

Duration of auditory sensory memory in parents of children with SLI: A mismatch negativity study

Johanna G. Barry ^{*}, Mervyn J. Hardiman, Elizabeth Line, Katherine B. White, Ifat Yasin,
Dorothy V.M. Bishop

Department of Experimental Psychology, University of Oxford, OX1 3UD, UK

Accepted 12 February 2007
Available online 6 April 2007

Abstract

In a previous behavioral study, we showed that parents of children with SLI had a subclinical deficit in phonological short-term memory. Here, we tested the hypothesis that they also have a deficit in nonverbal auditory sensory memory. We measured auditory sensory memory using a paradigm involving an electrophysiological component called the mismatch negativity (MMN). The MMN is a measure of the brain's ability to detect a difference between a frequent standard stimulus (1000 Hz tone) and a rare deviant one (1200 Hz tone). Memory effects were assessed by varying the inter-stimulus interval (ISI) between the standard and deviant. We predicted that parents of children with SLI would have a smaller MMN than parents of typically developing children at a long ISI (3000 ms), but not at a short one (800 ms). This was broadly confirmed. However, individual differences in MMN amplitude did not correlate with measures of phonological short-term memory. Attenuation of MMN amplitude at the longer ISI thus did not provide unambiguous support for the hypothesis of a reduced auditory sensory memory in parents of affected children. We conclude by reviewing possible explanations for the observed group effects.

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Keywords: Specific Language Impairment; Parents; MMN; Auditory sensory memory; Phonological short-term memory; Nonword repetition; Individual differences

1. Introduction

Specific Language Impairment (SLI) is defined as delayed development of language in the absence of any obvious explanation such as hearing loss, frank neurological damage or below normal nonverbal intelligence. Among other phenotypic features of the disorder, a deficit in phonological short-term memory as measured by nonword repetition has been consistently reported (for review see Gathercole, 2006). Nonword repetition is a task in which participants are required to repeat a series of nonsense words that vary in numbers of syllables and phonotactic complexity e.g., 'ballop' or 'perplisteronk'.

Difficulties in performing this task may stem from deficits in the storage capacity for verbal materials, poor encoding of incoming speech materials due to impaired speech perception, weak knowledge of phonotactics due to limited vocabulary, and/or problems with speech production. In the case of children with SLI, Gathercole (2006) argues that poor performance on the task is due, at least in part, to deficits in the storage capacity of verbal short-term memory, with phonological representations showing unusually rapid decay. This conclusion is based on work by Gathercole and Baddeley (1990). In a study focused on investigating which component of short-term memory was impaired in children with SLI, they found that children with SLI were more sensitive to increasing numbers of syllables i.e., increasing memory load than they were to variations in phonotactic complexity i.e., articulatory complexity. Gathercole and Baddeley acknowledged some role for perceptual deficits,

^{*} Corresponding author. Fax: +44 0 1865 281255.
E-mail address: oto_jo@yahoo.com (J.G. Barry).

but argued that any contribution of such deficits to poor performance on nonword repetition tasks was far outweighed by the deficits in the storage capacity of short-term memory.

It is a moot point whether weak short-term memory in SLI is purely associated with verbal materials. Memory for nonverbal auditory sequences has been investigated far less than memory for verbal material, in part because of difficulties in finding a behavioural paradigm that does not introduce other task demands that confound interpretation of the data. An early study by Tallal and Piercy (1973) used a task in which children were presented with sequences of high (300 Hz) or low (100 Hz) tones and trained to associate one response button with the high tone and another with the low one. They were then required to tap out presented sequences of tones of varying lengths using the corresponding buttons. Although Tallal and Piercy were primarily interested in assessing the impact of inter-tone interval on performance, they also considered the effect of tone sequence length, and found that regardless of presentation rate, children with SLI were significantly worse at longer sequences, suggesting an impairment in auditory memory. Lincoln, Dickstein, Courchesne, Elmasian, and Tallal (1992) subsequently replicated this result and further showed that the deficit was specific to SLI, since children with a diagnosis of autism showed no evidence for a similar deficit.

