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ELECTROPHYSIOLOGY OF HEARING: EVERYTHING YOU NEED TO KNOW BEFORE STARTING YOUR EVALUATIONS (PART II) – POLARITY OF STIMULI

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ELECTROPHYSIOLOGY OF HEARING: EVERYTHING YOU NEED TO KNOW BEFORE STARTING YOUR EVALUATIONS (PART II) – POLARITY OF STIMULI

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This bulletin aims to deepen knowledge of some theoretical and technical aspects needed for developing appropriate protocols for electrophysiological testing.

Before we do so, we invite you to read part I (bulletin published in March 2025) which discussed a fundamental mathematical concept often used in measuring auditory evoked potentials, the choice of standard deviation. Continuing this line of approach, the current theme is about the polarity of sound stimuli.

Understanding the appropriate use of the polarity of a sound stimulus can help the evaluator make a more definite diagnosis. Increasingly, technology can facilitate neurodiagnosis and auditory assessment; however, for such tools to be effective, the evaluator must have knowledge of some basic science.

There are certain parameters that are fixed and so cannot be modified; however, there are others that need to be configured according to the aim of the test.

Electrophysiological testing is often directed to solving problems or probing uncertainties in the test parameters. More commonly, though, there is a demand for mapping the evaluation criteria of each electrophysiological procedure. Undirected searching for electrophysiological parameters, is however, in large part, is due to a lack of knowledge of the concepts and technical parameters that precede the evaluation.

One parameter that can be adjusted according to the diagnostic objective, and one that can provide pertinent information when well applied, is the polarity of acoustic stimuli. Polarities can be categorized as:

- Stimuli with rarefied polarity (negative)
- Stimuli with condensation polarity (positive)
- Alternating polarity (negative and positive).

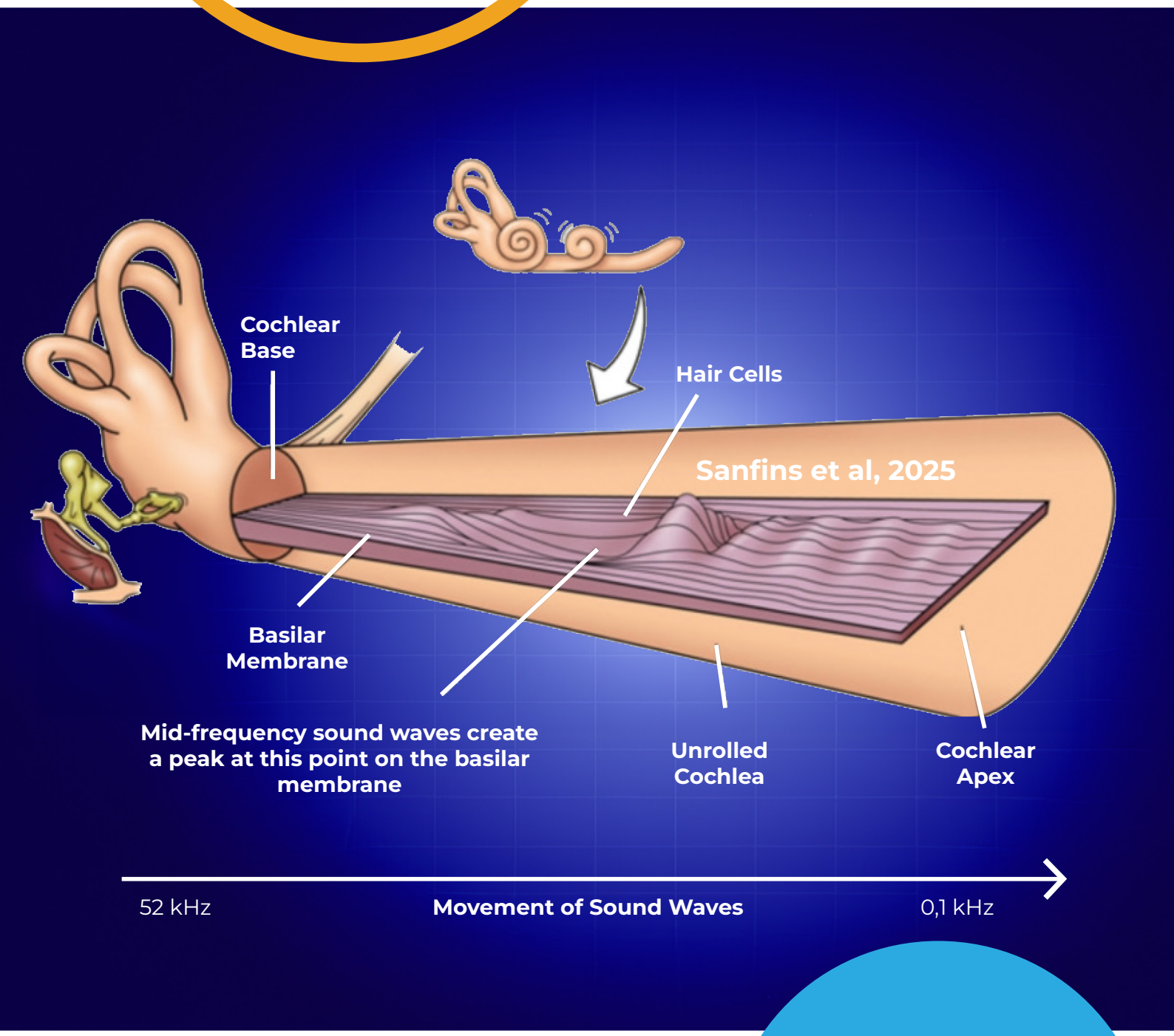
PHYSIOLOGICAL PERSPECTIVE OF POLARITY

The physiology of hearing involves a complex interaction between acoustic stimuli and neural response. The polarity of the sound stimulus, whether it is a rarefaction (negative), condensation (positive), or even an alternating mode (negative + positive), triggers different mechanisms in the auditory system. This movement propagates to the basilar membrane, moving it either upwards or downwards.

