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AUDITORY ELECTROPHYSIOLOGY: EVERYTHING YOU NEED TO KNOW BEFORE STARTING YOUR ASSESSMENTS (PART IV) – RATE OF STIMULUS PRESENTATION

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AUDITORY ELECTROPHYSIOLOGY: EVERYTHING YOU NEED TO KNOW BEFORE STARTING YOUR ASSESSMENTS (PART IV) - RATE OF STIMULUS PRESENTATION

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The purpose of this bulletin is to deepen the understanding of essential theoretical and technical aspects for the development of appropriate protocols within the practice of auditory electrophysiological assessment. Before that, we invite you to read the previous bulletins on this relevant topic.

- **PART I** (newsletter published in March/2025) which discussed an important and fundamental mathematical concept that is frequently used in the practice of auditory evoked responses ... the choice of standard deviation.

PART II (bulletin published in May/2025) which reports on the choice of stimulus polarities (rarefaction, condensation, and alternating) within the diagnostic process.

PART III (bulletin published in June/2025) presented information on the importance of the number of stimuli presentations, or the amount of signal averaging, for auditory electrophysiological evaluation.



In this bulletin, we will focus on an often overlooked test parameter in auditory evoked response measurement stimulus presentation rate. If you were to ask a group of 10 audiologists to identify a stimulus parameter that contributed to successful ABR measurement, the answers would be rather diverse. Most respondents would probably mention stimulus intensity which is routinely and constantly manipulated to in an auditory electrophysiological evaluation. High stimulus intensity levels are utilized to evoke a clear and complete response for neuro-diagnostic assessment, whereas lower stimulus intensity levels are typically required to estimate auditory threshold. Almost certainly one or more of the audiologists would comment on the importance of the mode of stimulation (air- and bone conduction) and the types of acoustic stimuli ... traditional click and tone bursts and maybe broadband and narrowband chirp stimuli. It's possible that clinician experienced in ABR measurement would cite one of the stimulus parameters that we reviewed in previous bulletins, such as stimulus polarity of the number of stimuli that should be presented to obtain a single ABR waveform. There's a good chance that none of the audiologists would include presentation rate on their short list of clinically critical stimulus parameters.

Stimulus presentation rate, also known as repetition rate, represents a fundamental parameter that significantly influences the quality and reliability of the auditory evoked responses and, importantly, the duration or test time of assessments. In this paper, we describe neurobiological mechanisms underlying the effects of stimulation rate, changes in the characteristics of auditory evoked responses at different stimulus presentation rates, the clinical implications of protocol choices, evidence-based recommendations for stimulus presentation in contemporary clinical practice, and suggestions for employing optimal stimulus presentation rates to minimize precious test time.

