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The nature of auditory discrimination problems in children with specific language impairment: An MMN study

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ABSTRACT

Many children with specific language impairment (SLI) show impairments in discriminating auditorily presented stimuli. The present study investigates whether these discrimination problems are speech specific or of a general auditory nature. This was studied using a linguistic and nonlinguistic contrast that were matched for acoustic complexity in an active behavioral task and a passive ERP paradigm, known to elicit the mismatch negativity (MMN). In addition, attention skills and a variety of language skills were measured. Participants were 25 five-year-old Dutch children with SLI having receptive as well as productive language problems and 25 control children with typical speech- and language development. At the behavioral level, the SLI group was impaired in discriminating the linguistic contrast as compared to the control group, while both groups were unable to distinguish the non-linguistic contrast. Moreover, the SLI group tended to have impaired attention skills which correlated with performance on most of the language tests. At the neural level, the SLI group, in contrast to the control group, did not show an MMN in response to either the linguistic or nonlinguistic contrast. The MMN data are consistent with an account that relates the symptoms in children with SLI to non-speech processing difficulties.

1. Introduction

Children with specific language impairment (SLI) fail to develop normal language, which cannot be explained by a general cognitive impairment, hearing problems, major neurological abnormalities, and/or abnormal behavior (Bishop, 1992; Leonard, 1998). They often have problems in speech comprehension, such as phonological processing of auditory information (Bishop, 1997; Leonard, 1998). For instance, children with SLI have difficulties in discriminating stimuli that are minimal pairs (e.g., /ba/vs./da/). These discrimination problems are related to a phonological deficit; an impairment in representing, storing, and/or retrieving phonemes (Snowling, 2000). A phonological deficit interferes with the ability to learn the correspondences between phonemes and graphemes and hence many children with SLI develop difficulties in learning to read (Bird, Bishop, & Freeman, 1995; Bishop & Adams, 1990). To better understand the nature of these auditory discrimination problems, many studies investigated whether these problems are primarily speech specific, or whether they coincide with non-speech processing difficulties. This has been studied both in children with SLI and in children with dyslexia, since phonological problems are present in both groups (Bishop & Snowling, 2004). However, due to inconclusive results questions regarding the specific nature of auditory discrimination problems remain unanswered (Ramus, 2001; Ramus et al., 2003; Rosen, 2003). The present study was designed to shed more light on the nature of these auditory discrimination problems, by using equally complex speech and non-speech contrasts in a behavioral study and a mismatch negativity (MMN) study in which the brain's automatic responses are measured.

In the past, several behavioral studies have obtained evidence for a primarily phonological and speech specific deficit in children with SLI and/or dyslexia, supporting theories such as the phonological deficit theory (e.g., Mody, Studdert-Kennedy, & Brady, 1997; Snowling, 2000; Studdert-Kennedy, 2002; Studdert-Kennedy & Mody, 1995). For example, Mody et al. (1997) showed that reading impaired children had more difficulties than controls discriminating speech sounds but this was not the case with non-speech sounds. However, other studies have suggested that the phonological deficit is caused by a more general prob-

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lem in processing non-speech sounds (e.g., Farmer & Klein, 1995; McAnally, Castles, & Stuart, 2000; Stein & Walsh, 1997; Tallal & Piercy, 1973a, 1973b, 1974, 1975). Tallal and Piercy (1973a, 1973b, 1974, 1975), for example, showed that children with SLI, referred to by them as children with developmental aphasia and developmental dysphasia, display problems with both speech and non-speech stimuli containing short and/or rapid acoustic changes.

A limitation of these behavioral studies is that the results may have been influenced by attention problems of the participants. To accomplish a behavioral task, attention and motivation is required, and around 35% of all children with speech and language disorders have been shown to suffer from an attention disorder (Beitchman, Hood, & Inglis, 1990). Other studies have investigated the nature of auditory discrimination problems by means of a passive oddball paradigm measuring event-related brain potentials (ERPs). In such a paradigm no attention to the auditory stimuli, no instruction, and no motor or verbal response is required. In these studies, the ERP of interest was the MMN, which has been shown to be indicative of auditory and phonemic discrimination processing at a preconscious level (Näätänen, Gaillard, & Mantysalo, 1978; Näätänen, Paavilainen, Rinne, & Alho, 2007).