Movement of the stapes causes a pressure wave to be transmitted to the cochlea. Pressure inside the cochlea displaces the basilar membrane, which is responsible for converting this vibration into nerve signals. Basilar membrane displacement occurs inside the cochlea, and this movement hyperpolarizes the hair cells, culminating in neural firing and sound perception.

The neural response to these stimuli, especially at low frequencies, exhibits a phenomenon known as "phase blocking". Hair cells tend to fire in sync with a specific phase of the sound wave, contributing to the temporal coding of auditory information.

Thus, in a simplistic way, it can be said that the polarity of the sound stimulus is directly related to the movement of the basilar membrane relative to the other parts of the auditory system.


Cochlear Base
Hair Cells
Sanfins et al, 2025
Basilar Membrane
Mid-frequency sound waves create a peak at this point on the basilar membrane
Unrolled Cochlea
Cochlear Apex
52 kHz
Movement of Sound Waves
0,1 kHz

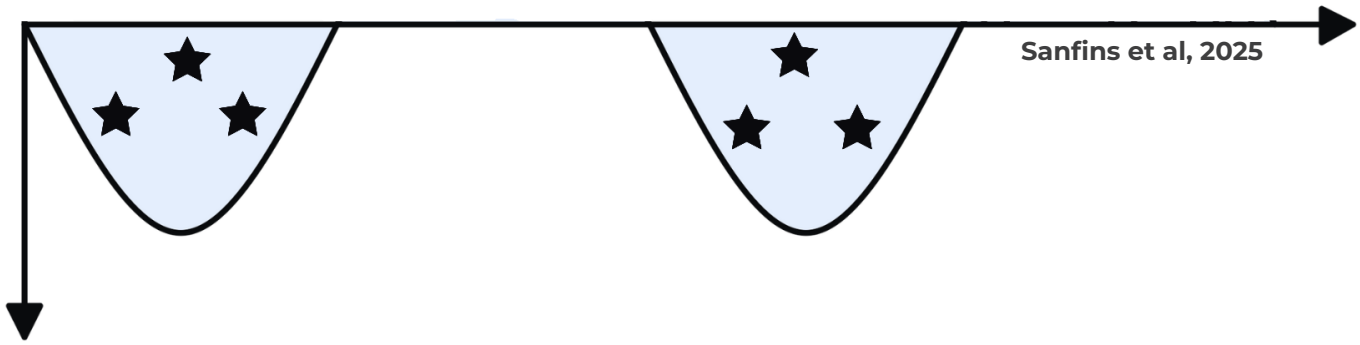
THE USE OF DIFFERENT POLARITIES FOR ELECTROPHYSIOLOGICAL EVALUATIONS

The polarities of the stimuli in the auditory evoked potentials refer to the direction of the electric current that will be applied to the auditory system. The polarity of the sound stimulus affects the way the basilar membrane vibrates and, consequently, the way sound information is encoded and sent to both the peripheral and central auditory nervous systems.