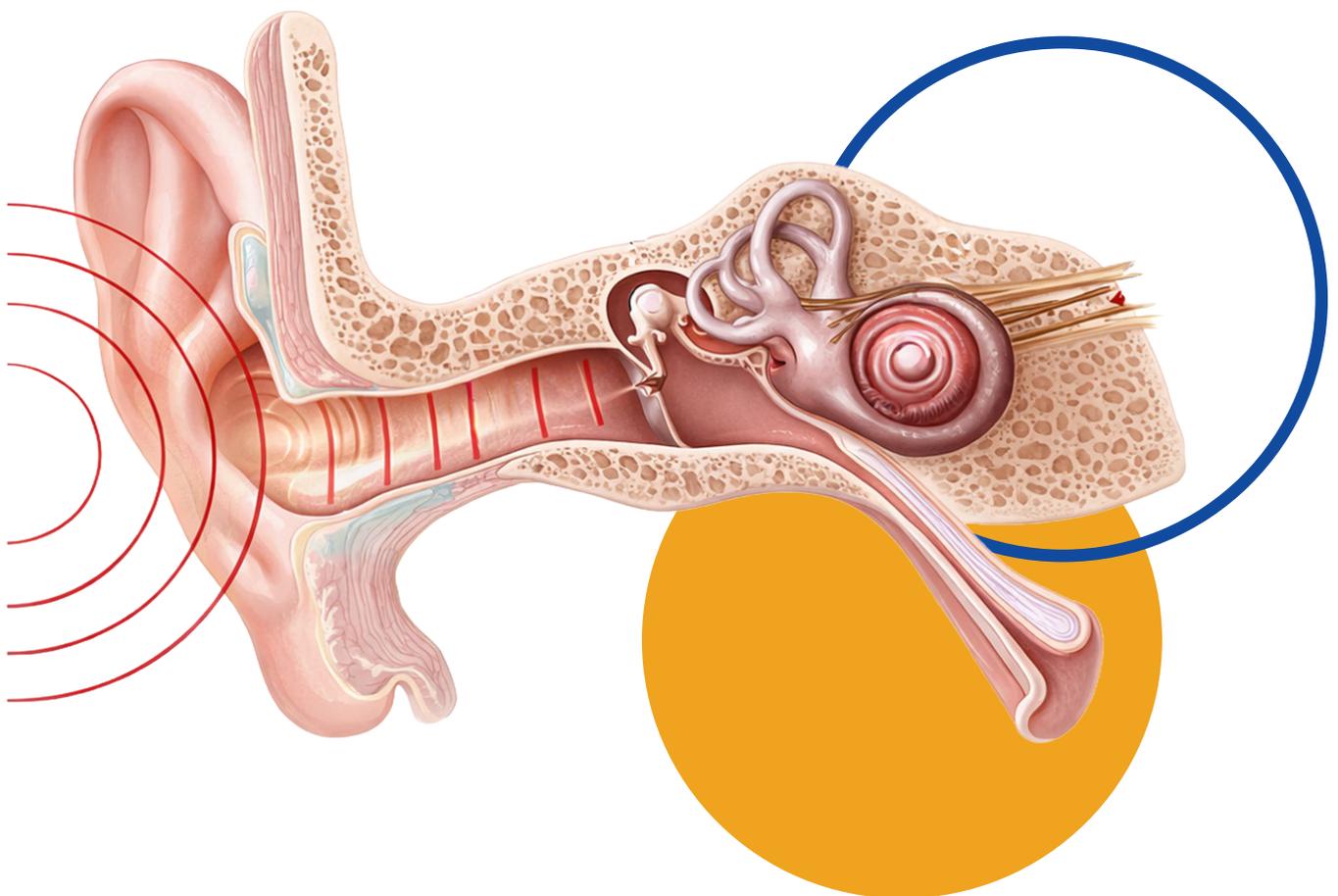
FUNDAMENTAL CONCEPTS

Defining auditory stimulus presentation rate

Stimulus presentation rate refers to the frequency with which auditory stimuli (e.g., clicks, tone bursts, broadband chirps, narrowband chirps, speech signals) are presented during an electrophysiological evaluation. This rate can be expressed in units of stimuli per second (e.g., 19.1 click stimuli per second - 19.1/s) or in Hertz (Hz) (e.g., 19.1 Hz). Stimulus presentation rate is inversely related to interstimulus interval in milliseconds.



