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Review Article

Complex evoked Auditory Brainstem Response

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Abstract:

An extremely helpful method for evaluating brainstem neuronal function is the auditory brainstem response (ABR). Clicks or bursts of tone can evoke it. However, subsequent studies have demonstrated that complex stimuli, including spoken stimuli, music, and complex tones, can also elicit a response. (e.g., /da/, /ba/, and /ga/). The complex-evoked ABR provides unique neural representations of speech sound offset, phase-locking to the fundamental and formant frequencies, and speech sound onset. An indicator of subcortical speech processing is the speech evoked auditory brainstem response (S-ABR). A voice stimulus is especially beneficial since it can illustrate how the brainstem maintains temporal and spectral information. Compared to normal people, the introduction of complex stimuli increases sensitivity to minute variations in people with hearing impairment, central auditory processing disorders , or cognitive affection more than clicks or tone bursts do. S-ABR is helpful for assessment, recording treatment results, and tracking improvements because of its high reliability and consistency across time.

Keywords: ABR, S-ABR, neural generator, waveform

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Introduction:

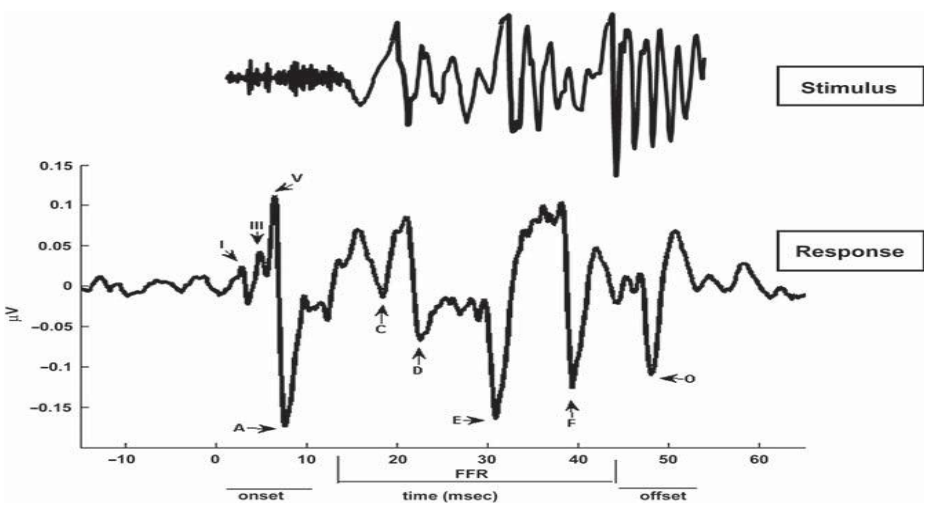
Clicks or tone bursts are the most popular ways to elicit (ABR), which has been shown to be a helpful technique for evaluating neurogenic processing at the brainstem level. More recent studies have demonstrated that complex stimuli, including spoken stimuli, music, and complex tones, can also evoke a response (e.g., /da/, /ba/, and /ga/). [1]

The first person to use complex stimuli to record ABR was **Greenberg.** He noted that the ABR also accurately encodes speech-specific information, such as vowel formants. [2] **Galbraith** [3] provided more support for this stimulus fidelity by showing that when converting a neural signal into an audio signal, complex auditory brainstem responses to words can be perceived as understandable speech. The speech evoked ABR gives distinct neurogenic depictions of onset of speech, phase-locking to the fundamental and formant frequencies, and end of speech, among other elements of the acoustic features of speech. [2]

An indicator of subcortical speech processing is the (S-ABR). A speech stimulus is especially helpful since it can reveal how the brainstem retains temporal and spectral information. [1]

Description of S-ABR:

The neural response to Speech is composed of seven prominent peaks that named V, A, C, D, E, F, and O (fig. 1). These waves occur 7 to 8 msec post stimulus initiation due to the neural impulse travelling delay between the cochlea and rostral brainstem. [4]



(fig. 1) Description of S-ABR(4)

The brainstem response to Speech consists of:

A- Transient Response: Since they represent the start and finish of voicing, respectively, and transient stimulus properties, V and A, C, and O are regarded as intermittent responses. The onset response is another name for the V-A complex. It includes periodic information (wave V is similar to the V wave produced by the click stimulus) and signifies the start of the consonant "stop burst". The transition areas, the beginning of the vowel, are all potentially reflected in wave C. On the other hand, wave O reacts to the sound stopping. [5]

B- Sustained Response (Frequency Following Response):

Phase locking to the sound's fundamental frequency is reflected in the FFR. While the waves between waves D, E, and F indicate phase locking to the first formant frequency (F1), the peaks D, E, and F of the FFR reflect the stimulus's fundamental frequency (F0). [6]

Neural Generators:

The initial positive peaks most likely come from low levels of the auditory system (like wave I and III in click evoked ABR), specifically the lower part of brainstem and the eighth nerve, respectively. The sound's onset in upper portion brainstem (lateral lemniscus/inferior colliculus) is represented by the Wave V-A complex. [7] They are obviously of brainstem origin because the start response happens 5–10 ms after the stimulus onset. [8]

