PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Benefits and challenges of bimodal hearing in children

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ABSTRACT

Binaural hearing is important for listening in and navigating everyday acoustic environments. Unilateral deafness during development drives extensive reorganization in bilateral auditory pathways, limiting spatial hearing and putting children at risk for social and educational challenges. In an effort to reduce these listening challenges and support bilateral development, implantation criteria are expanding to provide children who have asymmetric hearing loss a cochlear implant for the deaf ear and a hearing aid to the other ear when needed, known as bimodal hearing. Our work has assessed hearing development in bimodal users through evoked potentials and behavioural measures of spatial hearing and speech perception. This talk will discuss how bimodal hearing can promote symmetric bilateral development but faces limitations for preventing or reversing asymmetry-driven reorganization when implantation is delayed or residual hearing is insufficient. Challenges still faced by children who hear bimodally will also be discussed.

Keywords: Cochlear implant, Development, Outcomes

1. INTRODUCTION

Children spend much of their time in complex acoustic environments, in which they need to be able to hear where different sounds are coming from and pick out different voices in order to listen. These environments can be challenging, with multiple competing sounds. To localize sound and listen in noise, the auditory system compares the timing and level differences of sound reaching the two ears, called binaural hearing (1). However, if children have a deficit in one or both ears, these cues are distorted, and spatial hearing is compromised. Not only do issues with spatial hearing make listening in noise harder, but they put children at risk of challenges to language acquisition, socialization and academic progress (2–5). Indeed, periods of unilateral hearing during key developmental periods drive reorganization of bilateral auditory pathways through strengthening of pathways from the hearing ear and relative weakening of pathways from the deaf ear (6–9). These neurophysiological changes create a system that remains preferential to information from the only/better hearing ear, called “aural preference”, that distorts and disrupts binaural representation of sound and compromises binaural hearing (10). Therefore, it is important to consider the binaural system when deciding on treatment of hearing loss. Consequently, it is now recommended to provide children with bilateral hearing as early as possible with the most appropriate device(s) for the hearing loss in each ear (10).

Both cochlear implants (CI) and hearing aids are auditory prostheses that restore access to sound for children with hearing loss. Some children benefit from a hearing aid if their residual hearing is sufficient, but when the hearing loss is too severe a cochlear implant can electrically stimulate the auditory nerve to provide sensation of sound. In line with the recommendation to provide bilateral devices early, it has become standard practice at many centres around the world to give two cochlear implants to children who are bilaterally deaf. If both cochlear implants are provided early and with short to no delay between surgeries, then symmetric cortical development occurs (8). Otherwise, if children experience unilateral stimulation with one cochlear implant for more than two years before they receive a second implant, unilaterally driven aural preference develops and persists despite years of subsequent bilateral implant use. As candidacy criteria are expanding to include children who have asymmetric hearing with residual hearing in the better ear, bilateral hearing is provided through bimodal hearing – electrical hearing with a cochlear implant to the deaf ear and acoustic hearing with a hearing aid in the better hearing ear with residual hearing.

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2. HEARING DEVELOPMENT IN CHILDREN WITH BIMODAL HEARING

We assessed hearing development in bimodal users by measuring changes in the brainstem and cortex, as well as measuring how children hear speech and important differences in sound between their ears. Here we quickly review the benefits and challenges of bimodal hearing for promoting bilateral auditory development in children.

2.1 Benefits of bimodal hearing

Electrical and acoustic hearing are unique and stimulate the auditory system in different ways. Despite this, bimodal hearing promoted symmetric development of the bilateral auditory pathways for children who had sufficient residual hearing and received an implant with limited delay. These children with residual hearing exhibited symmetric neural conduction in bilateral brainstem pathways, as measured by similar wave III-V interwave intervals on each side (11). In the auditory cortices, expected contralateral representation of each ear rapidly developed within six to ten months of implant use (12,13) and consistently maintained this expected organization after two years of bimodal hearing experience (14). Moreover, most children experienced a bilateral advantage for speech perception over wearing either device alone (15), benefited from spatial hearing (15) and could detect changes in binaural inter-aural level cues (11). These findings suggest that the auditory system can use different modalities for bilateral hearing.

2.2 Challenges of bimodal hearing

However, there are limitations to the ability of bimodal hearing to promote symmetric bilateral auditory development. Various degrees of asymmetric hearing loss drove reorganization within the auditory system that resulted in an aural preference for the better hearing ear (12–14). This indicates that the developing auditory system is sensitive to imbalances in excitation and inhibition coming from each ear. Remarkably, asymmetrically driven reorganization followed a similar time course as unilaterally driven reorganization (14). These changes could be reversed if a cochlear implant was provided quickly (12), but longer delays to implantation coupled with poorer hearing in the worse hearing ear limited neuroplastic changes upon implantation (13). Furthermore, longer periods with greater degrees of asymmetric hearing limited the advantage afforded by wearing both the cochlear implant and the hearing aid over listening with the better ear alone (15). Children with bimodal hearing may experience further challenges for binaural hearing due to the large timing differences in delivery of electro-acoustic stimulation to the auditory system (11,16) and the independent processing strategies employed in their two separate devices (17). These issues may distort binaural timing and level cues that are important for spatial hearing and listening in noise, and may further contribute to challenges faced by children listening through bimodal devices.

3. CONCLUSIONS

For children with sufficient residual hearing in their better hearing ear, bimodal hearing promotes cortical development and benefits speech perception and spatial hearing. However, prolonged experience with asymmetric hearing while waiting for a cochlear implant extensively reorganizes the auditory system, limiting future efforts to restore bilateral and spatial hearing with bimodal devices. These findings testify to the remarkable ability of the auditory system to use whatever input it receives to help process and interpret the sounds occurring in daily life. Future advances in device programming may help overcome peripheral and processing challenges experienced by bimodal users, which may in turn improve their binaural hearing abilities.

ACKNOWLEDGEMENTS

This work was completed during my doctoral studies with Dr. Karen Gordon and Dr. Blake Papsin at the Hospital for Sick Children and The University of Toronto. Funding was provided by the Canadian Institutes of Health Research (CIHR), The Hospital for Sick Children Research Institute, and The University of Toronto.

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