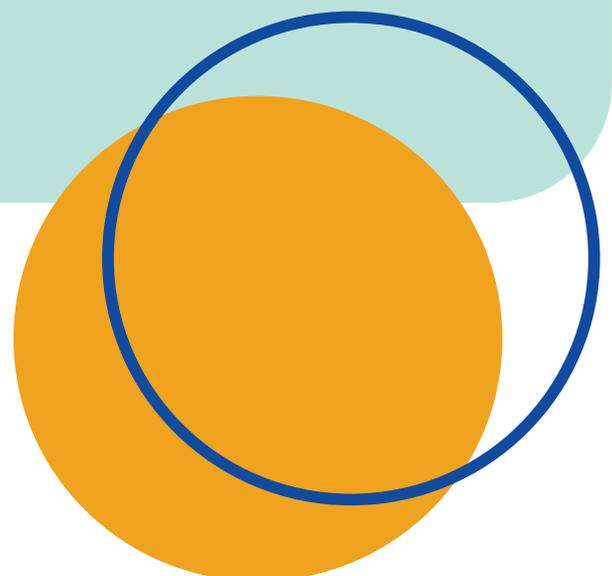
The rate of stimulus presentation varies markedly among different types of auditory evoked responses. Typically, presentation rates are < 1 stimulus per second (e.g., 0.5/second or one stimulus every two seconds) for late-latency auditory evoked responses occurring in the 100 ms to 300 ms time frame. Examples are the auditory late response, the auditory P300 response, and the mismatch negativity (MMN) response. The slow stimulus presentation rate and corresponding long interstimulus interval optimizes detection of cortical neuronal activity. In contrast, short-latency auditory evoked responses, such as electrocochleography (ECoChG) or ABR, can be elicited with relatively fast stimulus presentation rates (e.g., > 20 /sec).



The choice of the stimulus presentation rate produces clinically important influences on auditory evoked response measurement, and outcome of the assessment.

Some effects of the rate of stimulus presentation on auditory evoked responses are:

- **Changes in latency** and amplitude values for major waves or components;
- **Emergence of** response abnormalities at high stimulus presentation rates in patient with abnormalities involving relevant auditory pathways, that is, sensitization of responses to neurological dysfunction (e.g., patients with an acoustic tumor or multiple sclerosis);
- **Differentiation among** types or etiologies of auditory dysfunction and pathology Enhancement of auditory evoked response morphology, latency, and amplitude with slower stimulus presentation rates in patients who require longer neuronal recovery periods (e.g., young children);
- **Enhancement of auditory evoked response morphology,** latency, and amplitude at specific stimulus presentations rates due to greater neural synchrony (e.g., the 40 Hz response);
- **Clinically important reduction in the duration** of an auditory evoked response assessment permitting a complete ear-specific description of hearing status in relatively short time frame, e.g., < 30 minutes for a pediatric ABR assessment.

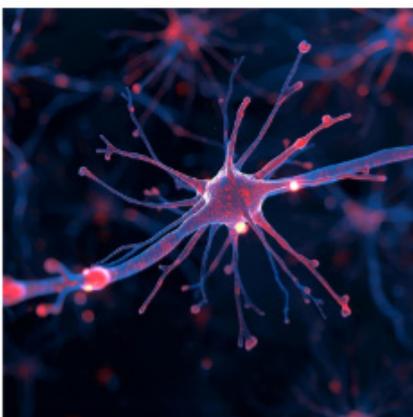


PHYSIOLOGICAL BASIS UNDERLYING STIMULUS PRESENTATION

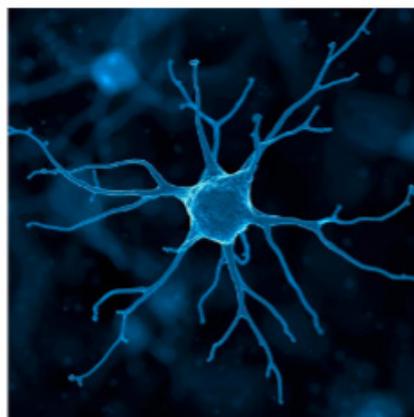
A key concept in understanding the physiological basis underlying stimulus presentation is neuronal refractoriness. **Neuronal refractoriness** is related to the intervals between neuronal responses which is directly determined by stimulus presentation rate and interstimulus interval. In a very simplistic way, this interval is a period of time in which the neuron recovers so that it can perform a new action.

The refractory period is relatively brief in duration, typically milliseconds. However, it has the potential to significantly affect the temporal coding of acoustic stimuli by auditory neurons, particularly auditory fibers capable of processing stimuli with great precision and fidelity. When the stimulation rate approaches or exceeds the recovery rate of the neural system (refractory period), significant changes occur in the patterns of neurophysiological response, changes that result in alterations in the amplitude and latency values of auditory evoked responses.

