On the use of a natural audio-motor associations in visually impaired children to enhance their social cognition

SARA FINOCCHIETTI[1], GIULIA CAPPAGLI[1] AND MONICA GORI[1]

[1] U-VIP: Unit for Visually Impaired people, Center for Human Technologies, Italian Institute of Technology (IIT), Italy
e-mail: sara.finocchietti@iit.it

Abstract

Vision provides the most precise spatial information about the distal environment. Consequently, individuals with visual impairments present a delayed or impaired development of spatial capabilities, that affects their psychomotor, emotional and social development. Most of the technology developed to date aims at substituting the visual information with another modality. We instead think that new technologies should be developed to rehabilitate the impaired cognitive ability, specifically addressing the multisensory integration capability of the brain.
We have recently developed a new rehabilitative technology for blind and low vision children called ABBI, the Audio Bracelet for Blind Interaction. The idea behind ABBI is that it is possible to rehabilitate the spatial and social deficits by exploiting a natural audio-motor association. When moving the arm, a sighted child can observe their own actions and their consequences. In the absence of vision, visual feedback of the movement is not available. The ABBI bracelet positioned on the main effectors produces an audio signal that provides spatial sensory feedback similar to that used by sighted children in an intuitive and direct manner. Our results indicates that spatial and social impairments can be weakened by reinforcing their audio spatial representation of the environment. This approach is innovative for increasing accessibility and could also be beneficial in the interactive media domain.

1 Introduction

Social cognition refers to the psychological processes that are involved in the perception, encoding, storage, retrieval and regulation of information about other people and ourselves. These processes include social cue perception, experience sharing, inferring other people's thoughts and emotions, and managing emotional reactions to others [1].
In everyday life, humans come across a varied array of social cues not only from others' faces and voices but also body movements, including gait, posture and gestures. Many of these processes rely on vision. Recent works showed that preschool-age children with visual impairments often have difficulties engaging in positive social interactions, making their assimilation into preschool programs difficult and giving rise to feelings of frustration [2].
Obviously, the absence of visual information is the main cause of these difficulties, but it has been recently demonstrated that blindness can also impact on the localization of sounds in space as well as the perceived posture of one's own body with respect to the world [3, 4]. Vision is essential in building spatial representations, so lack of vision at an early age results in impairments to spatial representation in general. An early intervention is fundamental, as these representations are built during the early years of sensorimotor development.
Starting from these observations we propose to rehabilitate the sense of space in visually impaired children by strengthening the natural sensory-motor association of the intact senses.
This approach requires the development of innovative technologies to permanently rehabilitate spatial and, consequently, social skills in visually impaired children.

2 Related Work

In the past years we investigated how perceptual functions develop in children with and without sensory disabilities. In particular we focused on how different senses are integrated during development, and how an impairment of one modality, such as vision in blind children, can impact on other modalities.
Our research showed that unlike adults, children of less than eight years of age do not integrate visual and haptic spatial information, with one or the other modality dominating totally, even in conditions where the dominant sense is far less precise than the other. We

found statistically optimal integration in children, like in adults, only for the age of eight to ten years old [5-9].
We suggest that the reason why the young children do not integrate sensory information is that during the first years of development, when the limbs are growing rapidly and neural systems maturing, they use the cross-sensory information to calibrate the senses to physical reality: the more robust sense calibrates the other [4, 5].
The calibration between modalities occurs within the first three years of life. An audio feedback about body movements might then help the blind child to build a sense of space.
ABBI, the Audio Bracelet for Blind Interaction, is the device we had develop to achieve this goal.
This approach is innovative, because unlike most existing sensory-substitution devices introduced in late childhood or adulthood, it does not require learning new "languages", and can be applied in the first years of life.

