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Association between temporal resolution and Specific Language Impairment: The role of nonsensory processing

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ABSTRACT

Introduction: Many authors have suggested that a perceptual auditory disorder involving temporal processing is the primary cause of Specific Language Impairment (SLI). The aim of this study was to compare the performance of children with and without SLI on a temporal processing task controlling for the confounding of verbal short-term memory and working memory.
Method: Thirty participants with SLI aged 6 years were selected, along with 30 age- and gender-matched participants with typical language development. The Adaptive Test of Temporal Resolution (ATTR) was used to evaluate temporal resolution ability (an aspect of temporal processing), and the digit span subtest of the Wechsler Intelligence Scale for Children was used to evaluate auditory short-term memory and working memory.
Results: The analysis of covariance showed that children with SLI performed significantly worse than children with typical language development on the temporal resolution task (ATTR), even when controlling for short-term memory and working memory. Statistically significant correlations between ATTR and digit span were found for the group of children with SLI but not for the children with typical language development.
Conclusion: Children with SLI showed significantly worse temporal resolution ability than their peers with typical language development. Such differences cannot be attributed solely to the immediate memory deficit associated with SLI.

1. Introduction

Children with Specific Language Impairment (SLI) show difficulty in both language comprehension and expression. SLI is by definition a significant language disorder that cannot be explained by auditory, cognitive, neurological, or oral motor problems [1].

Regarding the cause of this disorder, authors as early as 40 years ago suggested that an auditory perceptual deficit connected to temporal processing may be the primary dysfunction underlying SLI [2–5]. From an auditory perspective, temporal processing is defined as the perception of sound or the alteration of sound within a restricted or defined time domain [6]. Temporal processing can be divided into four aspects [7]: temporal resolution, temporal ordering, temporal masking, and temporal integration. One aspect of temporal processing that has been extensively studied in children with SLI is temporal resolution. Temporal resolution is defined as the minimum time interval necessary for a subject to distinguish between distinct acoustic events [8].

Tallal and Piercy [9] were amongst the first researchers to investigate temporal resolution and temporal ordering in children with and without SLI. They did so by measuring their capacity to discriminate and repeat sequences of two or more tones of different frequencies. The authors showed that the performance of children with SLI worsened significantly as compared to children without SLI when the time interval between the two tones was diminished. In this regard, Tallal [10,11] suggested that a perceptual deficit related to auditory temporal processing underlies the language difficulties observed in children with SLI. According to this author, children with SLI show a particular difficulty for the processing of auditory information that is rapidly presented or for the processing of brief acoustic signals. Thus, SLI may have a non-linguistic perceptual basis [9–11]. Evidence in favour of this claim is provided by a study of Benasich and Tallal [12]. The authors carried out a longitudinal study in children with and without a family history of language disorder. They

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demonstrated that the threshold for rapid auditory processing at 7.5 months of age was the single best predictor of language outcome at the age of 2 years. At the age of 3 years, rapid auditory processing threshold and being male, together predicted 39–41% of the variance in language outcome.

From a similar perspective, McArthur and Bishop [13] proposed that poor auditory processing generates unstable representations of spoken sounds, leading to difficulty in perceiving and producing language. This hypothesis has been investigated by a number of other authors [e.g. 14–16]. An important aspect that should be taken into consideration is that most studies investigating the association between auditory temporal processing and language outcomes in children with SLI have used behavioural tasks that normally depend on nonsensory processing such as working memory. In these tasks, a listener typically must attend to and remember the ordering of sequentially presented sounds and then indicate which of the sounds had a distinguishing feature [17]. Importantly, a number of studies have shown that children with SLI have immediate memory deficits relating to working memory and short-term memory capacities and that these deficits may contribute to their language problems [18–22]. Thus, previous research may have observed a nonsensory-driven deficit in temporal processing tasks, rather than a primary auditory deficit. Consequently, it may be hypothesized that children with SLI demonstrate a poorer performance on auditory temporal processing tasks than children without SLI due to a deficit in short-term memory and working memory, and not due to a primary auditory dysfunction. To address this issue, the aim of this study was to compare the performance of children with and without SLI on a temporal processing task controlling for the confounding of verbal immediate memory, including short-term memory and working memory.