Characteristics of each type of polarity

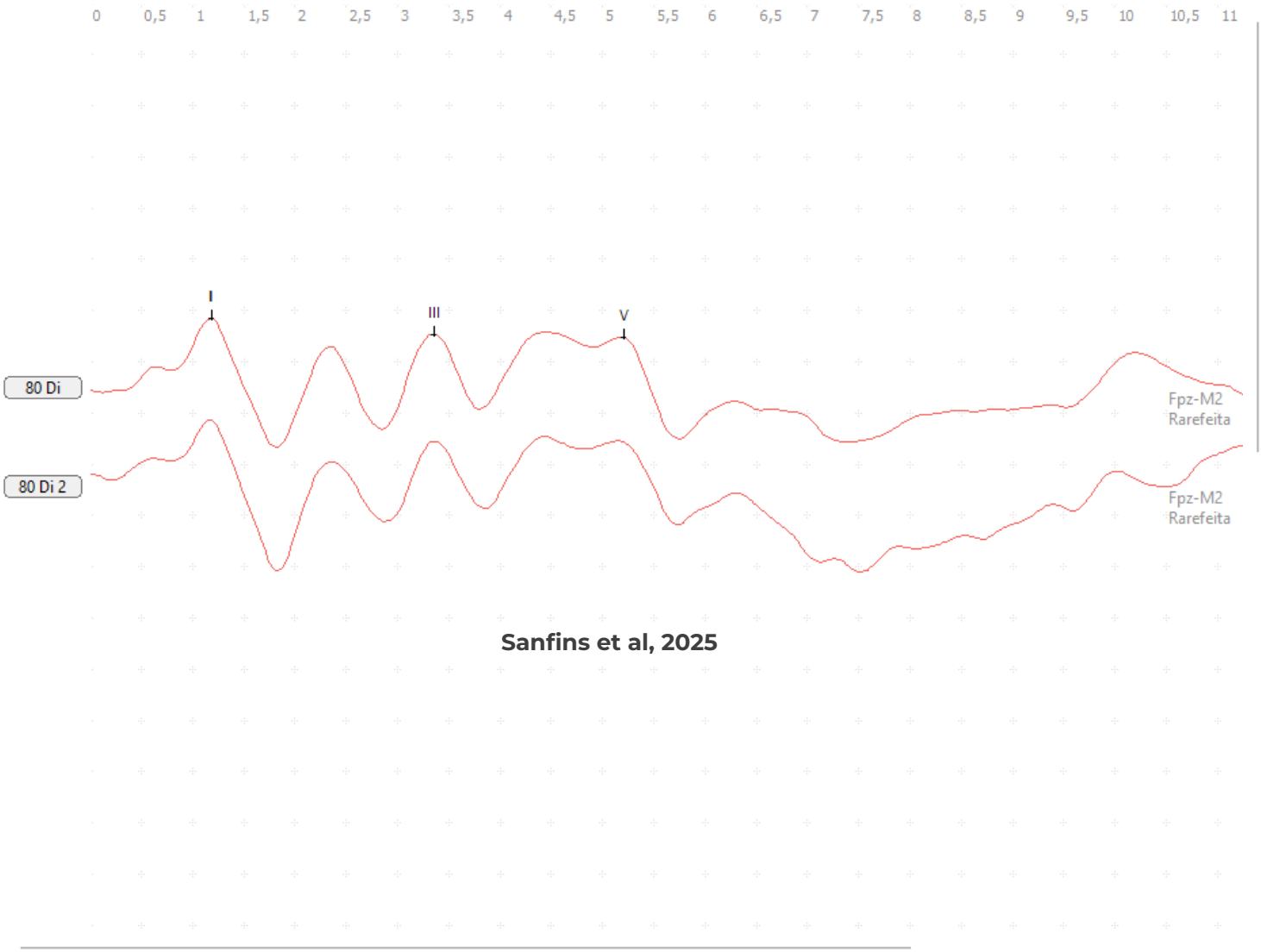
1 RAREFIED POLARITY

In rarefied polarity, the sound stimulus causes the expansion of air, thus promoting the decompression of cochlear hair cells. The rarefied sound has a low sound pressure and causes a slight ripple in the cochlea. Thus, the rarefied sound, as the name implies, involves a smaller number of particles which are more scattered and separated. Because of this, the morphology of acquired waves in rarefied polarity tends to be represented with lower amplitudes and shorter latencies in relation to condensed and alternating polaritiesAssim, de uma forma didática, o som rarefeito, como o próprio nome diz apresenta um número menor de partículas que estão mais espalhadas e distantes em um determinado espaço.



It is also important to note that rarefied polarity is recommended for the assessment of cochlear dysfunctions and peripheral auditory conditions.

A decrease in the amplitudes of the Brainstem Auditory Evoked Potential (BAEP) occurs in all components. It is suggested that the use of stimuli with rarefied polarity has the power to elicit lower frequency neurons that are sensitive to phase differences.



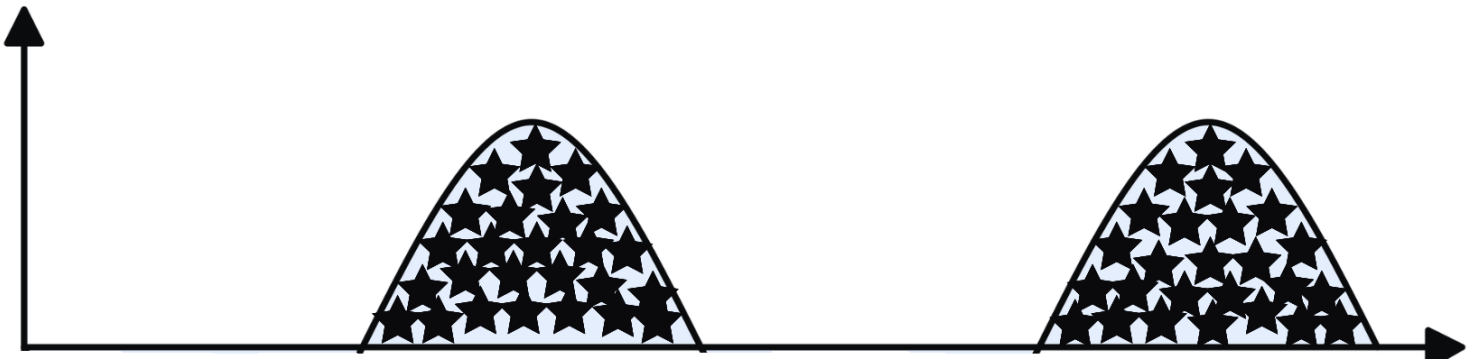
Sanfins et al, 2025

Figure 1: BAEP evaluation with a click-type stimulus with rarefied polarity at an intensity of 80 dBnHL in the right ear of a 35-year-old female patient. Image from the authors' collection.

2 CONDENSATION POLARITY

In condensation polarity, the pressure of the stimulus in the transducer produces an increase in acoustic pressure (reduction of the volume of air in the earphone capsule), an effect which induces compression of the hair cells.

The condensed sound has a high sound pressure and causes a more pronounced undulation in the cochlea and an increase in the deflection of the cilia located in the cochlear cells. Thus, a condensation, as the name implies, presents a greater number of particles that are aggregated and condensed at the same point.



Sanfins et al, 2025

Morphologically, waves with condensation polarity have higher amplitudes, precisely because they have a more intense activation of the brainstem.

Some studies, such as Picton et al. (2003), show that condensed polarity may be more sensitive to detect some conditions and changes in cases of sensorineural hearing loss or cochlear lesions. Additionally, it is important to acknowledge that this polarity can be very useful to improve the reproducibility of responses, which is an essential step for a reliable diagnosis through auditory evoked potentials.

Condensation clicks cause longer latency because they initially produce hyperpolarization of cochlear hair cells followed by depolarization, resulting in longer latencies of BAEP-click components.