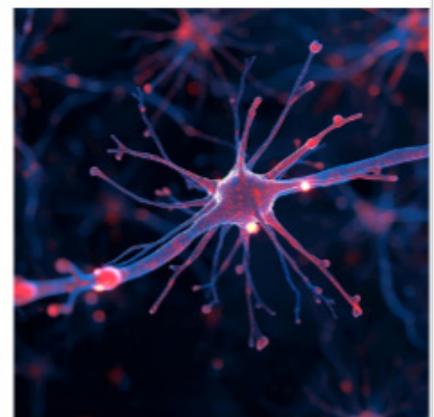
We'll focus the remainder of this discussion on the stimulus presentation rate for the auditory evoked response commonly applied clinically in audiology... the auditory brainstem response (ABR).



Neuron in action



Neuron in a refractory period



Neuron in action



EFFECTS OF PRESENTATION RATE ON AUDITORY BRAINSTEM RESPONSE (ABR)

Introduction

The ABR is, by far, the most widely used auditory evoked potential in clinical audiology practice. ABR is essential for neurologic auditory diagnosis and for the objective estimation of auditory thresholds (audibility) in any patient for whom behavioral audiologic evaluation is not feasible and/or yields incomplete or inconclusive findings.

These patient populations include:

- Infants and young children;
- Any “difficult-to-test” patient;
- Patients with developmental delay;
- Patients who must undergo evaluation during natural sleep, sedation-induced sleep, or under general anesthesia.

Manipulation of the stimulus presentation rate is very useful to increase ABR sensitivity to neural auditory dysfunction in adults and to optimize ABR outcomes in infants. If you'd like, I can also adapt this to a more technical scientific tone (for publication) or a simplified version (for presentation slides).



High-rate Stimulus Presentation in Neuro-diagnostic ABR Assessment

Em altas taxas de apresentação de estímulos, o sistema auditivo é bombardeado com sons muito rápidos, o que aumenta o estresse fisiológico das vias neurais.

Estruturas neuronais como axônios que estão "cansadas", "danificadas", "fracas" ou "doentes", não conseguem continuar funcionando de forma ideal ou normal em taxas excessivamente altas de apresentação de estímulos. Os neurônios mais "cansados" precisam de um período de descanso mais longo (período refratário) para responder plenamente antes da chegada do próximo estímulo auditivo.

Essa ineficiência resulta em um atraso no tempo de resposta dos neurônios e nos potenciais evocados auditivos associados, que podem ser identificados com o prolongamento dos valores absolutos das latência assim como entre as ondas.

Em 1992, Lightfoot publicou um artigo descrevendo o valor clínico das altas taxas de apresentação de estímulos em uma série de pacientes com schwannoma vestibular confirmado (também conhecido como neurinoma do acústico). As latências do PEATE às vezes estavam dentro dos limites normais em taxas modestas de apresentação de estímulos (< 20/segundo) tipicamente usadas na avaliação do PEATE.

Ao aumentar significativamente a taxa de apresentação do estímulo (para 88 estímulos por segundo), os valores de intervalos interpicos anormais do PEATE permitiram detectar a presença de patologia retrococlear em 100% deste grupo de pacientes.

Este estudo e outros (veja Hall, 2015 para revisão) demonstraram que altas taxas de apresentação de estímulos aumentaram a sensibilidade neurodiagnóstica do PEATE em pacientes com disfunção auditiva neural.

O valor clínico associado ao aumento da taxa de estimulação para aumentar a sensibilidade neurodiagnóstica da avaliação PEATE é especialmente evidente em pacientes com pequenos tumores ou em estágio inicial.

What is the recommended stimulus presentation rate to increase neurodiagnostic sensitivity with ABR?

Several presentation rates have been proposed; however, a rate of > 80 stimuli per second is the most effective.

