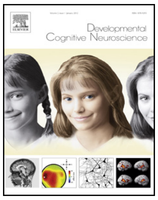
Developmental Cognitive Neuroscience 5 (2013) 134–148

Contents lists available at SciVerse ScienceDirect

Developmental Cognitive Neuroscience

journal homepage: http://www.elsevier.com/locate/dcn



ERPs reveal the temporal dynamics of auditory word recognition in specific language impairment

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ARTICLE INFO

Article history:
Received 3 April 2012
Received in revised form 16 February 2013
Accepted 22 February 2013

Keywords:
Auditory word recognition
SLI
Picture–word matching
ERPs
Phonological processing
Lexical competition

ABSTRACT

We used event-related potentials (ERPs) to compare auditory word recognition in children with specific language impairment (SLI group; $N = 14$) to a group of typically developing children (TD group; $N = 14$). Subjects were presented with pictures of items and heard auditory words that either matched or mismatched the pictures. Mismatches overlapped expected words in word-onset (cohort mismatches; see: DOLL, hear: *dog*), rhyme (CONE – *bone*), or were unrelated (SHELL – *mug*). In match trials, the SLI group showed a different pattern of N100 responses to auditory stimuli compared to the TD group, indicative of early auditory processing differences in SLI. However, the phonological mapping negativity (PMN) response to mismatching items was comparable across groups, suggesting that just like TD children, children with SLI are capable of establishing phonological expectations and detecting violations of these expectations in an online fashion. Perhaps most importantly, we observed a lack of attenuation of the N400 for rhyming words in the SLI group, which suggests that either these children were not as sensitive to rhyme similarity as their typically developing peers, or did not suppress lexical alternatives to the same extent. These findings help shed light on the underlying deficits responsible for SLI.

1. Introduction

Spoken word recognition involves processing incoming auditory information and mapping it onto the knowledge of sounds in a language in order to arrive at a meaning. This is a complex process that can break down at any level: poor spoken language comprehension can occur as a result of deficits in basic acoustic processing, impaired knowledge of speech sounds (phonological processing), abnormal word-level knowledge (lexical processing), and/or deficits in processing meaning (semantics). Difficulties with spoken word recognition are a hallmark of specific language impairment (SLI), a developmental impairment occurring in about 7% of children (Tomblin et al., 1997a,b) characterized by delayed language development despite otherwise typical development and exposure to adequate learning opportunities (see Bishop and Snowling, 2004;

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http://dx.doi.org/10.1016/j.dcn.2013.02.005

Schwartz, 2009, for reviews). Despite the widespread acknowledgment of spoken word recognition deficits in SLI, the level of breakdown in the word recognition process remains a matter of considerable debate. Deficits in children with language impairment have been observed at the levels of acoustic processing (Tallal and Piercy, 1973; Tonnquist-Uhlén et al., 1996; Bishop and McArthur, 2004; McArthur and Bishop, 2004; Shafer et al., 2011), speech perception (Joanisse et al., 2000; Ziegler et al., 2005; Robertson et al., 2009; Archibald and Joanisse, 2012), syntax (Norbury et al., 2001; van der Lely, 2005), lexical processing (Seiger-Gardner and Brooks, 2008; McMurray et al., 2010), semantics (McGregor et al., 2002; Seiger-Gardner and Schwartz, 2008), phonological short-term memory and working memory (Archibald and Gathercole, 2006; Leonard et al., 2007a,b; Alloway et al., 2009; Helenius et al., 2009), as well as other processes. There is also an ongoing debate regarding whether these deficits are the result of a specific deficit in grammar (van der Lely, 2005) or impaired phonology (Joanisse and Seidenberg, 1998; Joanisse, 2004), or are instead due to more general deficits in procedural learning (Ullman and Pierpont, 2005) or difficulties in tracking statistical regularities in speech input (Evans et al., 2009; Hsu and Bishop, 2010).

