International Journal of Pediatric Otorhinolaryngology 78 (2014) 1107–1114

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

The strengths and weaknesses in verbal short-term memory and visual working memory in children with hearing impairment and additional language learning difficulties

Suzi Willis *, Juliet Goldbart, Jois Stansfield

Health Professions Department, Speech Pathology & Therapy, Manchester Metropolitan University, Manchester, UK

ARTICLE INFO

Article history:
Received 6 September 2013
Received in revised form 12 April 2014
Accepted 16 April 2014
Available online 26 April 2014

Keywords:
Hearing-impaired
Children
Short-term memory
Working memory
Cochlear implants
Language impairment

ABSTRACT

Objectives: To compare verbal short-term memory and visual working memory abilities of six children with congenital hearing-impairment identified as having significant language learning difficulties with normative data from typically hearing children using standardized memory assessments.
Methods: Six children with hearing loss aged 8–15 years were assessed on measures of verbal short-term memory (Non-word and word recall) and visual working memory annually over a two year period. All children had cognitive abilities within normal limits and used spoken language as the primary mode of communication. The language assessment scores at the beginning of the study revealed that all six participants exhibited delays of two years or more on standardized assessments of receptive and expressive vocabulary and spoken language.
Results: The children with hearing-impairment scores were significantly higher on the non-word recall task than the "real" word recall task. They also exhibited significantly higher scores on visual working memory than those of the age-matched sample from the standardized memory assessment.
Conclusions: Each of the six participants in this study displayed the same pattern of strengths and weaknesses in verbal short-term memory and visual working memory despite their very different chronological ages. The children's poor ability to recall single syllable words in relation to non-words is a clinical indicator of their difficulties in verbal short-term memory. However, the children with hearing-impairment do not display generalized processing difficulties and indeed demonstrate strengths in visual working memory. The poor ability to recall words, in combination with difficulties with early word learning may be indicators of children with hearing-impairment who will struggle to develop spoken language equal to that of their normally hearing peers. This early identification has the potential to allow for target specific intervention that may remediate their difficulties.

Introduction

There are between one and three children per 1000 live births each year in the UK who are diagnosed with permanent congenital hearing loss [1]. It is well known that hearing loss causes speech and language delays [2]. Digital hearing aids and cochlear implants (CI) have now made it possible for many children with severe and profound hearing loss to acquire age appropriate spoken language after initial, expected language delay of approximately three to four years [3,4]. Historically, research attributed the variability in spoken language outcomes for children using cochlear implants (CI) to factors such as age of implant, communication mode, and family support [3–9]. There is a proportion of children with hearing-impairment (HI) that exhibit delays in both receptive and expressive spoken language, even after several years of device use and intensive support from professionals and parents [10–13]. Even in ideal circumstances, of very early fitting of hearing aids or cochlear implants and the involvement of educated parents, there is a proportion of children with HI who still do not achieve spoken language commensurate with peers by the age of 4.5 years [12].

* Corresponding author at: Speech Pathology & Therapy, Elizabeth Gaskell Campus, Manchester Metropolitan University, Hathersage Road, Manchester M13 0JA, UK. Tel.: +44 01612474639.
E-mail address: s.willis@mmu.ac.uk (S. Willis).

http://dx.doi.org/10.1016/j.ijporl.2014.04.025
0165-5876/

These deficits in language can have long term effects on the children's ability to access the curriculum, as well as their development of literacy skills [14].

It is hypothesized that, the early deprivation of auditory input that children with HI experience may have negative impact upon their development of verbal memory and adversely affect their spoken language learning [15]. It is commonly recognized that deficits in memory can have long-term effects on school performance [16]. Researchers are exploring the relationship between short-term memory (STM), working memory (WM) and spoken language abilities in children with hearing-impairment, as one possible explanation for the large individual variations in paediatric outcomes [17–21].

Working memory

Working memory (WM) is defined as the temporary storage and manipulation of either verbal or visual information. It acts as a workbench or mental workspace for information that requires immediate attention and processing. The most influential model of working memory is that of Baddeley [22]. Baddeley's model comprises the central executive, the two modality-specific subsystems (e.g. the phonological loop and visuo-spatial sketchpad) and the episodic buffer, which is defined as "the multidimensional storage system" [22] (p.189). The phonological loop's function is that of interpreting phonological information and creating temporary phonological representations that begin to decay after approximately 2 s. The function of the phonological loop is to support word learning and vocabulary development. The visuo-spatial sketch pad's role is similar to that of the phonological loop, but in relation to visual and spatial information. The episodic buffer provides temporary storage of information and integrates information from the phonological loop and visuo-spatial sketch pad. The central executive is involved in processing and co-ordinating information from either sub system. It is a component involved in working memory, but not short-term memory (STM).