A technical note is necessary here. An analysis time of 15 ms is generally appropriate when recording ABR in children and adults with hearing thresholds within normal limits as well as with hearing loss under various test conditions, for example, high and low air- or bone-conduction intensity levels, click and tone-burst stimuli, etc.

However, a shorter analysis time of 10 ms should be used when recording ABR at rapid stimulus presentation rates, to avoid the occurrence of two successive stimuli within the same time window.

To illustrate, with a stimulus presentation rate of 91/s, the time interval between successive stimuli is 10.99 ms ($1000 \text{ ms} / 91.1$).

Thus, a 10 ms analysis time is sufficient to record one ABR response without the risk of presenting a second stimulus within the same time period. **Finally, it should be mentioned that the use of high stimulus presentation rates is not routinely applied in the diagnostic process.**

In elderly patient populations, the high-rate technique should be used with caution. **The auditory system of an older individual may be affected by the normal aging process. The neuronal refractory period may require a longer recovery time for auditory information to be processed.** As a result, delays in transmitting this information to the brain and slower neuronal recovery are common. Prolongations in ABR latencies in elderly patients may be due to aging rather than necessarily indicating an auditory pathology.

The high-rate technique is employed to increase ABR sensitivity to neural dysfunction only when the clinician suspects the presence of an abnormality, such as a vestibular schwannoma.





Well-known red flags for possible retrocochlear auditory dysfunction include:

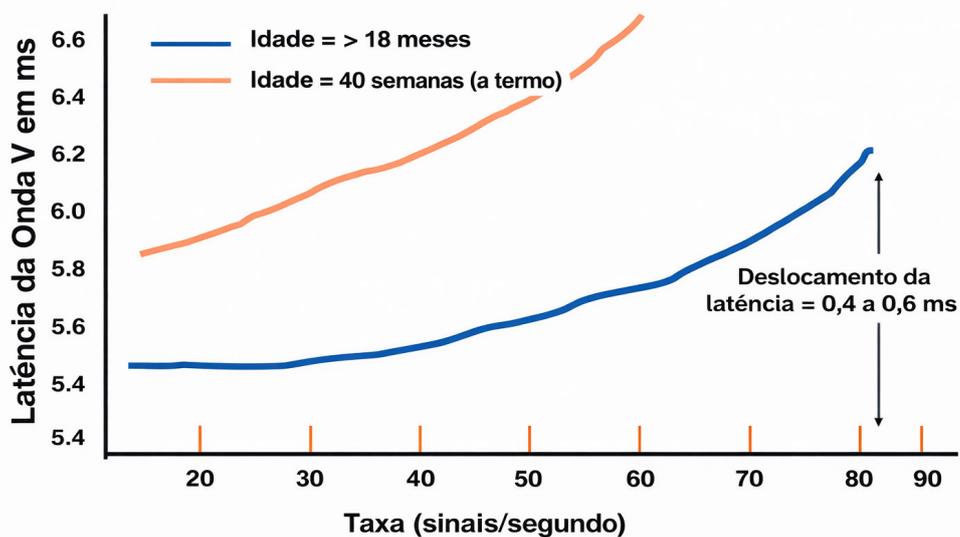
- Unilateral tinnitus;
- Asymmetry in hearing thresholds;
- Asymmetric word recognition scores;
- Or asymmetry in word recognition performance–intensity functions;
- Acoustic reflex abnormalities (e.g., absence, decay, or prolonged latency);
- Normal otoacoustic emissions in the presence of sensorineural hearing loss.



Age and Stimulus Presentation Rate in Pediatric ABR Measurement

Stimulus presentation rate is a critical factor to consider in pediatric ABR assessment, particularly in children under the age of 1.5 years (18 months). There is a clear relationship between maturity of the central nervous system and the effect of rate on ABR. Stimulus rate has a more pronounced influence on ABR latency for premature than term neonates. Changes in ABR latency as a function of stimulus rate are often expressed in units of 10- μ sec per decade of rate. As shown below in **Figure 1**, stimulus rate versus ABR latency slopes are both considerably steeper than the linear latency-versus-rate slope of approximately 35 to 40- μ sec/decade in rate in adults.

