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Semantic and syntactic reading comprehension strategies used by deaf children with early and late cochlear implantation

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ABSTRACT

Deaf students have traditionally exhibited reading comprehension difficulties. In recent years, these comprehension problems have been partially offset through cochlear implantation (CI), and the subsequent improvement in spoken language skills. However, the use of cochlear implants has not managed to fully bridge the gap in language and reading between normally hearing (NH) and deaf children, as its efficacy depends on variables such as the age at implant. This study compared the reading comprehension of sentences in 19 children who received a cochlear implant before 24 months of age (early-CI) and 19 who received it after 24 months (late-CI) with a control group of 19 NH children. The task involved completing sentences in which the last word had been omitted. To complete each sentence children had to choose a word from among several alternatives that included one syntactic and two semantic foils in addition to the target word. The results showed that deaf children with late-CI performed this task significantly worse than NH children, while those with early-CI exhibited no significant differences with NH children, except under more demanding processing conditions (long sentences with infrequent target words). Further, the error analysis revealed a preference of deaf students with early-CI for selecting the syntactic foil over a semantic one, which suggests that they draw upon syntactic cues during sentence processing in the same way as NH children do. In contrast, deaf children with late-CI do not appear to use a syntactic strategy, but neither a semantic strategy based on the use of *key words*, as the literature suggests. Rather, the numerous errors of both kinds that the late-CI group made seem to indicate an inconsistent and erratic response when faced with a lack of comprehension. These findings are discussed in relation to differences in receptive vocabulary and short-term memory and their implications for sentence reading comprehension.

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1. Introduction

Deaf people often exhibit problems in learning to read as a result of their difficulties in developing spoken language (Conrad, 1979; Domínguez, 2003; Perfetti & Sandak, 2000). The cochlear implant has changed this situation considerably in recent years, as it pertains to spoken language and, by extension, to reading. The benefits of cochlear implantation (CI) to the spoken language skills of children with prelingual profound deafness are well established (Boons et al., 2012, 2013a, 2013b; Sparreboom, Langereis, Snik, & Mylanus, 2015). Similarly, and probably as a consequence, the use of cochlear implants has increased the reading potential of deaf students. However, this does not seem comparable yet to that of normally hearing (NH) children (see, for example, Archbold et al., 2008; Connor & Zwolan, 2004; Domínguez, Pérez, & Alegría, 2012; Geers, 2003, 2004; Geers, Tobey, Moog, & Brenner, 2008; Johnson & Goswami, 2010; López-Higes, Gallego, Martín-Aragoneses, & Melle, 2015; Marschark, Rhoten, & Fabich, 2007; Marschark, Sarchet, Rothen, & Zupan, 2010; Nicholas & Geers, 2008; Spencer, Gantz, & Knutson, 2004). The age at implantation seems to be one of the factors that determine the extent to which implanted children will benefit (Miyamoto, Hay-McCutcheon, Kirk, Houston, & Bergeson-Dana, 2008).

There seems to be a sensitive period in early postnatal life, particularly before age three, during which the brain is highly efficient in establishing connections between speech auditory input and the development of linguistic skills, such as lexical and grammatical knowledge (Kuhl, Conboy, Padden, Nelson, & Early, 2005; Markman et al., 2011). In turn, the higher the sound deprivation in these first years of life, the greater the negative impact on the maturation of auditory pathways, nuclei, and centers (Sainz & de la Torre, 2005). The benefit derived from wearing hearing aids is limited in the severe to profound hearing loss range. In fact, when hearing loss is profound, the expected hearing level in prelingually deaf individuals using conventional hearing aids is *residual effective*, which means that the child is not able to discriminate a verbal message through auditory processing only, and that comprehension using lip-reading improves not more than 50% with auditory support (Juárez, Monfort, & Monfort, 2005). The cochlear implant allows these children to access auditory information similar to that received by a child with moderate hearing loss who wears hearing aids (Spencer & Marschark, 2010). However, the exact nature of auditory stimulation that is received through cochlear implants is difficult to predict or describe because it depends on various factors, such as the quality of pre-implant auditory representations, or how brain plasticity contributes to transforming these representations (Sharma, Dorman, & Kral, 2005). For example, it has been found that cortical responses to auditory stimulation in children implanted before the age of three and a half are similar to those observed in children with normal hearing, though the pattern of activation seems to depend on audiological background variables (Sharma, Nash, & Dorman, 2009).

Thus, an incomplete spoken language input prior to implantation, combined with the atypical auditory perception following cochlear implant placement, can affect language development not only at the phonological level, but also at lexical-semantic, morpho-syntactic and pragmatic levels. Among other effects, the ability to establish relevant phonological contrasts should be significantly impeded as a consequence of inadequate speech input. This could make it difficult to distinguish between similar words, such as different verb tenses, or nouns with or without a plural marker (Johnson & Goswami, 2010). In fact, it has been proposed that the specific developmental sequence for grammatical skills in children with cochlear implants is determined by the perceptual prominence of the relevant acoustic markers (Svirsky, Stallings, Lento, Ying, & Leonard, 2002). Obviously, this atypical acquisition of morphophonological representations at the auditory comprehension level will consequently be reflected in reading comprehension. Furthermore, as suggested for other romance languages such as Italian (Caselli, Rinaldi, Varuzza, Giuliani, & Burdo, 2012), the language difficulties observed in English-speaking implanted deaf children could be increased for children who learn Spanish as their native language, given the complexity of its morphology, and also its phonetic and prosodic features. In a previous study, which is part of a broader research as the present work, López-Higes and coworkers (2015) just found that Spanish-speaking deaf children with prelingual severe to profound hearing loss who had been implanted from age 2 to 5 years differed significantly from their normally hearing peers, even from children implanted before 24 months with the same age and educational level, in both nominal and verbal morphology indices of a written morphological awareness test. In addition, verbal inflectional morphology was the most important factor in distinguishing between late implanted children and the other two groups of children in a consistent manner.

Moreover, the lack of an early auditory and articulatory experience seems to have negative effects on other cognitive and linguistic factors that could also affect reading comprehension in children with cochlear implants, specifically vocabulary knowledge and working memory processes (Connor & Zwolan, 2004). Obviously, there is a strong association between vocabulary knowledge and reading comprehension. Hearing loss negatively impacts children's vocabulary development. Deaf children tend to have slower rates of word acquisition and smaller lexicons (Prezbindowski & Lederberg, 2003). Regarding working memory, there is abundant evidence of its involvement in processes related to reading ability, and its influence in the morpho-syntactic comprehension of children with cochlear implants has been proven (Asker-Árnason, Wass, Gustafsson, & Sahlén, 2015; Asker-Árnason, Wass, Ibertsson, Lyxell, & Sahlén, 2007; López-Higes et al., 2015). Some studies have also shown a direct relationship between working memory span and vocabulary size in implanted deaf children (e.g., Harris et al., 2013). In general, it has been noticed that children with cochlear implants have shorter spans than their normally hearing peers (Burkholder & Pisoni, 2003, 2004; Cleary, Pisoni, & Geers, 2001; Harris et al., 2013). According to Burkholder and Pisoni (2003, 2004), this could be due to less efficient short-term memory processes, in particular to those associated with verbal rehearsal and serial scanning of information. In a recent study, Arfe, Rossi, and Sicoli (2015) found that children without hearing impairment exhibited higher scores than deaf children on both reading comprehension and