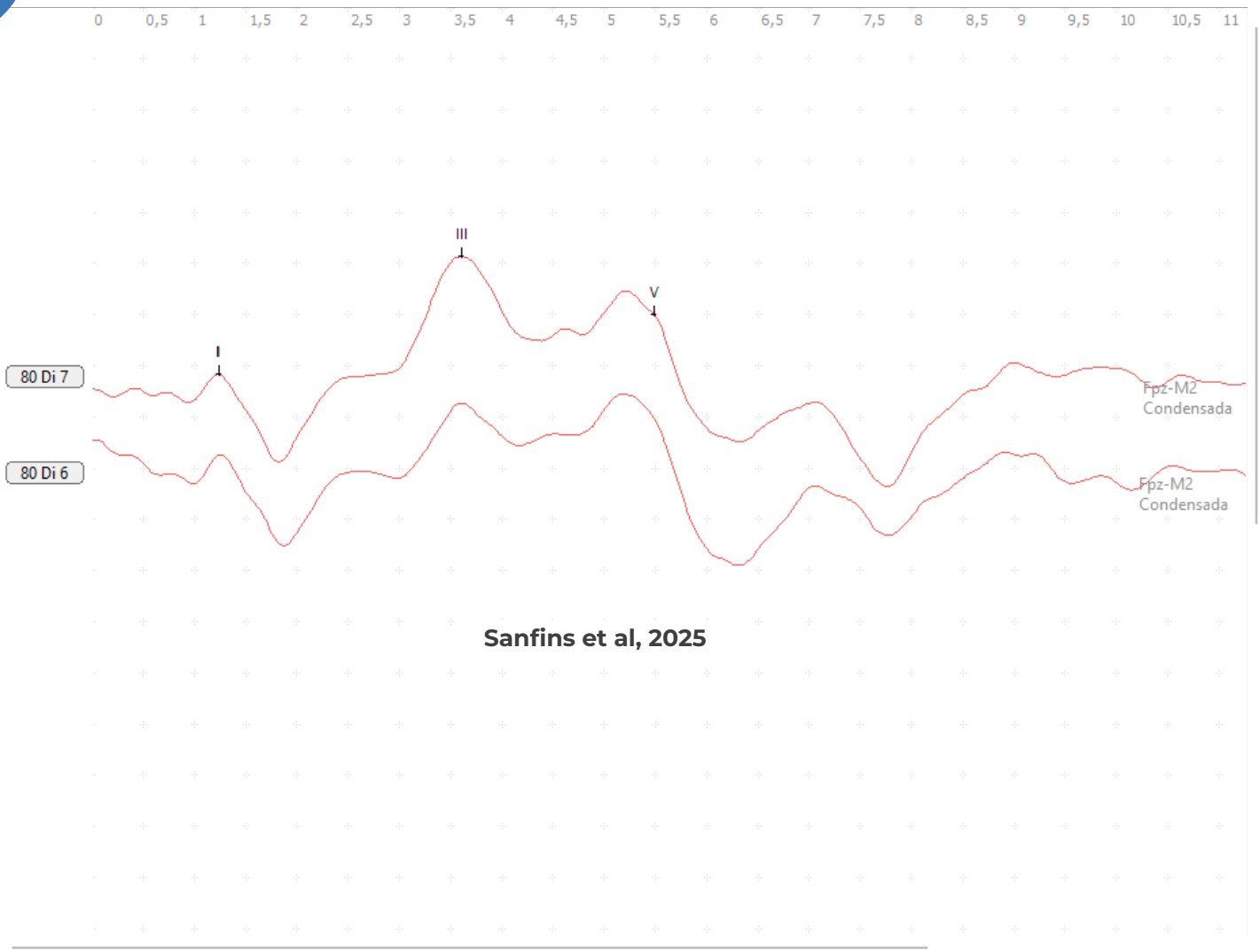
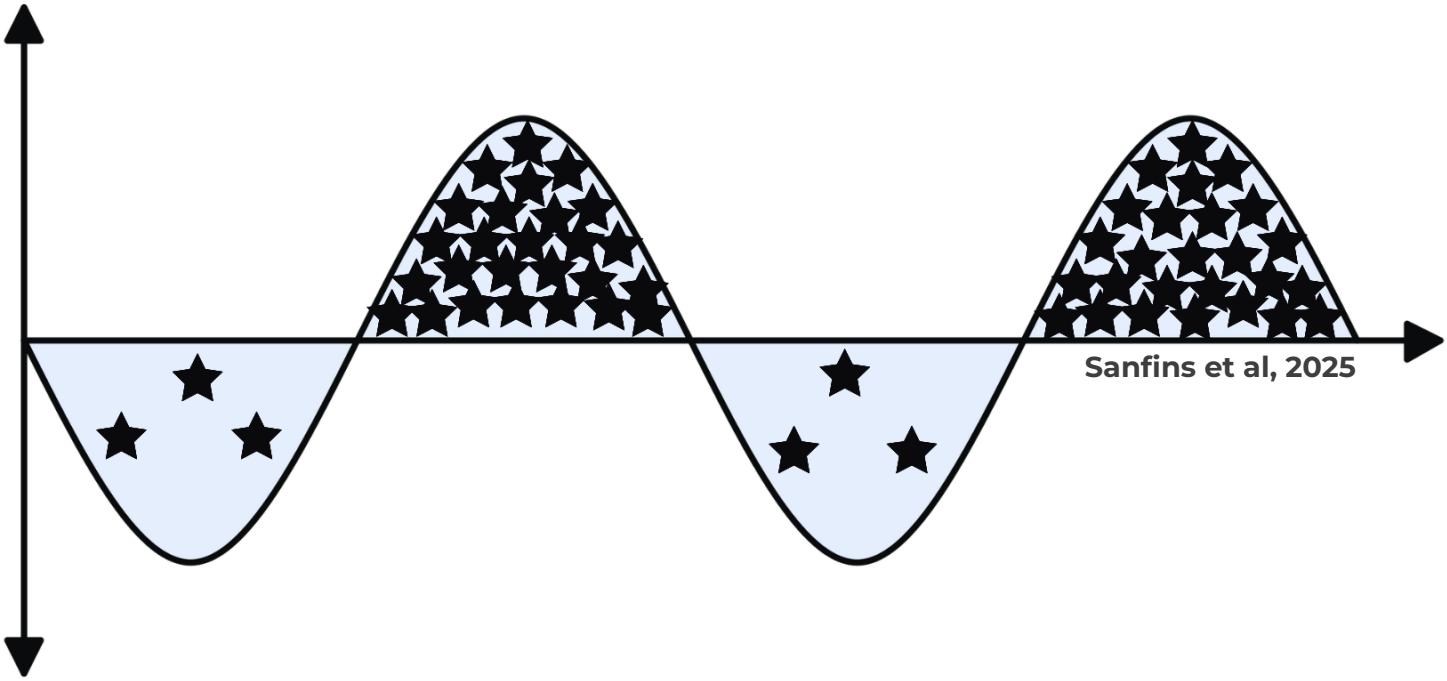