Interação do efeito da idade e da taxa de estímulo na latência da onda V da resposta auditiva do tronco encefálico



Source: Hall JW III (2015). eHandbook of Auditory Evoked Responses. New York: Kindle Publishing.

As a rule, the stimulus rate effect is greatest for wave V. This results in a combined effect of young age and rate on the wave I to V interval. Prolonged neural transmission in younger subjects suggests a general neurophysiologic basis for these age-rate-latency interactions related to incomplete myelination and reduced synaptic efficiency. Stimulus rate in older children and adults can be increased to at least 20/second with no resulting effect on ABR latency or amplitude. These age-rate-ABR interactions along with the possible influence of even more factors such as stimulus intensity and polarity must be considered both in developing a normative database, in establishing clinical ABR protocols, and in recording and analyzing ABRs clinically (Hall, 2015).

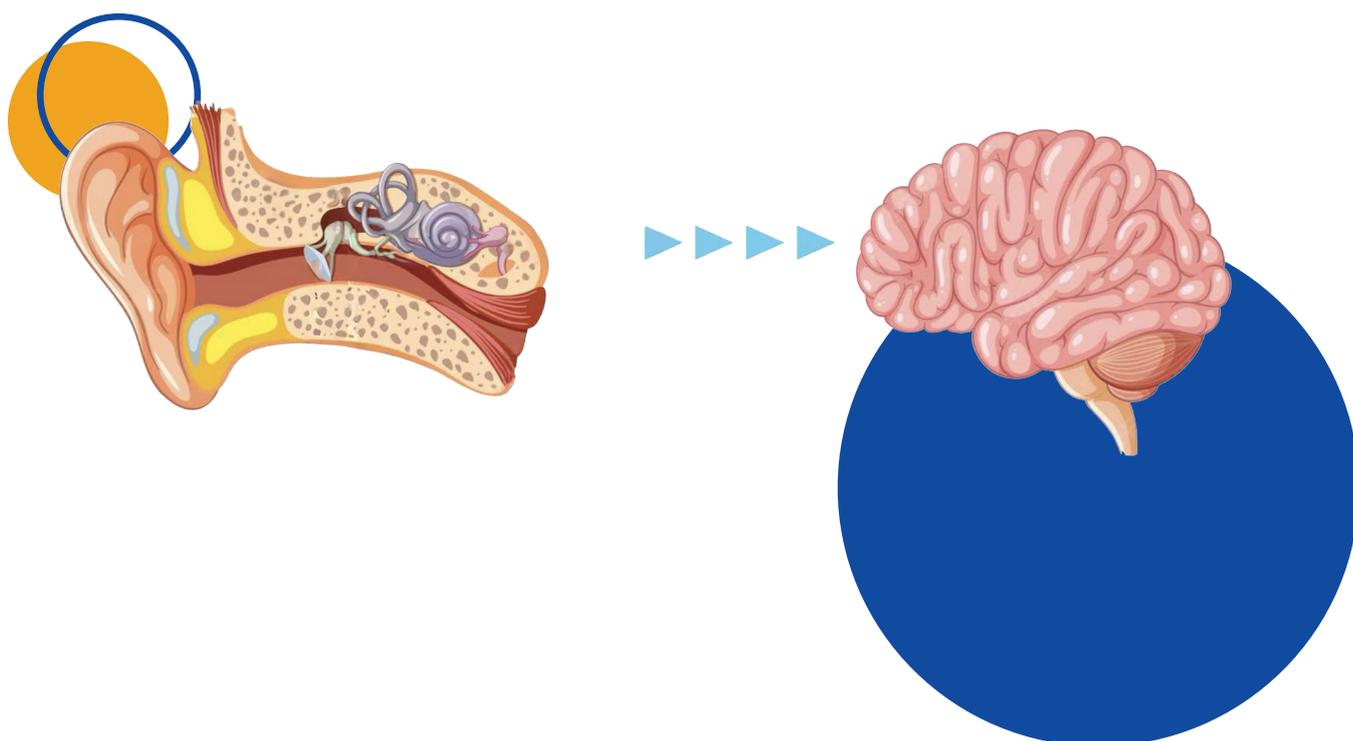


Optimizing Stimulus Presentation Rates to Minimize ABR Test Time

