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Development of Cognitive Maps by Individuals with Blindness Using a Multisensory Application

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Abstract

Spatial knowledge is fundamental for the autonomy and the improvement of quality of life for individuals with blindness. Multisensory applications that integrate tactile and audio stimuli can provide to individuals with blindness valuable information associated with the structure and the content of space. Low cost haptic devices can significantly contribute in this direction. The present study examines the spatial knowledge that individuals with blindness may build by studying an audio-haptic map of a multisensory application, through the use of the low cost haptic device Novint Falcon. Ten adults with blindness (totally blind or only light perception) took part in the research. The age ranged from 19 years to 46 years. Participants managed to build significant spatial knowledge using the multisensory application. More specifically, rich cognitive maps were observed. The results reveal the usefulness of similar applications for individuals with blindness.

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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 points¹. Vision plays a chief role in comprehending the spatial structure of an environment² and as such, individuals with blindness seem to face

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difficulties in the acquisition of concepts relevant to spatial relationships³. Nevertheless, it has been argued that even individuals who are congenitally blind are able to form mental representations based mainly on tactile and acoustic stimuli^{4,5}.

These mental representations, stored in the long-term memory are called cognitive maps and determine the behavior of individuals with blindness in a space⁶. More specifically, cognitive maps are symbolic structures which reflect spatial knowledge and lead individuals with blindness take crucial decisions, related to where to move to, how to move and which path to follow⁷. However, all information available on the cognitive maps of an individual with blindness is in dynamic relation with the individual's experience and they together contribute to planning and decision making related to movement in space⁸.

According to Warren³, the conceptualization of the environment depends mainly on three interrelated types of experiences which are visual, acoustic, and tactile (combined with motor activities). Researches have revealed that blindness adversely affects the development of spatial skills for individuals with blindness⁹. In addition, age for the onset of blindness was proved determinant for mental representation and spatial skills in general¹⁰. Consequently, individuals with blindness, in order to form their own cognitive maps, compensate the lack of vision by gathering experiences for space through other senses. Touch and hearing are the main senses through which individuals with blindness acquire knowledge about the structure and the content of an environment^{11,12}.

In contemporary times, experiences are reinforced by assistive technology which plays a fundamental role in education and everyday life of individuals with blindness^{13,14}. Assistive technology has recently shown great strides in the field of non-visual access to information for individuals with blindness¹⁵. Apart from the widespread screen readers who are a practical solution for access to electronic texts and information content on the screen of a personal computer, particular interest lies in the capabilities of haptic devices (touch tablets, Logitech Wingman force-feedback mouse, Novint Falcon, Sensable Phantom, etc.) and the representation of information that relates to spatial knowledge. More specifically, haptic devices, in recent years, are widely used by individuals with blindness in order to improve access to the structure and the content of two-dimensional and three-dimensional representations¹⁶. Their function is based on forces, vibrations and motions addressed to the user of the device, in order to realize surfaces, shapes and textures¹⁷. However, haptic devices differ in various parameters such as size, design, technical characteristics, cost and quality of feedback they can produce¹⁶. Through haptic devices, individuals with blindness can receive through appropriate multisensory applications tactile and auditory information and form spatial knowledge¹⁸. More specifically, individuals with blindness can use haptic feedback devices either independently or in conjunction with audio information in order to gain access to information representing objects, images, graphs and maps^{15,19,20,21}. Research data reveal that coexistence and adaptation of auditory and tactile information has been proved significant to the success of an application for spatial knowledge with respect to the satisfaction of individuals with blindness¹.

The study of how people build spatial knowledge through multisensory applications can contribute significantly to the improvement and redesign of similar approaches in the future⁶. In this effort, a variety of haptic devices is used and it should not be taken for granted that expensive devices are always capable to deliver the best results. Often, low-cost devices derived from the field of three-dimensional virtual gaming, such as Novint Falcon, may offer an abundance of information related to the structure and the content of spatial knowledge¹⁶. A key element of using haptic devices in conjunction with multisensory applications for individuals with blindness should also be the fact that applications need to be designed in such a way so as to meet the requirements of a variety of haptic devices and offer users the opportunity to choose a haptic device based on their personal preferences rather than the manufacturers' ones¹⁶.

Technical details also seem to be a fundamental factor for the success of an application for individuals with blindness, as users seem to show preference in the technique of grooves rather than the one of raised lines when it comes to the representation of streets in a virtual environment referring to a map²². Additionally, different colors displaying information on the maps of sighted are often asked by individuals with blindness to be replaced with different textures in corresponding virtual environments¹⁷. Moreover, friction is considered as a useful technical element for the points of interest on a map, where audio and tactile stimuli are received simultaneously by individuals with blindness¹⁹. Mason & Manduchi¹⁷ tried to integrate such technical details, through the use of Novint Falcon haptic device, by designing an application for the haptic representation of a four-way intersection, while they

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