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Research paper

Brainstem response to speech and non-speech stimuli in children with learning problems

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ABSTRACT

Neuronal firing synchronization is critical for recording auditory responses from the brainstem. Recent studies have shown that both click and/da/synthetic syllable (speech) stimuli perform well in evoking neuronal synchronization at the brainstem level. In the present study, brainstem responses to click and speech stimuli were compared between children with learning problems (LP) and those with normal learning (NL) abilities. The study included 49 children with LP and 34 children with NL. Auditory brainstem response (ABR) to 100-μs click stimulus and speech ABR (sABR) to/da/40-ms stimulus were tested in these children. Wave latencies III, V, and Vn and inter-peak latency (IPL) V–Vn in click ABR and wave latencies I, V, and A and IPL V–A in sABR were significantly longer in children with LP than children with NL. Except IPL of I–III, a significant positive correlation was observed between click ABR and sABR wave latencies and IPLs in children with NL; this correlation was weaker or not observed in children with LP. In this regard, the difference between correlation coefficients of wave latencies I, III, and V and IPLs I–V and V–Vn/V–A was significant in the two groups. Deficits in auditory processing timing in children with LP may have probably affected ABR for both click and speech stimuli. This finding emphasizes the possibility of shared connections between processing timing for speech and non-speech stimuli in auditory brainstem pathways. Weak or no correlation between click and speech ABR parameters in children with LP may have a clinical relevance and may be effectively used for objective diagnoses after confirming its sufficient sensitivity and specificity and demonstrating its acceptable validity with more scientific evidence.

1. Introduction

Click-evoked auditory brainstem response (ABR) is the most commonly used auditory evoked potential to assess data processing in auditory neural pathways in the first 10 ms after stimulus presentation. This response comprises 7 waves with positive and negative peaks that can be used to estimate auditory threshold. This response can also be used for otoneurologic assessment, particularly to diagnose possible lesions along the auditory nerve and/or in auditory brainstem pathways (Burkard and Don, 2007; Hall, 2007; Roeser et al., 2007). The brainstem is a structure with high neural synchronization, and the effects of its different pathologies usually manifest as changes in the absolute latency, inter-peak latency (IPL), and/or amplitude of waves in the click ABR. The reliability of results for auditory threshold estimation and their applications in differential diagnosis of sensory-neural hearing impairments are the most important reasons for the widespread use of click ABR along with other diagnostic tests in clinical practice (Hall, 2007).

Over the past two decades, use of more complex stimuli such as speech sounds or music that challenges the brainstem has been the

List of the abbreviations: ABR, Auditory brainstem response; ADHD, Attention deficit hyperactivity disorder; AEP, Auditory evoked potential; ANSD, Auditory neuropathy spectrum disorder; ANSI, American national standard institute; CI, Confidence interval; FFR, Frequency following response; IPL, Inter peak latency; LP, Learning problem; MANOVA, Multivariate analysis of the variance; NL, Normal learning; sABR, Speech ABR; SD, Standard deviation; TD, Typically-developed; WISC-R, Wechsler intelligence scale for children - revised; WIAT-II, Wechsler individual achievement test - second edition

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focus of study (Banai et al., 2007). Researchers have studied brainstem responses to complex stimuli and the impact of training, experience, and intervention on such responses. Effects of these factors on brainstem responses to complex stimuli have been investigated in individuals with varied disorders. The findings of most of these studies are interesting in terms of displaying capabilities and functions of the auditory brainstem. In addition, most authors are of the opinion that ABR to 40 ms/da/synthetic syllable or speech ABR (sABR) can be used an objective and non-invasive tool to study the role of the brainstem in processing complex auditory stimuli such as speech in individuals with developmental and learning difficulties (Skoe and Kraus, 2010). Furthermore, many studies have reported that most children with learning problems (LPs) and attention deficit disorders are likely to have a potential impairment in the neural encoding of complex acoustical signals compared with typically developed (TD) children with normal learning (NL) abilities (Banai et al., 2009; Cunningham et al., 2001; Hornickel et al., 2011; Kraus et al., 1996; King et al., 2002; Song et al., 2006, 2008; Wible et al., 2004).

By definition, children with LPs are those who cannot be effectively taught and expected to progress when regular education programs, even in the presence of support, are implemented. They need to be "pulled out" into special settings where they can receive remedial services (Will, 1986). By the time these children reach school-going age, much of the critical time for language development has already passed. Therefore, it is not surprising that these children lag behind their peers not only in language learning and speech but also in various other skills. A substantial percentage of these children exhibit difficulties in perceiving and discriminating between auditory stimuli, including speech sounds (King et al., 2002; Mody et al., 1997; Tallal and Stark, 1981; Wible et al., 2004). Studies have shown a relationship between impairment of speech recognition tasks and deficits in cortical and brainstem auditory processing times (King et al., 2002). The present study examines neural brainstem responses to click and speech stimuli in children with LPs and compares them with the results in children with NL abilities.

