDUCATION
Proceedings of the International Scientific Conference. Volume III, May 28th-29th, 2021. 99-107

THE DEVELOPMENT OF MENTAL MODEL OF PEOPLE WITH VISUAL IMPAIRMENT

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Abstract. *The Development of mental model of people with visual impairment in spatially-orientational and cultural-historical context, is longer Title of the Post. The ability to create mental models is, for people with visual impairment, one of the basic preconditions for the use of available information from the environment and in all areas of everyday life. Tactile graphics can provide one of the means for the development of imagination; they are particularly suitable for the creation of a complex picture of a given situation and its processing into supporting information. Their facilitating function in the development, refinement and consolidation of the imagination is indisputable and proven by empirical studies. The purpose of this paper is to present the application possibilities of three-dimensional displays of haptic information for the purposes of spatial orientation, as well as access to cultural and historical objects with emphasis on the formation of mutual relations and connections within the knowledge base of each individual with visual impairment.*
Keywords: *visual impairment, spatial orientation, imagination, space perception, three-dimensional display, tactile graphic.*

Introduction

One of the important determinants of the successful reduction of the information deficit arising due to severe visual impairment, is the lifelong development of compensatory mechanisms. Cognitive processes work in tandem with the use of other senses in a compensatory fashion to create a comprehensive picture of reality.

In particular, the continuous development and refinement of the mental models nation of people with visual impairment are one of the basic preconditions for the use of available, compensatory information obtained from the environment across all areas of everyday life. One of the means to develop the mental representations are various types of relief depictions and special pedagogical objects. Their facilitating function in the development, refinement, and

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https://doi.org/10.17770/sie2021vol3.6341

consolidation of the complex of the imagination is indisputable and proven by empirical studies. Finding new ways to improve spatial knowledge and stimulate not only the spatial imagination of visually impaired people is an important challenge for the professional public. In this context Picard and Pry (2009) presented several research studies which are focused on the role of tactile maps in the practice and implementation of spatial orientation (Picard, Pry, 2009). As Picard and Pry (2009) point out, the ability to move effectively and orient oneself independently in micro space or macro space depends on the ability to construct and use mental representations of the environment. The process by which spatial information is integrated into mental representation is then referred to as cognitive mapping. The ability to construct effective spatial representations develops gradually during life (in Picard, Pry, 2009). Various authors point out that gaps in the spatial knowledge of people with visual impairment do not reflect a low level of education, but alternative ways of dealing with space in terms of coding and behavioral strategy (Picard, Pry in Růžičková, Kroupová, 2020).

Project Base at Palacký University in Olomouc

Information presented in a tactile display can thus be a means in particular for creating a complex picture of a given situation and for its processing into supporting information, including an understanding of the mutual relations between the parts and the whole. Since 2018, the research activities of the Faculty of Education and Faculty of Science, Palacký University Olomouc, Czechia, implemented with research projects supported by the Technology Agency of the Czech Republic – TACR (TL01000507; TL03000679), have been focused on these aspects. Their primary intention is to evaluate the effectiveness of relief (tactile graphical) information in reducing the information deficit and the influence of this type of information in the development of the spatial imagination of people with visual impairment.

The Presentation of the Project and Its Goals

Relief maps as a means of making space accessible and developing the spatial imagination of people with visual impairment, in audio-tactile 3D form, were examined by the project, which was completed in September 2020 (TL01000507). The key intention was to increase the subjective comfort of independent orientation and to support its development for people with visual impairment, through their education in working with a modern generation of tactile maps created by 3D printing technology. The result is a didactic set of prototypes of audio-tactile 3D maps with appropriate software (TactileMapTalk program) and a battery of teaching materials with a set of tasks for practicing their use (Vondráková, Růžičková, 2018). The results of the testing analysis revealed the undeniable benefits of this technology, both in the field of spatial orientation and its training, as well as in a broader context – in the development and refinement of the mental representations. These maps are a motivating element for people with visual impairment in learning about space and have a facilitating function in developing spatial orientation. When navigating on the map, participants with severe visual impairment have reported that elements that offer SoftWare (i.e. directions, tasks, and other specific information) were especially motivating. The "voice" maps were generally considered to be highly beneficial. It has been shown that once people with severe visual impairments orient themselves on a map showing a familiar environment, they find it easier to orient themselves in an environment unknown to them. Individuals with knowledge of map materials, in any form, are better acquainted with maps. Testing also showed that more conductive parts of the map help with orientation on the map, so each of the layers of the resulting map has landmarks too. The color of the map data was also tested – the results showed the predominant preference of white over yellow, in combination with blue and red. However, the individual character of the visual defect also manifested itself here, and this combination was unsuitable for some users. The result was the creation of new color swatches to quantify user preferences based on the type of disability. The course of testing and verifying the functionality of the designed relief maps is described in the following section.

