SPECIAL ISSUE

INDIVIDUAL DIFFERENCES IN AUDITORY PROCESSING IN SPECIFIC LANGUAGE IMPAIRMENT: A FOLLOW-UP STUDY USING EVENT-RELATED POTENTIALS AND BEHAVIOURAL THRESHOLDS

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ABSTRACT

It has frequently been claimed that children with specific language impairment (SLI) have impaired auditory perception, but there is much controversy about the role of such deficits in causing their language problems, and it has been difficult to establish solid, replicable findings in this area. Discrepancies in this field may arise because (a) a focus on mean results obscures the heterogeneity in the population and (b) insufficient attention has been paid to maturational aspects of auditory processing. We conducted a study of 16 young people with specific language impairment (SLI) and 16 control participants, 24 of whom had had auditory event-related potentials (ERPs) and frequency discrimination thresholds assessed 18 months previously. When originally assessed, around one third of the listeners with SLI had poor behavioural frequency discrimination thresholds, and these tended to be the younger participants. However, most of the SLI group had age-inappropriate late components of the auditory ERP, regardless of their frequency discrimination. At follow-up, the behavioural thresholds of those with poor frequency discrimination improved, though some remained outside the control range. At follow-up, ERPs for many of the individuals in the SLI group were still not age-appropriate. In several cases, waveforms of individuals in the SLI group resembled those of younger typically-developing children, though in other cases the waveform was unlike that of control cases at any age. Electrophysiological methods may reveal underlying immaturity or other abnormality of auditory processing even when behavioural thresholds look normal. This study emphasises the variability seen in SLI, and the importance of studying individual cases rather than focusing on group means.

Key words: specific language impairment, auditory, ERP, maturation

INTRODUCTION

The failure of some children to master language at the normal rate, despite good intelligence and adequate instruction, has puzzled researchers for several decades. One theoretical account proposes that specific language impairment (SLI) in children is caused by low-level auditory perceptual problems. Most children with SLI have literacy problems, and the theory has also been extended to account for developmental dyslexia.

Early studies of auditory perceptual deficits in children with SLI and dyslexia were conducted using the Auditory Repetition Test (ART, see Tallal and Piercy, 1978, for review). The ART requires a listener to press buttons to correspond to a sequence of brief tones that vary in frequency. Children with SLI performed poorly on this task if the tones were presented with an interstimulus interval (ISI) of less than around 250 ms, but they performed accurately at longer ISIs. This led Tallal and colleagues to propose that SLI results when the auditory system responds sluggishly. This will affect language development, because when listening to speech, processing of one sound may not be complete before the arrival of the next sound, and so formation of phonemic categories will be disrupted. Although several subsequent studies have found results consistent with this "temporal processing" hypothesis (see Habib, 2000; Wright et al., 2000, for reviews), others have failed to find the predicted perceptual deficits in people with dyslexia or SLI, both on the ART (Bishop et al., 1999a) and on other auditory temporal measures such as backward masking (Bishop et al., 1999b) or gap detection (McAnally and Stein, 1996; see also Rosen, 2003, for review).

Evidence for Spectral Deficits in SLI and Dyslexia

One issue that has arisen is whether poor performance on the ART may stem from deficiencies in spectral rather than temporal processing of auditory signals. A person with a spectral difficulty would have problems distinguishing sounds that differ in frequency, regardless of their duration or presentation rate. Evidence for poor frequency discrimination is apparent in some studies using the ART. First, many studies find a subset of children have to be excluded because they cannot learn the initial discrimination between tones of different frequency, even under optimal conditions when there is no time pressure (Bishop et al., 1999a; Breier et al., 2002; Heath et al.,1999; Reed, 1989; Tallal et al., 1981). Further, several studies have found that many children who do learn the initial tone discrimination to criterion have problems distinguishing tone sequences regardless of whether they are presented at slow or fast rates (Bishop et al., 1999a; Lincoln et al., 1992; Marshall et al., 2001; Waber et al., 2001). In a similar vein, Baldeweg et al. (1999) found that dyslexics were

inferior to controls at distinguishing a 50-ms, 1000-Hz tone from deviant tones that ranged from 1015 to 1090 Hz. In addition, several studies have found usually high frequency difference limens (i.e. the smallest difference in frequency that can be detected) in people with language or literacy problems (Ahissar et al., 2000; Cacace et al., 2000; Hari et al., 1999; McAnally and Stein, 1996).