Assessing STM/Phonological loop

It is commonly recognized that limitations in the amount of information that can be held and manipulated in the STM or WM can negatively affect linguistic functioning and educational achievement [16]. The inability to retain instructions long enough to act upon them in a classroom situation will inevitably affect a child's ability to function and achieve national curriculum targets equal to that of their peers. Non-word repetition is often utilized to evaluate the integrity of the phonological loop and the functioning of verbal short-term memory [23]. The most frequently utilized non-word repetition tests are the Children's Test of Non-word Repetition (CNRep) [24], Non-word Repetition Test (NRT) [25] and subtests from a Developmental Neuropsychological Assessment (NEPSY) [26]. These assessments ask listeners to repeat nonsense words (from audition alone) that increase in syllable length. The inability to correctly repeat multisyllabic nonsense words of three or more syllables is considered a reliable marker of language impairment in early childhood [27]. The Working Memory Test Battery for Children (WMTB-C) [28] is also an assessment that measures verbal and visual STM and WM. It contains specific subtests that evaluate the functioning and integrity of the phonological loop, visual-spatial sketch pad and the central executive. Forward digit recall also evaluates the functioning of the phonological loop and is commonly recognized as being significantly correlated with vocabulary development and language acquisition. However, numbers themselves are extremely familiar and may not accurately evaluate phonological STM [24]. The use of non-words in a verbal STM assessment task evaluates phonological storage capacity and access to long-term memory. This process is similar to what young language learners face in their acquisition of new vocabulary.

Cochlear implant research and memory

It has been hypothesized that the delayed and degraded signal that children receive via hearing aids or cochlear implant (CI) has a detrimental effect on word learning and memory and results in unclear phonological representations [18]. A number of researchers have investigated this hypothesis in their research and utilized traditional non-word repetition tests, as a way in which to identify weakness in phonological short-term memory in children with HI [15,20,29,30]. The performance on the multisyllabic non-word repetition task correlates highly with working memory, reading, and receptive vocabulary abilities in children with HI [30–32]. Lina-Granade et al. [20] reported, in their study of 17 CI users aged from 7–16 years, that working memory is also strongly correlated with language development and that deficits in working memory may be as a result of delayed auditory input as an infant or as a result of the hearing-impairment itself.

In addition, researchers also acknowledge that there may be a correlation between verbal rehearsal, working memory and linguistic achievement [33]. The process of rehearsal is said to be another accurate way in which to measure the efficiency and ability of phonological representations to be maintained in the STM. In an early study, Pisoni & Cleary [29] reported that verbal rehearsal speed was positively correlated with spoken language outcomes in 180 children who were CI users, aged between 8 and 9 years old. In a follow up study, Pisoni et al. [18] again utilized digit recall (forward & backward) and verbal rehearsal speed with 108 adolescent CI users, 10 years after their initial study. The population of adolescents who attended for the follow-up study after 10 years exhibited significantly higher scores in their speech perception, speech intelligibility and language scores than that of the 72 non-returning adolescents. Pisoni et al. [18] found that forward digit span and verbal rehearsal speed at ages 8–9 were positively correlated with future linguistic functioning in the high school years. In both of the above studies, the paediatric CI users used either spoken language (oral) or spoken language and signed language (total communication). It is worthy of note that even those CI users who achieved age appropriate language still demonstrated a weakness in STM abilities and verbal rehearsal. It would be of interest to examine the proportion of these CI users who had received their CI by the age of two and were orally educated, and exhibited language impairment and poor verbal STM.

There are few studies which have specifically targeted the population of CI children with additional language learning difficulties. Hawker et al. [34] focused upon CI users who displayed significant language learning difficulties and compared them to other CI users. The researchers paired six paediatric CI users with disproportionate language impairment with CI peers whose language development followed a more typical developmental trajectory. The CI children were matched on aetiology, age of implantation and CI experience. Hawker et al. [34] found that non-word repetition (using NEPSY non-word repetition subtest), [26] was an area of weakness for both the Control CI group and the CI group with disproportionate language impairment (DLI). They concluded that all six DLI–CI users had severe language impairment and phonological short-term memory difficulties and that the control group exhibited characteristics similar to children with specific language impairment. This study did not investigate visual memory, which would have demonstrated whether this population of children with HI exhibited generalized processing difficulties. Wass et al.'s [35] study of 34 CI children,