Figure1 ***3D Audio Tactile Maps with a Demonstration of Tactile MapTalk***

3D Models of Historic and Church Buildings with Auditory Elements

With regard to the findings and based on a positive response from users and interested professionals, a follow-up concept was created to improve the mental representation building of visually impaired people through 3D models with auditory elements, in cultural and historical contexts, where the displayed objects are important historical monuments. The aim of the project entitled "Reduction of information deficit and development of the imagination of people with visual impairment through 3D models with auditory elements" is to reduce the information deficit caused by loss or reduction of visual perception in people with visual impairment through a multisensory approach, and at the same time, to support the development of their spatial Representation building. The goal will be achieved through the design, creation, and practical implementation of 3D audio-tactile models of historical and religious monuments. It is an interdisciplinary project that uses the latest knowledge in the field of special education, cartography, and 3D modeling while taking into account modern approaches to humanities education. The project fundamentally combines technical and non-technical research content. Technical research, which will take place in the introductory parts of the project, will focus on the implementation of 3D models and verification of their suitability and functionality. Non-technical research will enable the implementation of the proposed solution into practice and enable the validation of the proposed didactic procedures. The key phase of the research will be user testing of models and evaluation of didactic approaches. The transdisciplinary overlap of the project under the auspices of experts on historical and religious monuments enables a significant improvement of joint research in terms of its societal contribution.

The presence of publicly accessible 3D models in historic buildings is rather sporadic in the Czech Republic. Most of these models are not intended directly for people people with visual impairment and are not adapted for this use. In the vast majority of cases, however, even haptic models provide only a basic idea of the overall shape of an object. In contrast, the solution proposed in this paper enables multisensory perception, where the placement of interactive elements on a 3D model significantly increases its information value. Practical issues of special education in the field of cultural heritage care were addressed in the publication, "The methodology of creation, implementation, and quality evaluation of educational programs in the field of cultural heritage care for participants with special educational needs" (Havlůjová et al. in Vondráková, Růžičková, Kroupová, 2020). The recommendation of this methodology emphasizes the need for tactile and auditory tools. The TouchIt3D technology used by the proposed project combines these two basic methods-tactile and auditory-and thus provides a greater amount comprehensive information that a person with visual impairment can obtain through studying the model. Several international publications deal with the issue of making monuments accessible to visually impaired people (Vondráková, Růžičková, Kroupová, 2020). These are various approaches to 3D visualization and access to models of parts of monuments, but always at a basic level and notably without the use of modern multimedia technologies.

The purpose of this project is to create procedures that will significantly reduce the information deficit of people with visual impairment in the field of cultural and historical education. The outputs of the project will be used by organizations dedicated to the education of people with visual impairment, as well as administrators of selected historical and religious monuments.

Figure2 ***Historical 3D Model with Its Creator***

Development and Testing of the 3D Audio-tactile Maps

User testing is considered a modern approach in science, although its origins go back a long way in many different industries. In cartography the elements of map design that relate to user experience have been the subject of long-term research (Vondráková, Barvíř, Brus, 2019). The organizing concept of “Map Use“ reflects the needs of users of map products and provides a framework for improving the usability of maps (Vondráková, 2013). This is a multifaceted concept which draws inspiration and knowledge from the disciplines of sociology, psychology, and the fine arts, among other areas.In the introductory stage of the project, the areas of relief graphics for people with visual impairment and relief-cartographic semiotics were addressed. Several swatches were made to test the suitability of height differences between layers, line thickness, size of point characters, line structure, the texture of area map characters, and other variables. An additional key element was the selection of a color contrast usable for people with preserved remnants of sight.

The results were relatively controversial and indicated a a great amount of variability between individual users, thus suggesting that there may be subjective factors at play.

Within the project, mainly large-scale plans of specific localities were created. One of the important aspects are technological limits for 3D printing (Voženílek, Vondráková, 2014). Due to the fact that the requirement was the creation of relief maps of very small sites, where commonly available data sets are not sufficient to implement such a scale, the method of non-automated computer 3D modeling was chosen. The size of the tactile maps was adjusted according to the size of the test equipment (tablets) and according to the parameters of the 3D printer. The selected size was 208 × 130 mm. The scale of each map was always adjusted so that the entire area of interest in this dimension is displayed in as much detail as possible. The process of designing tactile maps created on the basis of field surveys and cadastral maps took place in the SketchUp 8 program (Barvíř et al., 2018).

In accordance with the proposed didactic procedures mentioned below, which should lead to better and more effective understanding and learning by the target group, a series of prototype maps distinguished layers of streets (including parking lots and other areas commonly used by vehicles), layers of sidewalks (and other areas designated for pedestrians) and barrier layers (buildings, vegetation, other areas). The layers were level-separated by a height difference of 1 mm, which was identified as the most suitable from testing swatches in the target group of users. These "layer maps" form a didactic set for practicing the perception of partial spatial data, which is followed by the use of a complex map.