2. Methods

2.1. Subjects

A purposive sample of 60 children with and without SLI was selected for research purposes. The SLI group was comprised of 30 children aged between 6.0 years and 6 years 11 months, with an average age of 6 years 3 months. Nine children were female and 21 male. The control group was comprised of 30 children with typical language development, matched to the SLI group for gender and age (+/−6 months). The age range for the control group was the same as for the group of children with SLI, with an average age of 6 years 2 months.

Children with SLI were selected from the kindergarten and first-grade classes of 10 special schools and 7 mainstream schools from the Metropolitan Region of Santiago de Chile. These places were contacted as they were known to have students with a diagnosis of SLI. Children with typical language development were selected from the kindergarten and first-grade classes of mainstream schools in the Metropolitan Region of Santiago de Chile.

School officials provided prior authorization for the study, and the parents of participating children provided a signed informed consent form. Approval from the Ethics Committee of the Faculty of Medicine, University of Chile was obtained prior the commencement of the study.

2.2. Sample selection

To select the children for both groups (SLI and typical language development), the school files of students were reviewed to determine the ages and presence/absence of a diagnosis of SLI of potential study participants. Children younger than 6 years of age or older than 6 years, 11 months were excluded. For each SLI child selected (see below for further details about selection procedures), a gender- and age (+/−6 months) matched-control child with typical language development was selected using the same procedures as for the SLI group.

Following the pre-selection process based on children's ages and presence or absence of a diagnosis of SLI, children's parents were contacted to invite them to participate in the study. Oral and written information regarding the study's aims and procedures was provided to each parent. Those parents who consented to allow their children to participate in the study signed an informed consent form. Following consent, the parents filled out a questionnaire to collect data necessary to confirm that the child had an SLI (for the SLI group) or that they had a typical language development (for the control group). Children from either group were excluded if they presented with history of neurological or emotional disorders, or recurrent middle-ear problems.

Selected children based on the parents' questionnaire were scheduled for two evaluation sessions before inclusion in the final sample. The first session took place at the children's school and the second one at the Audiology Laboratory of the Department of Speech and Hearing Sciences, University of Chile (Santiago, Chile). The following procedures were carried out in a quiet room at children's school.

2.2.1. Test of Early Language Development (Third Edition) – Spanish (TELD-3: S) [23]

This test includes expressive (37 items) and receptive (39 items) language subtests and evaluates the semantic, syntactic, and morphological aspects of language. The manual provides norms for children aged 2–7 years. The results are obtained as raw scores which are then converted to quotients for expressive language, receptive language, and overall spoken language, which is a general indicator of the child's language ability. These values were used to classify children's language performance as: very high (quotient of 131–165), high (quotient of 121–130), above average (quotient of 111–120), average (quotient of 90–110), below average (quotient of 80–89), poor (quotient of 70–79), or very poor (quotient of 35–69). The inclusion criterion for participants in the SLI group was poor or very poor overall language performance. The inclusion criterion for participants with typical language development (control group) was normal language performance; thus below-average to very high performance for both the expressive and receptive subtests.

2.2.2. Test of Nonverbal Intelligence (TONI 2) [24]

This test is a standardized instrument that uses abstract figures to measure problem-solving ability. This tool is free of cultural and language factors and can be applied individually or collectively in subjects aged 5–85 years. The test provides nonverbal instructions and does not require fine motor skills. The content is abstract and the responses do not require specific knowledge or information. The inclusion criterion for children in both the SLI and the typical language development groups was normal performance on the non-verbal cognitive evaluation (a score above the 10th percentile for their chronological age).

The following procedures were carried out in one session at the Laboratory of Audiology, Faculty of Medicine, University of Chile.

2.2.3. Otoscopy

An otoscope (Heine 2000) was used to observe the external auditory canal and tympanic membrane, bilaterally. Selected participants from both groups (SLI and control) should present with an absence of obstruction in the external auditory canal and absence of abnormalities of the tympanic membrane, bilaterally.