In recent years, there has been an increasing trend in using online language measures to study this population to better understand the nature of the underlying deficit (e.g., Shafer et al., 2005; McMurray et al., 2010). The advantage of online measures is the ability to assess the neurocognitive substrates of speech processing as it unfolds, whereas traditional measures such as phoneme categorization and discrimination provide a measure at the end point of processing. Thus, using time-sensitive measures to examine the different elements of spoken word processing as auditory words unfold might shed light on the nature of the underlying cause of SLI. In the present study we focus on characterizing these underlying component processes using event related potentials (ERPs) to test cortical responses to spoken words (for a review, see Newman et al., 2012).

ERPs are well suited to addressing the nature of the underlying deficit in SLI, given our ability to assess specific cognitive processes based on the specific components that appear to be related to them. For example, in spoken word recognition, dissociable ERP components have been identified that index the different stages of processing from acoustic information toward meaning: early sensory processing is thought to be marked by the N100 (Näätänen and Picton, 1987), prelexical processing by the phonological mapping negativity (PMN; Connolly and Phillips, 1994; Newman and Connolly, 2009), and later, word-level processing by the N400 (Kutas and Hillyard, 1984). Furthermore, we can employ a task that modulates these components in distinct ways such that we can infer the stages of processing underlying overall deficits in spoken word recognition. For this, we have turned to the picture–word matching task used by Desroches et al. (2009), in which subjects judge whether a spoken word matches or mismatches a visually presented picture. In this task, the picture is presented first, to set up an expectation of auditory input, which might then be violated in various ways, based on the phonological relationship between a presented versus expected word. Different types of phonological relationships, such as words that overlap in onsets versus rimes, lead to different types of mismatch effects. The nature of these effects gives some insight into how a particular group of subjects processes auditory words.

In the current study, we examined the time course of auditory word recognition in SLI. To do this, we used the same design as Desroches et al. (2009) such that mismatches shared either word-initial phonemes with expected words (cohort mismatches; see: DOLL, hear: *dog*), rime (rhyme mismatches; see: CONE, hear: *bone*), or no phonemes at all (unrelated mismatches; see: SHELL, hear: *mug*). We compared auditory word recognition between children with SLI and typically developing age-matched controls, and specifically looked at three ERP components: the N100, the PMN, and the N400. For the N100, we compared ERP responses for the baseline "match" condition, to investigate potential group differences in auditory sensory processing, as this has been shown in prior studies (Tonnquist-Uhlén et al., 1996; McArthur and Bishop, 2004). However, one should note that these prior studies have tended to look specifically at non-speech sounds (Tonnquist-Uhlén et al., 1996; McArthur and Bishop, 2004), or have used synthetic speech (Breier et al., 2003; McArthur and Bishop, 2005), and so the use of natural speech in this study offers an interesting contribution in this regard. Conversely, for the PMN and N400, we compared responses to certain types of mismatches (cohorts versus rhymes) in order to elucidate whether these two groups might show differences in phonemic and lexical processing. This was based on evidence from prior studies that these groups show differences in processing consonants (Sussman, 1993; Burlingame et al., 2005) and vowels (Shafer et al., 2005) as well as differential sensitivity to onset versus rhyme similarity (Gray et al., 2012; Seiger-Gardner and Brooks, 2008; Shafer et al., 2004). Taken together, analysis of these three components offered us an opportunity to tease apart the component processes underlying deficits in spoken word recognition in SLI.

2. Materials and methods

2.1. Subjects

Fourteen children with specific language impairment (SLI group) and fourteen typically developing children (TD group) were recruited from the London, Ontario area. Both children and their parents gave their informed consent/assent to participate. The SLI group ranged in age from 8;4 to 12;9 ($M = 9;9$) and the TD group ranged in age from 8;4 to 12;7 ($M = 10;4$). Importantly, age was not significantly different between groups [$t(26) = 1.169$, $p = .25$, Cohen's $d = .44$]. Prior to taking part in the experimental task, children performed a series of standardized tests to assess their language abilities as well as their nonverbal IQ. Results of these standardized tests are summarized in Table 1. Critically, the TD and SLI groups differed in standardized scores on receptive grammar tests (either TROG-2; Bishop, 1989, or CELF-4; Semel et al., 2003), which