As regards the FFRs, they have multiple neural generators; cochlear nucleus, inferior colliculus or lateral Lemniscuses. [9] FFRs are most likely reflect brainstem sources; as they are highly consistent, amplitude is lower, less liable to adaptation with re-petitive stimulus, and indicates early maturation. [10]

Stimulus:

The ABR's representation of the fine feature characteristics of sounds has been investigated using complex stimuli. [1]

- **Vowels:** Synthetic: A, U (11), Natural: E, I, A, U (12).
- **Consonant vowels syllables:** Synthetic: *Da (13) *Ba (14)*Ba, Da, Ga continuum. [15] **Natural**: mandarin

pitch contour *Yi*Mi . [16] Hybrid: Ya with linearly rising and falling pitch contours. [17]

Beyond speech syllables, words and phrases are among the stimuli that can elicit brainstem reactions. Recording auditory brainstem responses to extended speech segments for words like "car," "minute," "chair," and "rose" was a first. [6]

Clinical consideration:

Compared to normal controls, complex stimuli are more sensitive to minor variations in impaired populations than clicks or tone bursts throughout time.

S-ABR is helpful for assessment, recording treatment results, and tracking improvements because of its excellent reliability and consistency. [4]

1- S-ABR in Central auditory processing disorders (CAPD):

Notable distinctions were found between normal participants without APD and those with auditory processing problems, with age range from 7 to 24. The study group had a decreased VA complex slope and a significant reduction in the duration of peaks A, C, and the VA complex. [18]

Abdulrahman studied how S-ABR affected children with CAPD.The results were connected with psychophysical tests of temporal processing, and they discovered aberrant start and offset [19]

2- Language impairment:

Wible found that children with linguistic impairments had a longer wave V–A complex duration. The input of lateral leminiscus to the inferior colliculus (wave V) and neural projection in the inferior colliculus (wave A) are not well synchronized, as indicated by this test.

When compared to their peers who learn normally, subjects with documented schooler underachievement due to language issues showed increased duration for waves A, C, and O. [20]

Gonc¸alves discovered that, in comparison to the control group, children with phonological faults showed much increased duration of responses to speech stimuli (waves V and A) and click stimuli (waves I, III, and V).Additionally, they found that compared to click-evoked auditory brainstem responses, complex evoked auditory brainstem responses had a greater specificity/sensitivity for detecting language abnormalities. [21]

Abdel -Rahman [22] evaluated children with specific language impairment using the S-ABR. In comparison to typical youngsters, they reported decreased amplitudes of F0 and F1, as well as notable latency shifts of waves V, C, and O latencies.

El-Danasoury. [23] investigated the Egyptian stutterers' subcortical speech encoding. Twenty-five patients and twenty participants who spoke fluently and normally participated in the study. They discovered that the detectability of wave C in stutters and the V/A slope were significantly reduced. Additionally, wave D had a notable latency delay. Therefore, stutterers have a pan-affection of subcortical encoding of the speech syllable /da/.

3- Dyslexia:

Compared to children who read better, children who read less frequently tended to exhibit longer latencies, worse waveform shape, and lower spectrum encoding of S-ABR. [4]

4- Hearing loss:

Akhoun [16] recorded S-ABR in patients with bilateral normal hearing and unilateral deafness. The deaf ear of the participants with unilateral hearing impairment did not respond, according to their findings. They came to the conclusion that speech ABR is a reflection of how the auditory circuits work.

El-Mahallawi. [24] examined how S-ABR was affected by mild and moderate sensorineural hearing loss. They discovered that most peak latencies were delayed when compared to norms, but not amplitudes. This suggested that the response synchronization was impacted earlier than the discharge rate. Additionally, the FFR was less influenced than the onset response.

Autism spectrum disorder (ASD):

Children with ASD displayed impairments in neural synchronization (timing) and phase locking (frequency encoding) of speech sounds, even though they had acceptable click-evoked brainstem responses (25). In background noise, children with ASD showed lower Wave F amplitude and significantly delayed Wave V, A, D, and F latencies. Furthermore, compared to properly developing controls, their speech-evoked reflexes were smaller and less precise. [26]

5- Elderly:

In response to transient speech information at the start of a spoken syllable, listeners aged 61–78 exhibited a general decrease in synchronous brain activation and a worse timing of the neural response to the offset of the stimulus. Therefore, the brain stem's response to a spoken stimulus offset may provide insight into the aging auditory system's ability to encode temporal data. [27]

Anderson. [28] evaluated the consistency of neural responses and found that older persons (60–71 years old) showed less constant brainstem responses to speech than younger adults. Without a comparable improvement in TFS (first formant, fourth, fifth, and sixth harmonics), they discovered increased envelope encoding (the amplitude of the fundamental frequency and the third harmonics). Therefore, there is a relative deficiency of TFS encoding in the FFR in older persons with impairment of hearing. This TFS coding deficiency might be a major factor in older persons with SNHL having trouble hearing over background noise.

7. Hearing aid Fitting.

Anderson. [28] examined sound field S-ABR recordings using various hearing aid algorithms in both unaided and assisted settings. They discovered that the waves' amplitudes in response to an assisted and an unaided condition differed significantly. It is feasible to show that some hearing aid algorithms produced a better representation of the stimulus than others by conducting stimulus-to-response correlations, which shows which algorithms best captured the temporal and spectral features of the spoken signal.

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