Further evidence of anomalous spectral processing in SLI was reported by Wright et al. (1997). They showed that poor backward masking performance of children with SLI could be ameliorated by placing a wide spectral 'notch' in the masking noise (i.e. using noise that excluded frequencies at or near the signal frequency). Children with SLI could detect a tone immediately followed by noise relatively well, provided the tone and noise were sufficiently different in frequency.

Results such as these raise the possibility that the principal reason for deficient performance on the ART is poor frequency discrimination, and that this is most evident when the task is made difficult by using a rapid presentation rate.

Variability within the Learning Disabled Population

Although there is evidence of frequency discrimination deficits in people with language and literacy problems, it is clear that not every individual is impaired. As stressed by Hill et al. (1999) and Amitay et al. (2003), there is substantial heterogeneity among poor readers on tests of frequency discrimination, with some doing very poorly and others scoring well within normal limits. McArthur and Bishop (2003) compared 16 young people with SLI and 16 controls on tests of frequency discrimination and recognition backward masking, and found that only around one third of the SLI group had evidence of auditory deficits, and these were poor at the basic frequency discrimination task, rather than showing selective problems on the backward masking task. Clearly, if auditory deficits are seen in only a subset of individuals, then one may mask genuine group differences by combining heterogeneous cases.

Maturational Considerations

As well as being aware of individual differences in auditory deficit, it is important to take into account the protracted course of auditory development in humans. Although there is ample evidence that the cochlea and auditory brainstem pathways are adult-like in young infants (Ponton et al., 2000), neuroanatomical studies by Moore (2002) have demonstrated striking changes in auditory cortex occurring throughout childhood and early adolescence. Mature axons in cortical layers 2 and 3, which are involved in cortico-cortical connections, do not begin to appear until 5 years of age and only reach adult levels by 11 or 12 years of age. As Moore (2002) pointed out, this late maturation of the auditory cortex could explain why certain aspects of auditory function do not reach adult levels until early adolescence: In general, adult levels of performance are achieved only by older children or adolescents on tasks that involve cortical processing, rather than more peripheral auditory mechanisms. These include perception of distorted or degraded speech, detection of a backward masked signal, and binaural unmasking, which assesses the ability to perceive small differences in the phase of auditory signals presented to the two ears (Hall and Grose, 1990; Hartley et al., 2000; Hogan and Moore, 2003).

Most auditory deficit accounts of SLI implicitly assume that language development is 'deviant' in affected individuals, because some crucial perceptual skill is chronically deficient. However, the literature on auditory development reviewed above suggests another possibility, which we shall refer to as the 'maturational hypothesis'. This maintains that any deficits seen in children with SLI or dyslexia reflect delayed maturation of cortical development, rather than a more permanent abnormality. This raises the question of whether auditory deficits are more commonly found in younger rather than older participants with SLI or dyslexia. McArthur and Bishop (2001) reviewed the relevant literature and found that this was not the case. Indeed, some of the most robust evidence for auditory deficits has been found in adult samples. However, our survey included a variety of auditory tasks that may have different developmental trajectories. To evaluate the maturational hypothesis adequately, one needs to see the same people assessed on the same task at different points in development. Bernstein and Stark (1985) adopted this approach and found that performance on the ART did change, and sometimes normalise, as children with SLI grew older. Wright and Zecker (2004) found that backward masked thresholds were impaired in 8-year-olds with learning disabilities but were normal in 12-year-olds. However, the older children did more poorly than controls on a simultaneous masking task. They suggested that the changing profile of auditory deficit might be explained in terms of auditory system immaturity. Similar arguments have been advanced by Hautus et al. (2003), who used a gap-detection task, and showed that whereas 6- to 9 year-olds with dyslexia were significantly impaired relative to controls, 10- to 13-year-olds were not. In this regard, it is noteworthy that the subset of people with poor frequency discrimination in the sample of McArthur and Bishop (2004) tended to be younger than the SLI cases with normal frequency discrimination thresholds.

The maturational hypothesis is of particular interest because it suggests that in focusing on