New Trends in Electrophysiology -
Auditory Steady State Responses (ASSR)
Background and Updates
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Auditory Evoked Response (AER)
- Evoking electrical responses from the auditory nervous system (peripheral and central) as a result of acoustic stimulation is defined as Auditory Evoked Response (AER). These responses are recorded with the use of electrodes.

Clinically Relevant Time-points in AER Testing
- Acoustic Reflexes: 1970s
- Auditory Brainstem Response: 1980s
- Other electrophysiological tests: 1980-90
- Oto-Acoustic Emission: 1990s
- Auditory Steady State Response: latest

What is the Auditory Steady State Response
- Periodic AER
- Recorded from the auditory nervous system
- Stimulus continuous
- Most commonly used stimuli are amplitude modulated tones.
- Response waveform is complex and constituent frequency components of the ASSR remain constant in terms of amplitude and phase over a period of time (Rickards, 1983).

Brief History
- Initial research was on the steady state responses in the visual system (Regan, 1972, 1989). “Photic driving Response in the ongoing EEG” (Picton et al., 2003, p. 178)
- Research on ASSR primarily started in Australia, Canada and the Cuba.
- Clinically, relatively new in the United States of America. The 1st well known paper on the ASSR was by Galambos et al (1981).

Different Terminology
- Amplitude Modulation Following Response (AMFR)
- Envelope Following Response (EFR)
- Steady State Evoked Potential (SSEP)
- Steady State Evoked Response (SSER)
Neural Generators: 40 Hz vs. 80 Hz Response

- ASSR can be presented at the modulation rates which may be low (e.g.: close 40 Hz) or high (e.g.: close 80 Hz).
- For the 80 Hz ASSR, the response is mostly from the brainstem.
- This response is not affected by attention, arousal or sedation. Hence, it is used in testing infants.

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Neural Generators: 40 Hz vs. 80 Hz Response (contd...)

- For the 40 Hz ASSR, the response is mostly cortical.
- This response is affected by attention, arousal or sedation. However, this response is more robust when compared to a the ASSR at a rate >80Hz.

The different Stimuli for ASSR

- Picton et al, 2003
- Stephe
- Sti
- Stimulus and Recording Parameters

- Transducer: Insert ear phones
- Frequency: 0.5, 1, 2, 4 kHz
- Modulation rate: ~40 Hz or ~80 Hz
- Polarity: Alternating
- Intensity: up to 120 dB HL
- Mode: Monaural/ Binaural/ Dichotic

Multiple stimuli for ASSR

- Balvalli et al., 2011
- Analysis: F test, phase coherence
Understanding what you see on the ASSR screen

Differences between ABR and ASSR

<table>
<thead>
<tr>
<th></th>
<th>ABR</th>
<th>ASSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus type</td>
<td>Transient (e.g. clicks)</td>
<td>Steady State (e.g. sinusoidally amplitude modulated tones)</td>
</tr>
<tr>
<td>Stimulus intensity (maximum)</td>
<td>Comparatively less</td>
<td>~120 dB HL</td>
</tr>
<tr>
<td>Analysis Algorithm (clinical)</td>
<td>Clinician needs to mark the peaks/ waves</td>
<td>Statistical response detection: F test, Phase Coherence</td>
</tr>
<tr>
<td>Conductive Hearing Loss</td>
<td>Masking may not be required for ear specific estimation of BC thresholds</td>
<td>Masking is required for ear specific estimation of BC thresholds</td>
</tr>
</tbody>
</table>

Differences between ABR and ASSR (contd...)

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</tr>
</thead>
<tbody>
<tr>
<td>Sensory Hearing Loss</td>
<td>Accuracy in estimating hearing loss is moderate to severe</td>
<td>Can accurately estimate thresholds for moderate to profound hearing loss</td>
</tr>
<tr>
<td>Neural Hearing Loss</td>
<td>Inter-peak latencies, interselular inter peak latency differences, high rate ABR rejection rules out neural involvement</td>
<td>This is still in research stage, but comparison of the patient’s ASSR threshold and their behavioral thresholds at the same frequency, could indicate retrocochlear involvement. Specifically, there is not yet research to differentiate AD, neural lesions and higher order lesions using ASSR</td>
</tr>
<tr>
<td>Auditory Dysynchrony</td>
<td>Presence of cochlear microphonics with other waves that are absent/abnormal</td>
<td>Same as above</td>
</tr>
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Commercially available ASSR systems

Common Characteristics:
- Approved by the U.S. Food and Drug Administration (FDA)
- Laptop compatible for portability
- Transducers: insert ear phones, BC oscillator, loud speakers
Commercially available ASSR systems (contd...)

- Viasys Audera [http://www.viasyshealthcare.com]
- MASTER (multiple auditory steady-state response system) [http://www.mastersystem.ca]
- Intelligent Hearing System [http://www.ihsys.com]

Advantages

- Automatic and completely objective detection of a response is based on statistical tests incorporated into the software
- Frequency specific
- Can be used to test air conduction as well as bone conduction pathways
- Can be used to test intensities as high as 120 dB HL
- Availability of clinical devices
- Testing is faster (using multiple stimuli/ear)

Clinical & Research Applications

- Objective Hearing Assessment
- Screening
- Hearing aid fitting (Picton et al, 1998)
- ESSR- objective assessment through a cochlear implant (Hofmann and Wouters, 2011)
- Detection of retro-cochlear pathologies

Potential in the future

- Research has indicated good correspondence between ASSR thresholds and word recognition scores in adults (Dimitrijevic et al. 2004) and ASSR thresholds and features discrimination in infants (Cone-Wesson et al., 2005).
- ASSR has the potential to be an important technique in the detection of retro-cochlear lesions (Ali and Jerger, 1992; Purcell et al, 2004; Rabelo & Schochat, 2011; Rance et al 1999, 2005; Shinn & Musiek, 2007).

Potential in the future (contd...)

- ESSR in the assessment of infants and the difficult to test population with cochlear implants

A word of Caution

- Stimulus artifacts and artifactual responses at high intensities
- Relatively new technique. Research still in its infancy.
Research in our lab at Cincinnati Children’s Hospital Medical Center (CCHMC)

Auditory Steady State Response (ASSR) in Cochlear Implant (CI) recipients:

1. Is it possible to acquire sound-field ASSR in normal hearing adults & CI recipients?
2. Is there a correspondence between the ASSR thresholds and the behavioral thresholds across the four carrier frequencies: 0.5, 1, 2 and 4 kHz for the normal hearing group?

(Contd…)

Participants:
Cochlear Implant or CI group (experimental group)
Normal hearing adults (control Group)

Test Set Up (from Stephens et al, 2011)

Results

Control Group

Mean thresholds and SD for all subjects for each of the measurement methods. These results with significant differences are indicated with either an * (significant differences in all comparisons) or an # (significant differences between behavioral ASSR and electrophysiological ASSR only). (from Stephens et al., 2011)

CI Group

Comparison of median NBN, Behavioral ASSR and Electrophysiological ASSR thresholds for the four frequencies for CI participants (from Balvalli et al, 2011)
Pilot study on a cadaver

The results of the cadaver study (from Balvalli et al, 2011)

Non Traditional Applications of ASSR

- Anesthesia
- Auditory Neuropathy research
- Neuro-psychological research

Selected References


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