Quick data collection and short test time is critical for pediatric ABR assessments. With highly efficient ABR data collection it is often possible to complete an entire neuro-diagnostic and frequency-specific threshold ABR assessment while a child is sleeping naturally. One of the most effective ways to minimize ABR test time is to use a relatively fast stimulus presentation rate that doesn't change the ABR morphology or latency. A click stimulus.

presentation rate of 21.1 to 27.7/sec is a good choice for quickly recording an optimal ABR for neuro-diagnostic purposes, that is, a reliable response with clear waves I, III, and V.

A faster stimulus rate of 37.7 or 39.7/sec is entirely appropriate for estimating auditory thresholds with tone bursts. The goal with tone-burst stimulation is simply to produce a reliable and easily detectable wave V at the lowest possible intensity level. Detection of wave I is not important. These stimulus presentation rates in pediatric ABR assessment are consistent with evidence-based clinical practice guidelines (e.g., Newborn Hearing Screening Program, 2013).

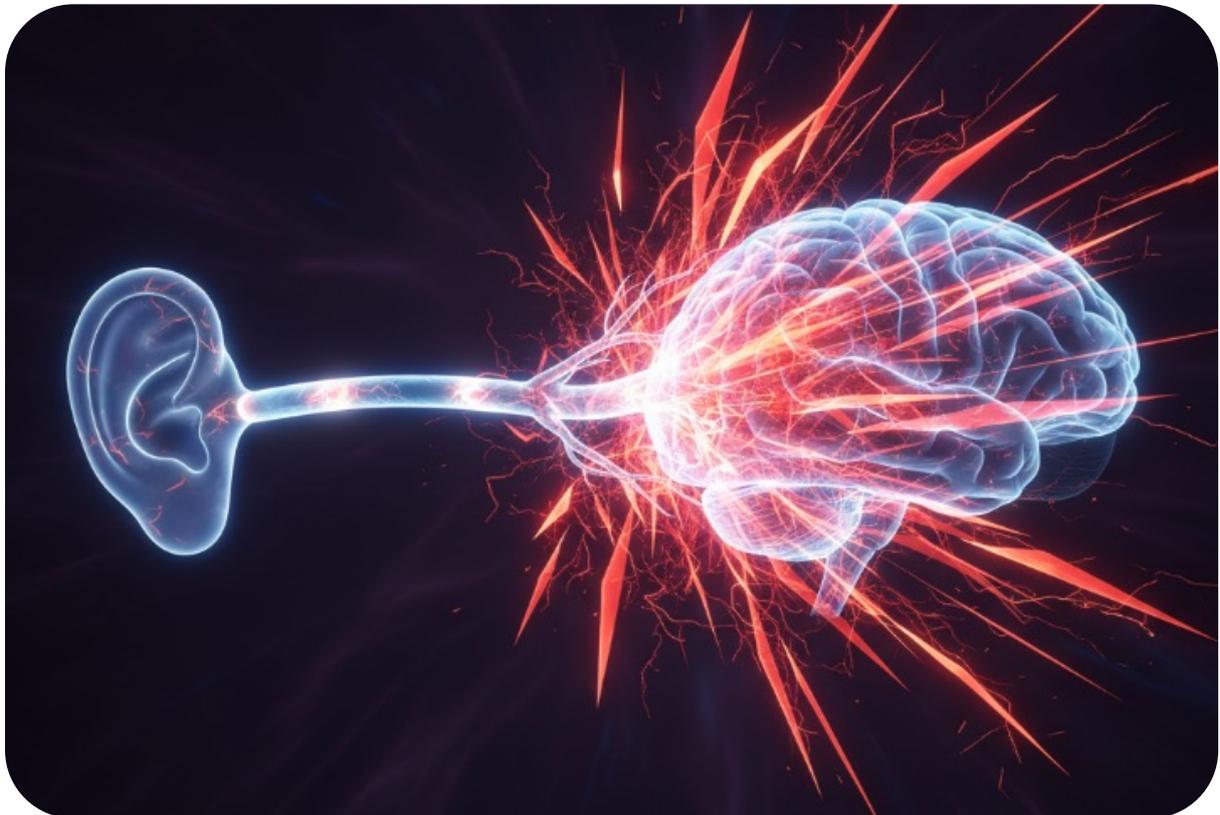
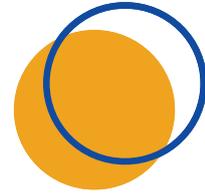