Approximately 9% children in the United States have reading and learning problems (King et al., 2002). In recent decades, several studies have tried to investigate the different levels of auditory neural pathways, which fail to process auditory stimuli, in such children. For instance, some studies have reported that abnormal cortical processing may be responsible for the inability to process speech (Kraus et al., 1996; Lachmann et al., 2005; Paul et al., 2006) and non-speech stimuli (Baldeweg et al., 1999; Kujala et al., 2006; Nagarajan et al., 1999). Despite the heterogeneous nature of LPs and the use of different research methods, the findings of most previously mentioned studies corroborate the theory that deficits in cortical processing of auditory stimuli are responsible for most LPs in children (Song et al., 2008). Electrophysiological studies measuring auditory processing times at the brainstem level have reported no differences in click ABR between children with LP and those with NL abilities (Grontved et al., 1988; Jerger et al., 1987; Lauter and Wood, 1993; Mason and Mellor, 1984; McAnally and Stein, 1997; Purdy et al., 2002; Tait et al., 1983). In contrast, some defects in speech stimuli processing timing, such as abnormalities in wave latencies or in the spectral content of the frequency following response (FFR) have been observed in sABR recordings (Cunningham et al., 2001; King et al., 2002; Wible et al., 2004).

The sABR to the/da/synthetic syllable gives information about time-locked responses that are either transient or sustained. Transient responses are the result of transient, non-periodic characteristics of the stimulus, whereas sustained time-locked responses are due to sustained, periodic characteristics of the stimulus (Kraus and Nicol, 2005; Skoe and Kraus, 2010). While most studies investigating sABR in children with LPs have focused on the abovementioned responses, a few studies have tried to study waves with latencies lower than wave V. Song et al. (2006) examined children with language-based LP and those with NL abilities and observed a relationship between wave latencies in click ABR and sABR. The study found no significant differences between the two groups of children for click ABR in the presence or absence of noise. However, longer latencies for waves V and A increased V-A duration, resulted in shallower V-A slope, and delayed wave III latency for sABR in the absence of noise. The result for sABR in the presence of noise was not reported in this study because earlier work (Banai et al., 2005; Cunningham et al., 2001; Johnson et al., 2005; King et al., 2002; Russo et al., 2004; Wible et al., 2004) demonstrated that the/da/-evoked response sufficiently provided means to objectively identify children at a risk of LP. Moreover, Russo et al. (2004) reported that the onset waves of the/da/-evoked response in the presence of noise are not reliably identifiable. The children participating in the study were divided into two groups- children with normal sABR and children with abnormal sABR (Banai et al., 2005), and the correlation between wave V latency for click ABR and the four measures of V–A onset response for sABR were examined (latencies of waves V and A, V–A duration, V–A slope). In the normal sABR group, a significant correlation was observed between wave V latency in click ABR and latency of wave V and A in sABR. However, these findings were not consistent with those seen in the abnormal sABR group (Song et al., 2006). Song et al. (2008) investigated the hypothesis that defects in auditory processing timing in children with LP originate either from the rostral level of the brainstem or from deficits in sensory encoding at the lower levels of neural auditory pathways. The study concluded that a significant difference existed in the rostral components of sABR (waves V and A) between children with LP and those with NL abilities. The authors of the study reported that wave I of sABR did not emerge reliably in either group. Moreover, no significant differences were observed in wave III between the two groups. They concluded that the defects in the auditory processing timing in children with LP with abnormal sABR resulted from the corticofugal modulation of subcortical activity.

Based on the potential shared connections in timing neural encodings between speech and non-speech stimuli at the brainstem level and the probable effects of corticofugal modulation or top-down processing of the subcortical activity, the present study compared the timing and amplitude components of click ABR and sABR between children with LPs and those with NL abilities. The relationship between matched components of click ABR and sABR was also investigated. Findings of this study corroborate the results of previous studies regarding auditory processing timing at the brainstem level and the possible relationship between processing timing of speech and non-speech stimuli.

2. Methods

2.1. Participants

The study was conducted at Rofeydeh Hospital. Eighty-three children aged 8–12 years were shortlisted to participate in the study. Among these, 49 children (33 boys, mean age: 9.88 ± 1.42 yr) had a history of LPs and the remaining 34 children (20 boys, mean age: 9.92 ± 1.51 yr) were typically developed with NL abilities and no history of educational problems or learning difficulties at school. All the study participants were patients at the Atiyeh Comprehensive Psychiatric Center. Children with a history of neurological problems, medical diseases, major affective disorders, or schizophrenia and those under systemic treatment were excluded from the study. All the