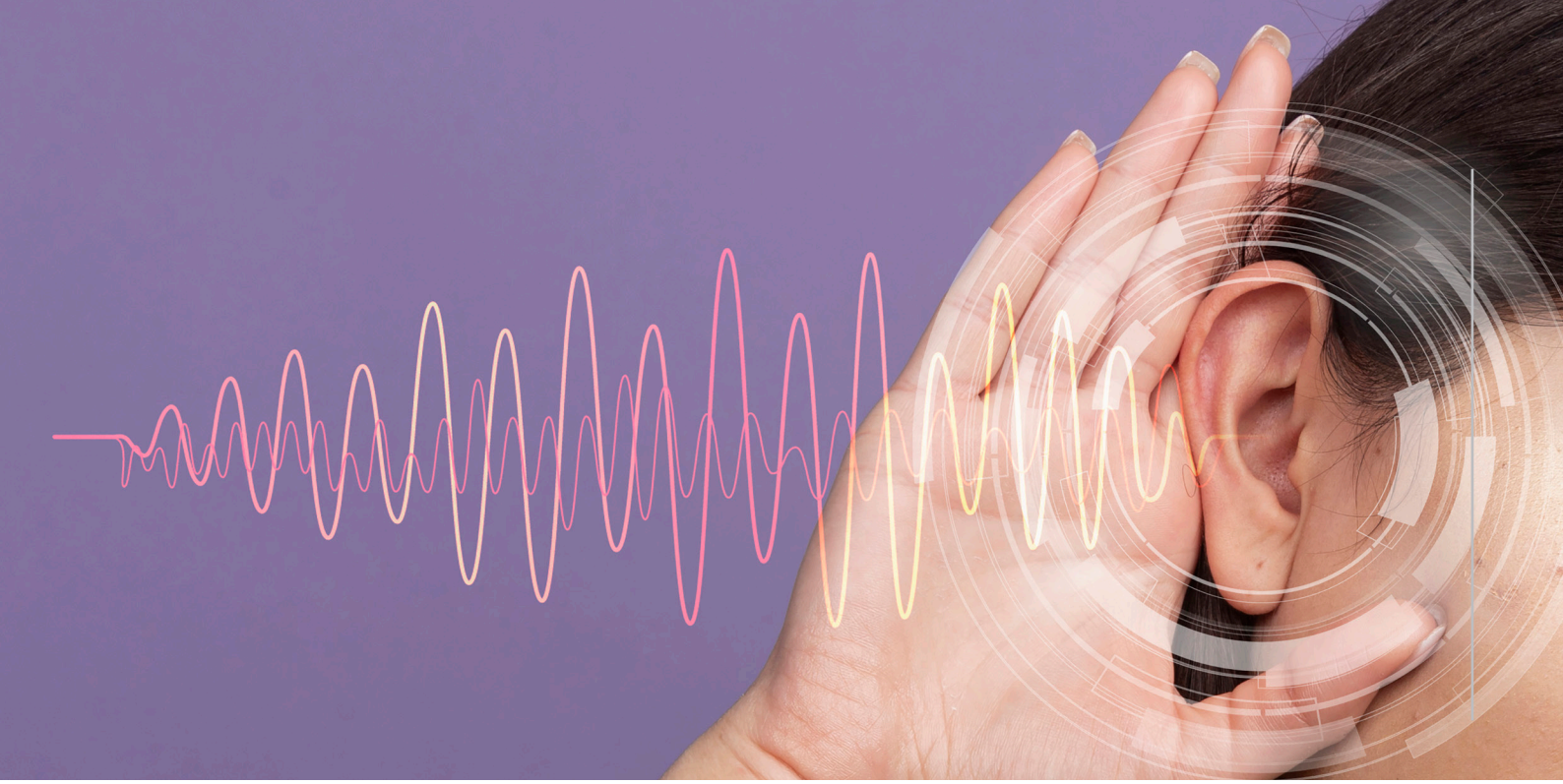
Figure 2: BAEP evaluation with a click-type stimulus with condensed polarity at an intensity of 80 dBnHL in the right ear of a 35-year-old female patient. Image from the authors' collection.