In the first phase, only these maps representing individual thematic layers were tested, without the need to work with the completely new concept of audio-tactile maps. The results of the user testing were favorable and only the color was adjusted to the scheme of the blue-yellow-red composition. The form of the characters otherwise suited most respondents, with individual reservations noted.

The TouchIt3D tactile map testing phase followed. Interactive map features were modeled on the map for each of the three selected test sites. These include a graphic scale bar indicating the length corresponding to 50 m (height 4.5 mm from the base, line width 5 mm), pedestrian crossings (at a height corresponding to the base layer of sidewalks and streets, i.e. with a height of 2 mm or 1 mm), the start and endpoints of public transportation transfers (a circle with a diameter of 10 mm, height 5.5 mm) and public transport stops (a square with an edge length of 8 mm, height 5.5 mm).

The 3D printing of the tactile maps took place on a two-extruder printer, the Ultimaker 3. Tactile maps were made of contrasting colors; while the color red was chosen for the barriers, the sidewalks were drawn in yellow and the lowest layer of roads was blue. All interactive map characters were black due to the type of material used. White was used for the background of special maps showing only one selected layer (sidewalks or barriers).

A special frame for attaching the tactile map to the tablet was designed and manufactured on a professional Stratasys F170 3D printer. Emphasis was placed on simple design, efficient production without the need for numerous support structures, easy handling and a firm connection of all three components (frame, tablet and tactile map) into one unit.

Based on the specifications of the required functionality, a beta version of the TactileMapTalk mobile application for tablets with the Android operating system was also created. For this test version of the application, templates containing the layout of controls for selected areas were subsequently created by measuring individual interactive characters. For the application, it is possible to define buttons under the appropriate interactive characters containing parameters about their position, dimensions, and text, which is then converted into speech by the application‘s TTS function.

The findings from the second phase of testing were incorporated into the design of the final form of the tactile maps. The color scheme was changed to blue-white-red, which suited more respondents. Various features were also tested in terms of their vertical shape (tip, sloping surface, horizontal surface), correct conductivity (executability of touchpoints), user-friendliness, and evaluation of user aspects within the concept of Map Use. The results of the testing included, for example, the definition of a new setting of the pavement width parameter to min. 5 mm for correct tactility and understanding of the presented layer. It was then confirmed that the changes made led to greater accuracy of the respondents' work with the tested tactile maps.

During testing, it was very useful to gradually acquaint the user with the concept of the map, with individual "layer maps" and then the subsequent acquaintance with the TouchIt3D map, where the user already knew which points would be touch activated and that he should wait for an audio response. In terms of the use of audio-tactile content of tactile maps, based on user testing, the plan to include several ways to start the audio track (possibility of double-clicking, long hold, etc.) was abandoned. Only one longer hold uniformly for the whole map turned out to be more suitable. The testing clearly showed that all conductive parts of the map must be elevated and ideally with their own characteristics (typeface), otherwise the user is very clumsy on the map and audio tracks are triggered when viewing the map without the user wanting to.

In the first two phases, testing took place with adult participants, and in the second phase, primary and secondary school pupils also took part in the testing, for which sets of tactile maps for teaching geography were created.

The test group of target users was heterogeneous, not only in terms of gender, age (from 8 to 73 years), but also in the scale of ophthalmological diagnoses (a predominance of individuals with age-related macular degeneration, cataract, glaucoma, with the group also including participants with neurologically conditioned visual disorders and genetically determined defects in the range from severe low vision to the zone of full blindness). More details are available in Vondráková et al. (2020).

The developed large-scale TouchIt3D maps thus have great potential to become a common tool for practicing the independent movement of people with severe visual impairments and a means to develop their, not only spatial, imagination.

Figure3 ***Field Testing of 3D Audio Tactile Map***

Summary

It is indisputable that relief graphics, whether in the form of 3D tactile maps or 3D models of cultural-historical and sacral objects, demonstrably reduce the information deficit caused by loss or reduction of visual perception and contribute to increasing quality and comfort in learning about learning about environments deemed culturally valuable in our contemporary society. Relief graphics in 3D with auditory elements open up another level of accessibility as well as a number of challenges for the professional public and opportunities for the users themselves.

Our research has shown not only the need for 3D tactile maps in a common educational environment. He also showed the need to reconsider the long-standing standards for tactile maps of the people with visual impairment.

At present, our research continues by displaying 3D models of historical and ecclesiastical monuments in order to show their need in creating general ideas for the people with visual impairment. However, we are already sure that modern 3D imaging techniques help people with visual impairment to create ideas about space and movement in it.

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