3 Methodology

1.1 ABBI

The idea behind the development of the Audio Bracelet for Blind Interaction (Figure 1) is that it is possible to rehabilitate the social deficits of visually impaired children by exploiting their natural audio-motor associations.
ABBI therefore allows the substitution of the visuo-motor with the audio-motor association. When moving the arm, sighted children can observe and monitor their own actions through visual input. In absence of vision, the visual feedback of body movements is not available, but an auditory feedback might help representing and monitoring actions occurring in space.
The device consists of a custom-made bracelet connected to a smartphone that produces a sound when a movement occurs. In its simplest version, a sound is played when the acceleration exceeds an adjustable threshold marking the beginning of movement.

Figure 1. The ABBI system.

Specifically, The ABBI bracelet contains a microcontroller, an integrated audio system, motion sensors and a wireless communication module. The dimensions and weight make it easy to mount on a wrist band adapted to children.
The device is programmed to synthetize continuous or intermittent sounds based from pure sine tones. The sound can be adjusted in volume and frequency. ABBI triggers sounds from the movement of the user. Movement triggering is achieved through the inertial sensors in the device. The communication between ABBI bracelet and the mobile phone is made by a Bluetooth LE (Bluegiga BLE113) module. An Android application has been developed [10].

1.2 Progress beyond the state-of-the-art

The technology and the approach proposed in ABBI are innovative for several reasons:

- they use the implicit capability of our nervous system and do not require the learning of new "languages", as most of the present sensory substitution devices do [11].
- they allow children to rehabilitate social cognition in a natural way, as they can be used form the first years of life.
- they do not require the use of additional attentive sources which increase the cognitive load, as the interpretation of new languages required in SSDs.
- they use the natural links between action and perception which, as observed with the use of sensory substitution devices, are thought to be essential for learning.
- they can easily be integrated in the homes and lives of blind children. In particular, from a rehabilitation point of view, the ABBI system can be used in diverse contexts (e.g., home, street, park) besides rehabilitation centers.
- it is be low cost and affordable.
- opposite to other SSDs, the ABBI system rehabilitates spatial and social cognition. After the rehabilitation period, both children and adults will have an improved sense of space and be better able to process available information such as sounds in the environment.
- this will allow blind children to develop something similar to echolocation, avoiding the creation of a stigma connected with the use of the device.

4 Experimental Results

Two different rehabilitations were carried out between October 2014 and December 2016 to enhance spatial and social cognition in visually impaired children using the natural audio-motor associations with ABBI.
Both rehabilitations included more than 30 children aged 6-18. Children were born blind or had visual residual less than 1/10. They didn't need to have any additional deficit besides the blindness.

1.3 Spatial rehabilitation

The rehabilitation session lasted 12 weeks, during which each child performed an individual training at the local rehabilitation institute every week for 45 minutes with a specialized rehabilitator. During this period children were also asked to perform the training at home, 1 hour per day alone or with one relative.
The mobility and spatial cognition was assessed via 3 different tests made to evaluate the audio spatial cognition, the proprioceptive ability, and the overall functional mobility.
Preliminary results have been published in [12]. On the whole, results showed that the ABBI is a promising tool for enhancing mobility and spatial cognition in visually impaired children.

1.4 Social rehabilitation

The rehabilitation lasted 12 weeks, children met once per week in groups and performed a group training with a professional therapist at the local rehabilitation center for 45 minutes. Children were divided in 2 groups depending on their age: group 1, age 7-11, and group 2, age 12-16.

The social cognition was assessed via a custom-defined task, the Audio Social Interaction Task, that was aimed to asses a coordinated action. Specifically, we recorded and calculated the information flow between the experimenter and the child while performing free hand movements one in front of the other.
Results have been published in [13]. The flow of information from the experimenter to the child is increased after the social training with ABBI. This impressive increase suggests that attention to sound can be improved with entertaining activities carried out with ABBI.

5 Conclusion

ABBI is a promising device for enhancing spatial and social cognition in visually impaired children.
In fact it provides spatial information on where and how the body movement is occurring, using auditory instead of visual information. This approach may help for social interaction and spatial orientation in visually impaired persons.
Importantly, the approach proposed in ABBI does not require to learn new “languages” and it can be applied in the first years of life.
This approach is innovative for increasing accessibility and could also be beneficial in the interactive media domain.

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