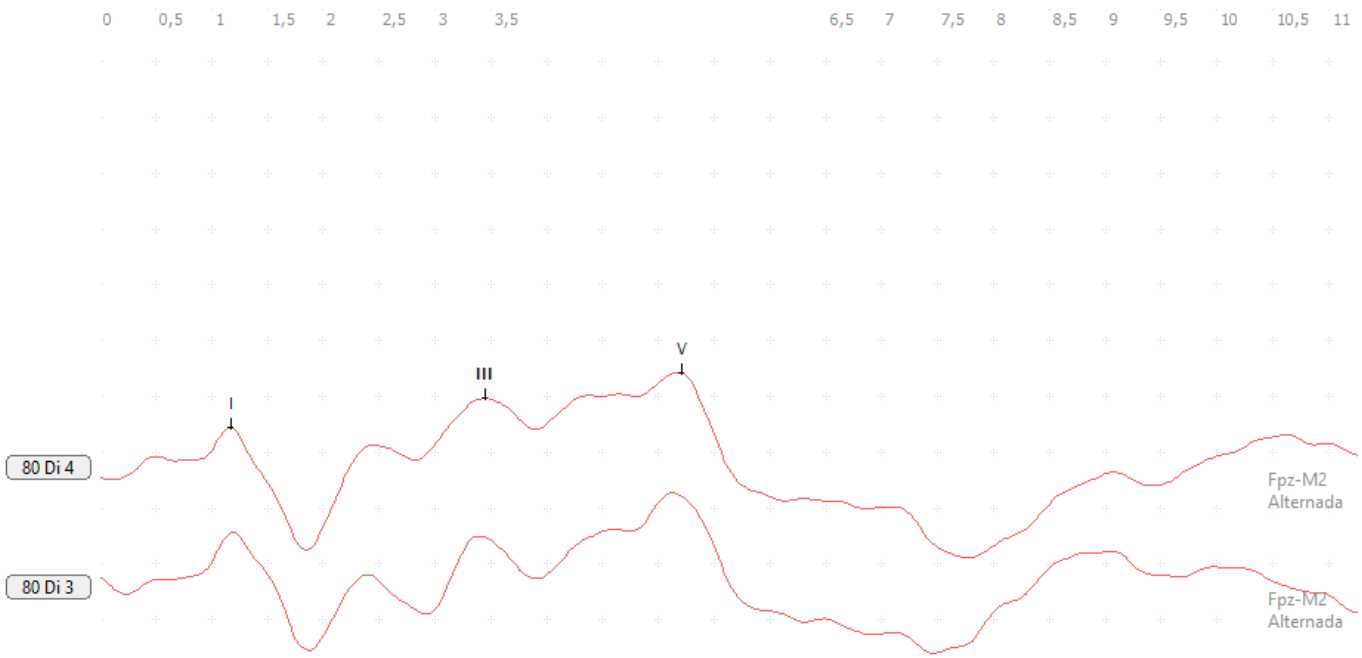
3 ALTERNATING POLARITY

In alternating polarity, there is a variation between condensed and rarefied stimuli in a regular rhythm. The alternation between polarities has gained prominence due to the ability to reduce artifacts and clearly delineate the morphology of the waves. Picton et al. (2003) observed that the alternation between condensed and rarefied stimuli allows the auditory response to be less affected by external interference and noise, which improves brainstem wave discrimination.



The potentials captured with alternating polarity are represented with smaller amplitudes compared to condensed ones. The alternating polarity can be useful for the evaluation of more complex auditory conditions, such as auditory neuropathy.





Sanfins et al, 2025

Figure 3: Evaluation of BAEP with a click-type stimulus with alternating polarity at an intensity of 80 dBnHL in the right ear of a 35-year-old female patient. Image from the authors' collection.

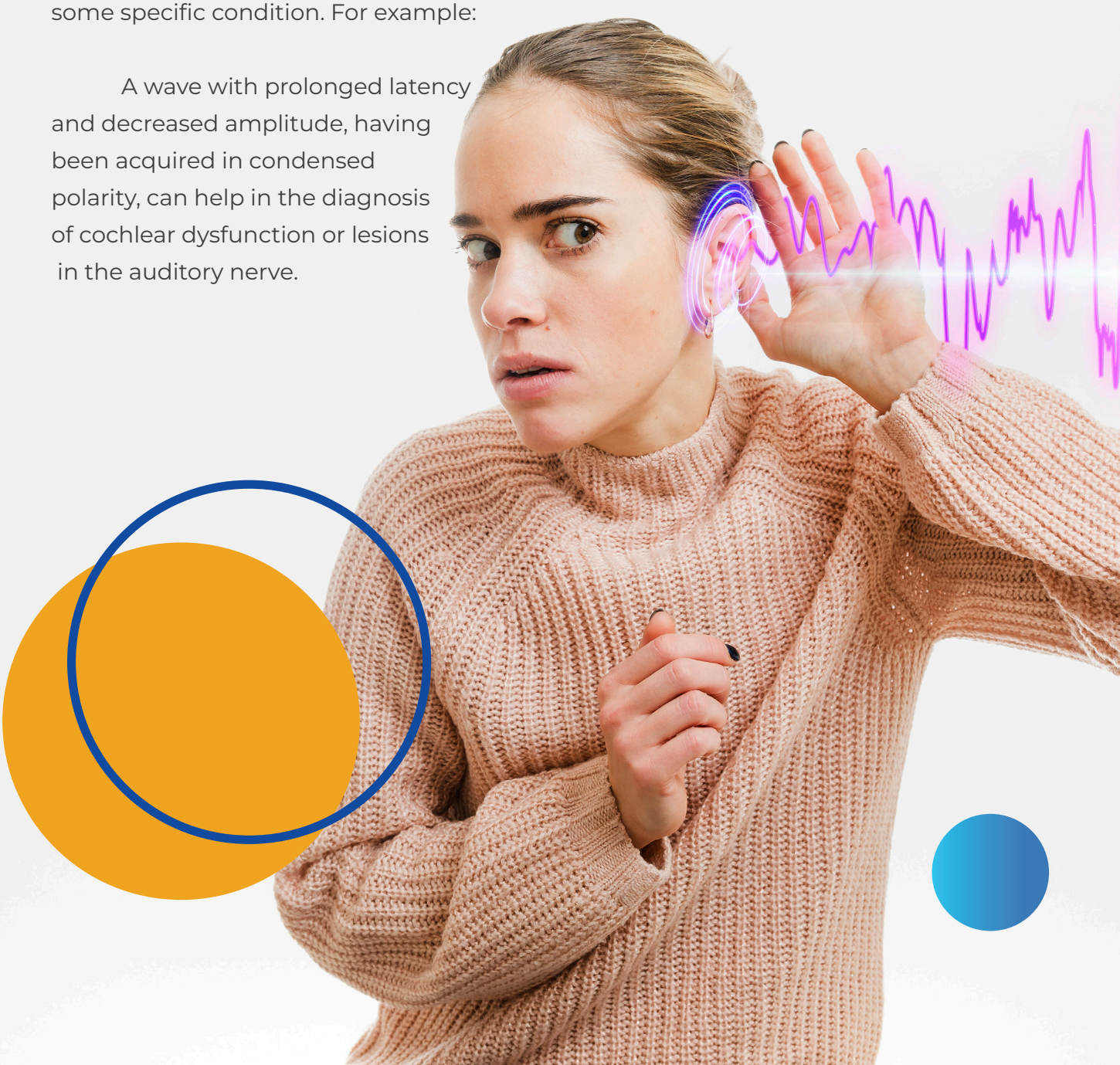
HOW DO DIFFERENT TYPES OF POLARITY AFFECT ELECTROPHYSIOLOGICAL RESPONSES?

