The audio-motor feedback: a new rehabilitative aid for the developing blind child.

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ABSTRACT

Early onset of blindness adversely affects psychomotor, emotional and social development [1], that mostly depend on spatial cognition. Some studies suggest that the lack of vision could potentially explain this delayed or weakened development since vision is the most accurate and robust sense to encode spatial information [2,3,4]. We recently found that blind people are severely impaired when asked to judge the orientation in the haptic modality and bisect intervals in the auditory modality [5,6]. These results confirm that vision is essential in building up spatial representations that might be essential to navigate in the environment and make interactive contacts with the others [6].
Here we report for the first time also a substantial spatial impairment in proprioceptive reproduction and audio distance evaluation in early blind children and adults. Interestingly, the deficit is not present in a small group of adults with acquired visual disability. Our results support the idea that in absence of vision the audio and proprioceptive spatial representations may be delayed or drastically weakened due to the lack of visual calibration over the auditory and haptic modalities during the critical period of development.

Recent findings suggest that the acquisition of spatial capabilities is driven by the reciprocal influence between visual perception and execution of movements [7]. We recently found that multisensory integration develops late (around 8-10 years of age) and that the absence of one sensory signal might impact on the development of perceptual skills in another sensory modalities. These results suggest that the absence of multisensory integration between vision and motion might cause perceptual disabilities in spatial perception.
We aim to rehabilitate the sense of space in visually impaired children by strengthening the natural sensory-motor association of the intact senses. To do this, we developed a new rehabilitative device (ABBI, Audio Bracelet for Blind Interactions) meant to restore the sense of space in blind children. ABBI will provide an audio feedback about body movements that might help the blind child to understand and internalize the spatial structure around his own body. 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.

Keywords

Visual disability, Blindness, Spatial perception, Multisensory integration, Development, Sensory Substitution Devices

1. INTRODUCTION

Spatial cognition is essential in everyday life for numerous human activities, as it entails the ability to understand and internalize the representation of the structure, entities and relations of space with respect to one's own body [8]. There is a general consensus on the crucial role of visual experience in guiding the maturation of space cognition in the brain. Vision takes advantages respect to other senses in encoding spatial information because it ensures the simultaneous perception of multiple stimuli in the environment [2,3] despite the apparent motion of the array on the retina during locomotion and enables us to extract more invariant spatial properties from the surrounding layout [4]. Indeed, data from sensorial conflict situations [9-11] show that spatial auditory and tactile perception are strongly biased by simultaneously presented visual information, suggesting that sighted people tend to organize spatial information according to a visual frame of reference. These results suggest that vision typically provides the most accurate and reliable information about the spatial properties of the external world, and therefore dominates spatial perception.

In people with visual disabilities, the absence of vision might cause substantial impairments in spatial cognition that are related to psychomotor, emotional and social competencies. The current literature provides few clues about how to reconcile the hypothesis that visual perception is essential to build up spatial representations in the other sensory modalities [6,12] with findings showing that blind people compensate for the lack of vision by strengthening the others senses [13]. The cross-sensory calibration hypothesis proposed by Gori et al. [6] states that during the early development vision calibrates the other senses to process specific aspects of spatial information for which it is the most robust sense. As a consequence, blind people would be impaired in those specific aspects of spatial cognition

In the past years we have investigated how different senses are integrated during development, and how an impairment of one modality, such as in blindness, can impact on other modalities. The ultimate goal of our research is to exploit this knowledge to understand the brain and to create new rehabilitation programs and devices to increment sensory-motor abilities of children with sensory disabilities. We have recently conducted behavioral and rehabilitative studies on the development of spatial cognition and mobility skills in sighted and blind children and adults.

Behavioral studies.
In the past years we observed 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 [13]. This result suggests that during the early years of development, children use the cross-sensory information to

calibrate the senses to physical reality: the more robust sense calibrates the other. An important question is what happens when the calibrating sense is impaired or absent, as is the case for children born without sight.
We run some behavioral studies to assess how the loss of vision impacts on the spatial sense of blind people. We found that both early children and adults are impaired in auditory spatial tests, like bisection and distance perception, and haptic spatial tests, like proprioceptive localization of arm and body in the space. The ability to localize sound sources in an environment is critically impaired in childhood but improves with ages. Moreover, the performance of the late blinds in both auditory and haptic tests is similar to the performance of the sighted individuals, showing that even a small period of visual experience allows the creation of a reliable spatial representation of the world.

Rehabilitative studies.
Since our studies reveal the presence of spatial impairments in blind people, our main goal is to successfully rehabilitate their sense of space. ABBI (Audio Bracelet for Blind Interaction) is the main device to achieve this goal [Fig.1]. This bracelet produces a sound when the acceleration of the arm movement exceed a fixed threshold: it gives precise information about when and how the movement is occurring, producing an auditory feedback about body movement similar to the one provided by the visual modality for the sighted person. This would help creating a spatial representation of the surrounding environment. Since the ABBI system can be used at an early age and in diverse contexts, it would represent an innovative and powerful rehabilitative tool for visually impaired people.
A preliminary study with blindfolded adults showed that a short training session with the ABBI bracelet might improve the pointing accuracy in a sound localization task. We run a 3-months rehabilitative protocol with ABBI with 20 early blind and low-vision children. They used ABBI for 1 hour per week in a controlled environment with expert rehabilitators and 1 hour per week of free play at home with parents. We found general spatial improvements in mobility skills such as walk velocity, auditory skills such as distance perception and proprioceptive skills such as sense of body location in the environment.

2. DISCUSSION

A veridical representation of space is fundamental for social interactions. The early absence of vision might adversely affect the full development of spatial cognition, leading to social impairments for the blind population. We think that social competence can improve by allowing blind people to understand and internalize an accurate representation of the surrounding space. We propose a new rehabilitative device (ABBI) that can help the young blind child to build up the spatial auditory maps necessary to navigate in the environment and make interactive contacts with the others.

3. ACKNOWLEDGMENTS

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3. FIGURES/CAPTIONS

Figure 1. On the right, the ABBI (Audio Bracelet for Blind Interactions) device on the wrist. On the left, the smartphone on which is installed the app used to control ABBI functions.

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