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Auditory and verbal memory predictors of spoken language skills in children with cochlear implants

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ABSTRACT

Background: Large variability in individual spoken language outcomes remains a persistent finding in the group of children with cochlear implants (CIs), particularly in their grammatical development.
Aims: In the present study, we examined the extent of delay in lexical and morphosyntactic spoken language levels of children with CIs as compared to those of a normative sample of age-matched children with normal hearing. Furthermore, the predictive value of auditory and verbal memory factors in the spoken language performance of implanted children was analyzed.
Methods & procedures: Thirty-nine profoundly deaf children with CIs were assessed using a test battery including measures of lexical, grammatical, auditory and verbal memory tests. Furthermore, child-related demographic characteristics were taken into account.
Outcomes & results: The majority of the children with CIs did not reach age-equivalent lexical and morphosyntactic language skills. Multiple linear regression analyses revealed that lexical spoken language performance in children with CIs was best predicted by age at testing, phoneme perception, and auditory word closure. The morphosyntactic language outcomes of the CI group were best predicted by lexicon, auditory word closure, and auditory memory for words.
Conclusions: Qualitatively good speech perception skills appear to be crucial for lexical and grammatical development in children with CIs. Furthermore, strongly developed vocabulary skills and verbal memory abilities predict morphosyntactic language skills.

What this paper adds?

This paper provides insight into the lexical and morphosyntactic spoken language skills of 39 Dutch children with cochlear implants (CIs) aged five to ten years, as compared to age-matched hearing peers. Furthermore, possible auditory and verbal memory predictors of lexical and morphosyntactic language outcomes were highlighted. Results demonstrated that quali-

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tatively good speech perception skills appear to be crucial for lexical and grammatical language development. In addition, morphosyntactic language outcomes are predicted by vocabulary skills and verbal memory abilities. Findings of the present study implicate that when grammatical language training is offered to children with CIs, the focus should not only be on auditory and lexical skills, but also on verbal memory skills.

1. Introduction

Many children with profound hearing loss who use spoken language experience language delays on all aspects of language, including phonology, lexicon, syntax, and morphology (Knoors & Marschark, 2014; Lederberg, Schick, & Spencer, 2013; Sarant, Holt, Dowell, Rickards, & Blamey, 2009). Cochlear implantation (CI) can help profoundly deaf children in acquiring higher levels of speech perception, improved speech intelligibility and better spoken vocabulary skills (Houston & Miyamoto, 2010; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto, 2000). However, the actual spoken language levels vary a great deal among these children. Not all deaf children seem to catch up with their hearing peers after implantation, due to several reasons, such as late intervention, receiving implant(s) after the age of 4;0 years, short duration of CI use, additional disabilities, poor speech reading abilities, multilingualism, or poor cognitive processing abilities (Boons et al., 2012; Knoors & Marschark, 2014; Pisoni et al., 2008; Schorr, Roth, & Fox, 2008; Willstedt-Svensson, Löfqvist, Almqvist, & Sahlén, 2004). Large variability in individual spoken language outcomes remains a recurring finding in the group of implanted children, particularly in their grammatical development. They continue to experience difficulties and delays in developing aspects of grammar, including syntax and morphology (Boons et al., 2013; Ganek, Robbins, & Niparko, 2012; Spencer, 2004; Szagun, 2000). At the present time, the causes of this variability are only partly understood. As a result, there is little consensus about the best way of treating spoken grammar delays and difficulties in these children. To explore the variation in more detail, a primary goal of the present study was to have a closer look at possible factors that predict the variation in morphosyntactic spoken language outcomes in children with CIs.

The majority of previous studies on language outcomes of children with CIs have focused on vocabulary skills and the variability of lexical language outcomes. With the help of CIs, a large group of deaf children, aged three to 12 years old, is able to develop (nearly) age-equivalent spoken lexical language skills (Boons et al., 2013; De Hoog, Langereis, van Weerdenburg, Knoors, & Verhoeven, 2015; Geers, Moog, Biedenstein, Brenner, & Hayes, 2009; Svirsky et al., 2000). The remaining lexical problems evidenced in children with hearing loss can partly be explained by their decreased exposure to new words, poorer verbal working memory capacity, and slower rate of word learning processes (Harris et al., 2013; Houston, Carter, Pisoni, Kirk, & Ying, 2005). Moreover, vocabulary skills of young children with hearing loss, aged three to five years old, correspond to their degree of hearing loss (Kiese-Himmel, 2008) and also to the age of first cochlear implantation (Nicholas & Geers, 2007). However, less is currently known about the grammatical language skills of implanted children and how these vary within the group. Studies have reported larger morphosyntactic deficits than lexical difficulties in children from five years old (Boons et al., 2013; Geers et al., 2009; Spencer, 2004). At least half of the children with CIs in the age range of four to seven years old do not reach age appropriate scores in acquiring grammatical structures (Hammer, Coene, Rooryck, & Govaerts, 2014). They typically show difficulties with the use of bound and free morphology and have poorer grammar comprehension development (Caselli, Rinaldi, Varuzza, Giuliani, & Burdo, 2012; Hammer et al., 2014; Nicholas & Geers, 2007; Nikolopoulos, Dyar, Archbold, & O'Donoghue, 2004; Ruder, 2004; Szagun, 2000).

Various factors are known to predict lexical and morphosyntactic language skills in hearing children and in deaf children alike. First, auditory factors have been found to predict spoken language performance. For instance, higher levels of auditory speech perception, including phoneme perception and phonological awareness are associated with better spoken language outcomes (Ingvalson & Wong, 2013; Svirsky et al., 2000; Schorr et al., 2008).

Secondly, research has indicated that verbal memory factors also contribute to the spoken language levels. Factors such as non-word repetition, verbal rehearsal speed, verbal short-term memory, and verbal working memory capacity strongly influence the language processing skills of children with hearing loss and are known as significant predictors of language outcomes (Casserly & Pisoni, 2013; Geers, Strube, Tobey, & Moog, 2011; Harris et al., 2013; Kronenberger et al., 2013; Pisoni, Kronenberger, Roman, & Geers, 2011; Willstedt-Svensson et al., 2004). Verbal working memory is important for language development, and particularly for morphosyntax and grammatical development (e.g., Caplan & Waters, 1999; De Abreu, Gathercole, & Martin, 2011; Gaulin & Campbell, 1994; Kidd, 2013). Studies of working memory have a lengthy history. There is ongoing debate concerning the specific processes underlying working memory, with a range of theoretical working memory models available (e.g., Baddeley, 2003; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Cowan, 2008; Kyllonen & Christal, 1990; Oberauer, Süß, Wilhelm, & Wittman, 2003). The models differ in the way they operationalize the relationship between short-term memory and working memory. According to Cowan (2008), this distinction depends on the definition one endorses. Most studies with CI call upon the working memory model of Baddeley (Baddeley, 2003; Baddeley & Hitch, 1974), in which working memory is a multicomponent with a central executive system that is responsible for the control of attention and processing activities, including the retrieval of information from long-term memory. The central executive system is assumed to link three components within the model, i.e., the phonological loop, the visuospatial sketchpad, and the episodic buffer. The phonological loop consists of a verbal short-term store and a verbal rehearsal process. The visuospatial sketchpad controls the temporary storage of visuospatial information, and the episodic buffer could be regarded as the storage component of the central executive system, crucial for the capacity of working memory (Baddeley, 2003). Hence, short-term memory storage can be divided into separate subsystems for domain-specific, i.e., verbal and