- **AMPLITUDES:** When compared, condensation polarity generates waves with higher amplitudes, followed by alternating polarity, which presents waves with an amplitude pattern within the average of the studies. Rarefied polarity, on the other hand, results in waves with lower amplitudes.

- **LATENCIES:** With the change in polarity, the latency of the waves can also be changed. In general, condensation stimuli trigger longer latencies, while stimuli with rarefied polarity have waves with shorter latencies.

These variations may indicate some specific condition. For example:

A wave with prolonged latency and decreased amplitude, having been acquired in condensed polarity, can help in the diagnosis of cochlear dysfunction or lesions in the auditory nerve.



CLICK- ABR WAVES IN DIFFERENT POLARITY TYPES (RAREFIED, CONDENSATION, AND ALTERNATING)

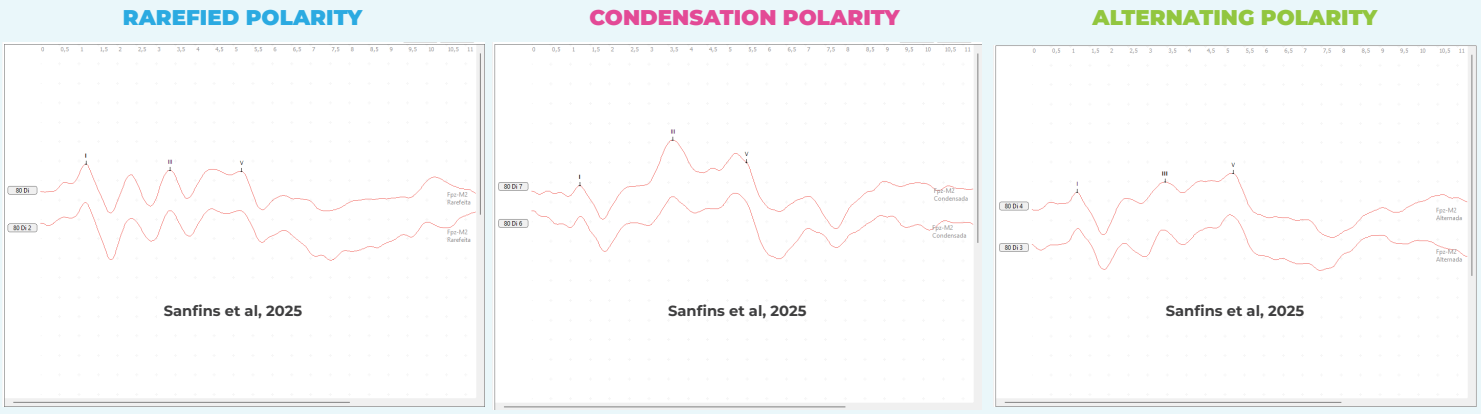
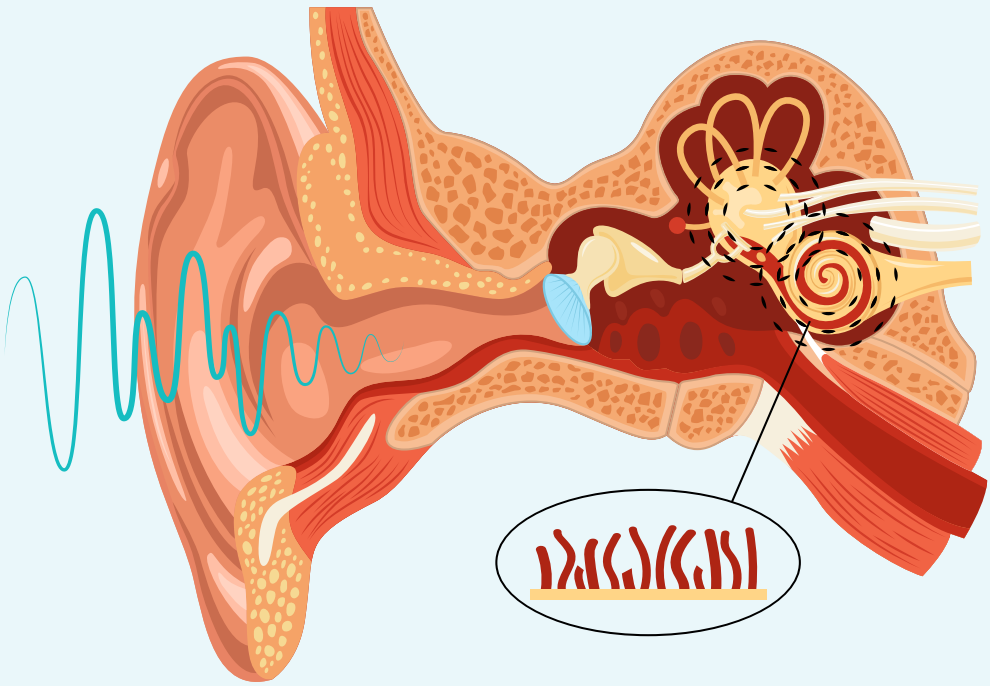


Figure 5: BAEP evaluation with click-type stimulus at an intensity of 80 dBnHL in the right ear of a 35-year-old female patient. Image from the authors' collection. Below are the values of latency, amplitude, and interpeak intervals in the different types of polarity (rarefied, condensation, and alternating, respectively).

