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Benefits of simultaneous bilateral cochlear implantation on verbal reasoning skills in prelingually deaf children

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ABSTRACT

Background: Impaired auditory speech perception abilities in deaf children with hearing aids compromised their verbal intelligence enormously. The availability of unilateral cochlear implantation (CI) auditory speech perception and spoken vocabulary enabled them to reach near ageappropriate levels. This holds especially for children in spoken language environments. However, speech perception in complex listening situations and the acquisition of complex verbal skills remains difficult. Bilateral CI was expected to enhance the acquisition of verbal intelligence by improved understanding of speech in noise.
Methods: This study examined the effect of bilateral CI on verbal intelligence of 49 deaf children (3;5–8;0 years). Relations between speech perception in noise, auditory short-term memory and verbal intelligence were analysed with multiple linear regressions. In addition, the interaction of educational setting, mainstream or special, on these relations was analysed.
Results: Children with bilateral CI obtained higher scores on verbal intelligence. Significant associations were present between speech perception in noise, auditory short-term memory and verbal intelligence.
Conclusion: Children with simultaneous bilateral CIs showed better speech perception in noise than children with unilateral CIs, which mediated by the auditory short-term memory capacity, enhanced the ability to acquire more complex verbal skills for BICI children in mainstream education.

What this paper adds?

The essential contribution of this study is that it identifies the link between auditory speech perception skills in challenging listening environments and complex verbal cognition. Furthermore, the interaction between educational setting and

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outcomes is reported. This adds important information for the education and rehabilitation of deaf children. The present study shows that bilateral listening experience in real life auditory environments with appropriate linguistic input enables deaf children with cochlear implants to achieve average verbal cognition levels.

1. Introduction

In deaf children the acquisition of spoken language development has been compromised in the past. Since the availability of cochlear implants deaf children have auditory access to spoken language. Studies on the effects of unilateral cochlear implantation in prelingually deaf children have focused initially on auditory speech perception and vocabulary development. These studies reported better speech recognition in children with a cochlear implant (CI) (Schauwers, Gillis, Daemers, De Beukelaer, & Govaerts, 2004) and significant improvements in vocabulary (Baldassari et al., 2009; Fulcher, Purcell, Baker, & Munro, 2012; Geers & Nicholas, 2013; Geers, Nicholas, & Sedey, 2003; Houston & Miyamoto, 2010; Niparko et al., 2010). Furthermore, better reading comprehension was reported (Johnson & Goswami, 2010; Lyxell et al., 2009; Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007; Wu et al., 2011). Additionally, several studies reported that an increasing number of children with CI were able to attend mainstream education. Deaf children with CI in mainstream schools achieved more favorable educational attainments than those in deaf education (De Raeve, & Lichtert, 2011; De Raeve, Vermeulen, & Snik, 2015; Geers, Brenner, & Tobey, 2011; Langereis & Vermeulen, 2015). Furthermore, several studies reported that children with CI who used total communication showed shorter auditory memory spans than children who used oral communication (Geers et al., 2000; Pisoni & Geers, 2000; Stacey, Fortnum, Barton, & Summerfield, 2006).

Despite the high speech perception skills in quiet, children with unilateral CIs still face difficulties in speech perception in challenging listening conditions, such as noisy environments and soft speech stimuli, as compared to children with bilateral fittings. Studies on the effect of bilateral CI use in children report a bilateral benefit for speech recognition in noise (Culling, Jelfs, Talbert, Grange, & Backhouse, 2012; Lovett, Kitterick, Hewitt, & Summerfield, 2010; Mok, Galvin, Dowell, & McKay, 2010; Sparreboom, Snik, & Mylanus, 2011) and lateralization skills (Grieco-Calub & Litovsky, 2012; Litovsky, Parkinson, & Arcaroli, 2009; Van Deun et al., 2010). This implies, that for these children with unilateral CI, perceptual processing may require extra listening effort and more mental resources, thus limiting the availability of processing resources for other tasks (Jerger, 2007). In addition, deaf children have limited access to spoken language phonology. Children with unilateral CIs still experience some delays in the development of higher-level language skills (Boons et al., 2013a, 2013b; Chilosi et al., 2013; Huber & Kipman, 2012; Nikolopoulos, Dyar, Archbold, & O'Donoghue, 2004), such as verbal intelligence (Geers and Sedey, 2011; Hashemi & Monshizadeh, 2012; Wu, Lee, Hwang, Sun, & Liu, 2008).

The perceptual and phonological limitations in deaf children with unilateral CI result in an increased strain on auditory working memory capacity. Verbal information in working memory is represented phonologically and is needed in order to comprehend the information, to process it and to construct a behavioral strategy (Baddeley, 2007; Barkley, 1997). For children with bilateral CIs listening effort is reduced, which may enhance the available working memory capacity resources (Jerger, 2007). Furthermore, these children have shorter auditory short-term memory spans than age-matched children with normal hearing (NH) (Burkholder & Pisoni, 2003; Dawson, Busby, McKay, & Clark, 2002; Harris et al., 2013; Pisoni & Cleary, 2003; Pisoni, Kronenberger, Roman, & Geers, 2011; Wass et al., 2008). These shorter auditory memory spans may be a result of difficulties with memory mechanisms and processing strategies, such as serial scanning and sub-vocal verbal rehearsal (Burkholder & Pisoni, 2004, 2003). No research has been performed on auditory short-term memory in children with bilateral CIs, however.

Better speech perception in challenging listening situations combined with more available auditory working memory resources may enable children with bilateral CIs to incidentally acquire language from the environment. Incidental learning refers to unintentional or unplanned learning within formal or informal contextual and daily social learning situations (Calderon, 2003; Connal, 2005; Rogers, 1997). Most of our learning occurs incidentally and this is important for developing auditory short-term memory, verbal cognition and narrative skills and for acquiring knowledge of emotions, social rules and manners (Moeller, 2007; Pulsifer, Salorio, & Niparko, 2003). Children with bilateral CIs show better auditory capabilities to incidentally acquire language from the environment, as opposed to children with unilateral CIs (Boons et al., 2012; Boons et al., 2013a; Nuytten, 2007; Sarant, Harris, Bennet, & Bant, 2014). As a consequence the acquisition of higher level linguistic skills, such as verbal reasoning, is feasible. Verbal intelligence refers to a child's ability to use verbal concepts, analyze information and solve problems using language-based reasoning. In most aspects of school work, verbal reasoning is of importance. Reading and language tasks require verbal reasoning skills and even the more abstract courses such as math and physics require verbal reasoning skills, as most concepts are either introduced orally by the teacher or introduced in written form in a textbook. The verbal intelligence quotient in early childhood is an important predictor of later academic, employment related success (Beitchman, Wilson, Brownlie, Walters, & Lancee, 1996; DeLoache, 1987; Wechsler, 2010).

Research on verbal intelligence quotient (verbal IQ) in deaf children is scarce, due to their limited access to spoken language. The characteristic intelligence profile of prelingually deaf children demonstrates a significant higher performance intelligence quotient (performance IQ) than verbal IQ (Geers & Sedey, 2011; Vernon, 2005). The gap between performance IQ and verbal IQ was attributed to limited development of the auditory and language systems. Children with only unilateral CI demonstrated already better verbal reasoning skills than deaf children with bilateral hearing aids, however, this performance-verbal IQ gap still remains. Geers et al. found that 30% of the children with unilateral CIs aged 8–9 years, achieved an age-appropriate verbal IQ (Geers et al., 2003).