Auditory short-term memory deficits have also been reported in dyslexia, a reading disorder that is frequently co-morbid with SLI (Bishop & Snowling, 2004; Catts, Adlof, Hogan, & Ellis Weismer, 2005). France et al. (2002) found circumstantial evidence for memory impairments in a study of frequency discrimination performance in people with dyslexia. As part of this research, they included a range of inter-stimulus intervals (ISI; silent interval between offset of one stimulus and onset of the next) from 0 to 1000 ms and observed that frequency discrimination ability in adults with dyslexia decreased with increasing ISI. Analysis of the data within the framework of a signal detection model of perceptual resolution (MacMillan, Goldberg, & Braida, 1988) suggested that the differences in frequency discrimination abilities in the group with dyslexia relative to the control group were attributable both to greater sensory variance (i.e., the internal noise associated with the processing of a stimulus) and to greater trace variance (i.e., sensory memory).

In another study involving people with dyslexia, Banai and Ahissar (2004) also noted considerable variability in their ability to perform a range of psychoacoustic tasks. Observing a bimodal distribution of frequency discrimination abilities among their participants, they subdivided them into two groups according to performance—either poor or adequate. After doing this, they found that people with dyslexia who were bad at the psychoacoustic tasks in their test battery also had deficits in working memory as measured using the digits backward recall task. Banai and Ahissar envisaged sound discrimination as a two stage

process involving first early sensory encoding then sound comparison. This latter stage was performed at a higher level by working memory. They suggested that participants who did poorly on the frequency discrimination task formed a subgroup who were characterised by a deficit in working memory as distinct from verbal memory. Impaired performance on the nonverbal auditory discrimination task thus arose as a consequence of this deficit rather than because of poor initial sensory encoding.

Finally, Marler, Champlin, and Gillam (2002) combined behavioural and electrophysiological techniques involving the same backward-masking stimuli to investigate whether higher order language deficits in children with SLI developed out of a neurophysiological impairment in auditory memory. They found significantly higher thresholds in the auditory backward-masking tasks for the children with SLI and further reported that the children had particular difficulty detecting the masked stimulus if it occurred earlier in the three-interval forced choice task. This suggested deficits in auditory memory. These findings were supported by the electrophysiological data. The event-related potentials (ERPs) of the children with SLI were normal, indicating normal auditory processing. However their mismatch negativities (see below) in response to a change in intensity of the masked stimulus differed significantly from those of the typically developing children in being longer in latency and reduced in amplitude. Marler et al. concluded that the children with SLI had deficits in their early memory systems for complex sounds rather than deficits in processing of the auditory stimuli.

Though differing in research focus and interpretation of the data, all these studies suggest that the short-term memory deficits observed in participants with language or literacy impairments may in fact extend to nonverbal as well as verbal auditory input.

SLI has a genetically heritable component (for review see Stromswold, 1998). In previous research, Barry, Yasin, and Bishop (2007) found that parents of children with SLI were poor at the nonword repetition task i.e., they had deficits in verbal short-term memory. In the present study, we wished to investigate whether the memory deficits for nonverbal materials that had previously been reported for children with SLI were also present in parents of children with SLI. Such a finding would implicate a broad range of heritable short-term memory deficits in the disorder.

Psychophysical tasks, such as those employed by France et al. (2002), are not ideal for this purpose because they provide rather indirect evidence of memory impairment, and may be affected by the use of encoding strategies (e.g., implicit labelling of stimuli) and variations in attention and motivation. The simpler methods adopted by Lincoln et al. (1992) may additionally be influenced by a person's musical background (Bishop, 2001). To avoid such confounds, we tested for auditory short-term memory deficits using electrophysiological rather than behavioural techniques, adapting a method developed by Grau, Escera, Yago, and Polo (1998) for this purpose. Specifically, we

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