Most MMN studies that have investigated the nature of a phonological deficit in children with SLI and/or dyslexia suggest phonological deficits do *not* coincide with non-speech processing difficulties (Meng et al., 2005; Schulte-Körne, Deimel, Bartling, & Remschmidt, 1998; Schulte-Körne, Deimel, Bartling, & Remschmidt, 1999; Sharma et al., 2006; Uwer, Albrecht, & von-Suchodoletz, 2002). For example, Uwer et al. (2002) showed that eight-year-old children with SLI showed smaller MMNs for linguistic contrasts (/da/vs./ga/and/ba/) than control children without any language problems. No group differences were found for non-linguistic contrasts in tone frequency and duration (1000 Hz vs. 1200 Hz; 175 ms vs. 100 ms, respectively). Nor were differences found between the MMNs of children with receptive SLI and children with expressive SLI. It should be mentioned that, in their study, rather late and long MMN latency windows were used for the statistical analysis. In contrast, recent findings from Lachmann, Berti, Kujala, and Schröger (2005) provided evidence for general non-speech processing difficulties. They found that, in contrast to control children, 8- to 11-year-old dyslexic children having difficulties with reading mainly high-frequent words did not show MMNs in a typical MMN latency window for both speech and non-speech contrasts (/ba/vs./da/; 700 Hz vs. 770 Hz, respectively).

However, in the MMN studies described above the non-linguistic contrasts were acoustically far less complex than the linguistic contrasts. Whereas linguistic contrasts consisted of rapid changes in several formant frequencies, non-linguistic contrasts consisted of stimuli with stable frequency contours. Therefore, a direct comparison between the phonemic and auditory discrimination abilities using these contrasts may be confounded by acoustic complexity differences (cf. Bishop, 2007; Serniclaes, Sprenger-Charolles, Carre, & Demonet, 2001). Alonso-Búa, Díaz, and Ferraces (2006) used more complex non-linguistic stimuli. Speech stimuli in their study consisted of a /ba/-/da/ contrast and the non-linguistic stimuli of short complex tones consisting of five concatenated simple tones. Their results revealed no group differences in MMN amplitude in the typical MMN latency window between 7- to 11-year-old children with reading problems and controls in both linguistic and non-linguistic conditions. In a later time window from 350 to 550 ms, the children with reading problems did show smaller negativities for both linguistic and non-linguistic conditions than controls. Whereas this non-linguistic contrast was more complex than the non-linguistic contrasts used in previous studies, it was still less complex than the linguistic contrast. In a behavioral study, Serniclaes et al. (2001) used identical contrasts for the speech and non-speech condition, where the formant frequencies of /ba/and/da/ were replaced by pure tones. In the non-speech condition, participants were told the stimuli were electronic whistles, and in the speech condition they were told that the stimuli were speech-like sounds. Their results revealed that, while five-year-old children with dyslexia were less categorical in the speech condition, they were *better* at discriminating within-categorical contrasts than average readers. Similar results were found in the non-speech condition. This provides evidence that children with a phonological deficit process linguistic as well as non-linguistic information differently as compared to children without phonological problems. Unfortunately, discrimination abilities were not assessed in a passive paradigm, making it impossible to elucidate the role of individual's attention skills in the behavioral results.

Bishop (2007) provided an in-depth review about the electrophysiological assessment of perception abilities in dyslexic and language impaired children. Building upon a suggestion emerging out of this review, here we investigated whether auditory discrimination problems in children diagnosed with SLI are primarily phonological, or whether they coincide with non-speech processing difficulties using speech and non-speech contrasts that have similar acoustically complex changes, in both an active behavioral task and a passive MMN paradigm. This was examined in five-year-old Dutch children diagnosed with SLI. We administered several language tests to assess their phonological abilities. In addition, an attention task was administered to study whether behavioral measures were influenced by attention skills. In the active discrimination experiment (Experiment 1), the nature of discrimination problems was investigated by means of a task in which children had to point to pictures to indicate which of the two stimuli they had heard. In the MMN experiment (Experiment 2), linguistic and non-linguistic discrimination abilities were tested passively, using a classic oddball paradigm. In this paradigm, no attention to the auditory stimuli was required, and participants were shown a silent movie. The results of the children with SLI were compared to children with typical speech- and language development.

The main experimental question in the present study is whether discrimination problems of children with SLI are primarily phonological in nature or whether they coincide with non-speech processing difficulties. For the active behavioral task, two different outcomes are possible. First, if discrimination problems are purely phonological, the SLI group should perform below the control group on the linguistic discrimination task, whereas the SLI group should show similar results for the non-linguistic discrimination task when compared to the control group. Second, if children with SLI suffer from non-speech processing difficulties that may affect linguistic information processing, the SLI group should score lower than the control group on both linguistic and non-linguistic discrimination tasks. However, if results from the attention task show that attention skills play a significant role when discrimination abilities are tested behaviorally, then measuring discrimination skills at a pre-attentive level using an MMN paradigm would be necessary to fully characterize discrimination problems in this clinical group. There are two potential outcomes of this study. First, if discrimination problems are restricted to phonological information, the SLI group should show an absence of or a smaller MMN in the linguistic condition as compared to the control group, whereas an MMN comparable to the control group should be observed in the non-linguistic condition. Second, if the discrimination problems of the SLI group are not restricted to phonological information but have a more general nature, the SLI group should show an absence of or smaller MMNs in both conditions as compared to the control group.