FINAL CONSIDERATIONS

In summary, the appropriate selection of the stimulus presentation rate in any auditory electrophysiological protocol must consider the:

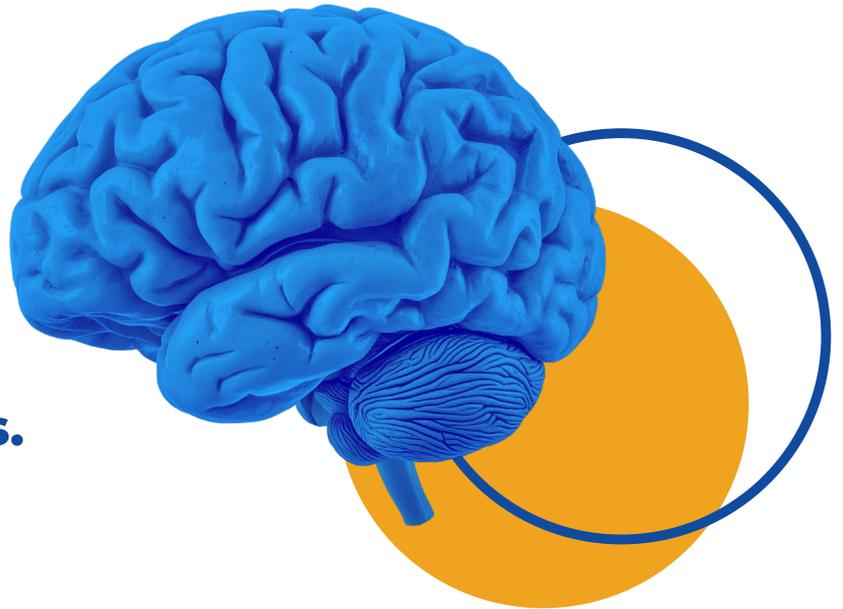
- Specific clinical objective of the test;
- Age of pediatric patients;
- Patient population to be evaluated;
- Acceptable duration of the evaluation;
- Specific auditory evoked response components of clinical interest.



The stimulus presentation rate is only one test parameter to be considered when selecting the auditory evoked potential protocol, keeping in mind that the choice should aim for the most appropriate parameter for a given patient.

Professionals should be familiar with and carefully select the various other stimulus and acquisition parameters available within the auditory evoked potential assessment process.

Test parameters should be evidence-based and consistent with clinical practice guidelines.



And, importantly, during the evaluation of each patient, test parameters should be adjusted as needed to optimize the quality of the evoked potential responses and, of course, to meet the clinical objectives.

We hope this bulletin has clarified important points and answered any practical questions you may have regarding the topic of stimulus presentation rate in the recording of auditory evoked potentials.

If you are interested in learning about or discussing a specific topic, please write to **msanfins@uol.com.br**.

Until our next bulletin!

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