TYPE OF POLARITY	WAVE I		WAVE III		WAVE V		INTERVAL I–III	INTERVAL III–V	INTERVAL I–V
	LATÊNCIA	AMPLITUDE	LATÊNCIA	AMPLITUDE	LATÊNCIA	AMPLITUDE			
RAREFIED	1.18	0.50	3.35	0.29	5.20	0.39	0.39	1.85	4.02
CONDENSATION	1.23	0.34	3.60	0.33	5.48	0.50	2.37	1.88	4.25
ALTERNATING	1.16	0.43	3.44	0.11	5.20	0.46	2.28	1.76	4.03



WHAT IS THE DIAGNOSTIC RELEVANCE OF THE USE OF DIFFERENT POLARITIES?

- **Peripheral Hearing Assessment:** In cases of cochlear problems, such as sensorineural hearing loss, condensed polarity analysis can help distinguish conditions such as ototoxicity or Ménière's disease, which more directly affect the cochlea.

- **Central Hearing Assessment:** In the assessment of the central auditory pathways, alternating polarity may be more sensitive to identify conditions such as lesions in the brainstem or upper auditory pathway. Changes in the morphology of the waves associated with this type of polarity can be indicative of neurological disorders, such as multiple sclerosis or traumatic injury.

- **Diagnosis of Auditory Neuropathy:** The analysis of polarities has also been useful in the investigation of auditory neuropathy, a condition in which the communication between the auditory nerve and the brainstem is compromised, and can be more easily observed with alternating polarity, which minimizes the effects of noise and improves the visualization of waves related to the brainstem.

In addition, the literature reports that the choice of using alternating polarity is important for patients in whom cochlear microphonism is suspected. Therefore, the evaluator, knowing this particularity, should perform this parameter change, aiming at a more accurate and precise diagnosis.

CONCLUSION

Studies such as those by Picton et al. (2003) suggest that variations in polarity have a direct impact on diagnostic accuracy, especially when observing responses with less interference from artifacts and greater clarity in wave parameters. These researchers have highlighted how the appropriate use of polarities can optimize the BAEP assessment, especially in cases of central and peripheral auditory discrimination.

Additionally, it is crucial to consider the significance of wave morphology analyses in the process of detecting early hearing disorders, particularly in children.

The analysis of polarities in the BAEP examination is a fundamental component in an auditory evaluation, as it allows a more refined interpretation of the waves and their morphological characteristics.

Condensation, rarefied, and alternating polarities alter the amplitude, latency, and shape of waves, which can provide important information about the nature and location of possible auditory dysfunction, whether peripheral or central.

Use of these polarity options can improve diagnostic accuracy, especially in complex conditions such as auditory neuropathy or central disorders of the auditory nervous system.

SUMMARY OF THE APPROPRIATE CHOICE OF POLARITY FOR SOUND STIMULI:

CLICK-TYPE STIMULUS

- A difference is observed in the latencies and amplitudes of BAEP-click waves when the examination is performed with rarefaction and condensation.
- In a neurodiagnostic evaluation, rarefaction polarity is mostly indicated, since it allows a better visualization of the waves, especially wave I of the BAEP-click.
- The wave I latencies of low-frequency tone responses are sensitive to the polarity of the stimulus, so the use of rarefaction polarity brings benefits.
- In cases of suspicion of Auditory Neuropathy Spectrum, alternating polarity should be used for better visualization of cochlear microphonism.
- The latencies of wave V are hardly affected by the polarity of the stimulus.

ESTÍMULO DO TIPO CHIRP

- The use of different polarities in a chirp stimulus has little or no effect on BAEP. Thus, in practice a chirp of alternating polarity is sufficient to elicit responses. The advantage of alternating polarity is that the processed ABR signal can be observed in real-time while the test is in progress.
- There is an increase in wave V amplitudes between click-type stimuli and LS chirp in the BAEP-click assessment, regardless of the polarities. The increase in wave-V amplitude when using LS chirps is due to improved neural synchrony through time-frequency adjustment.
- Overall, rarefied polarity is recommended for clinical application in the evaluation of BAEP-click and frequency-specific BAEP with the LS chirp stimulus due to the higher peak amplitudes of wave I, III, and V and higher SNR.

VERBAL STIMULUS (SPEECH STIMULUS)

- Although the effect of stimulus polarity has been extensively studied for click and tone burst stimuli, these observations cannot be generalized to complex sounds, such as speech sounds.

- The polarity of the stimulus does not affect the latency of some components in the evaluation of the Frequency Following Response (FFR); however, alternating polarity affects the amplitude of F1 and higher frequencies.

THE CHOICE OF POLARITY IN ELECTROPHYSIOLOGICAL EVALUATIONS

- It is up to the evaluator to understand the physiological mechanisms involved in the different types of polarity. The choice of the evaluator should take into account the studies carried out and how the choice of polarity can help in more accurate diagnostic information.

- The use of different polarities can influence the quality of the Auditory Evoked Potential tracing.

- The appropriate choice can influence the topographic diagnosis of hearing loss.

- There is no time sparing in performing the evaluation when choosing a certain polarity of sound stimulus.

We invite you to follow the next newsletters!
See you soon!

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