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FREQUENCY-FOLLOWING RESPONSE IN THE ELDERLY POPULATION: A SPEECH DECODING ANALYSIS

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Abstract: Goal: Describe the findings of *Frequency-following Response in elderly*. **Methodology:** this research was prospective, quantitative and cross-sectional. All seniors underwent anamnesis, meatoscopy, pure tone audiometry, logoaudiometry, imitanciometry, Edinburgh Manual Dominance Test, Mini Mental State Examination, Central Auditory Processing Assessment, Brainstem Auditory Evoked Potential with click stimulus and *Frequency-following Response*. Due to strict eligibility criteria, the sample consisted of 25 elderly people, aged between 60 and 81, mean age of 66.88 years, 8 men and 17 women. Regarding the audiological characteristics, elderly people with normal hearing thresholds and mild and moderate sensorineural hearing loss were included. **Results:** It was possible to build the reference values for all the variables of the *Frequency-following Response* with speech stimulus, in the elderly, in the equipment: "*Smart EP*" of the brand: *Intelligent Hearing Systems*. **Conclusion:** Descriptive values for the FFR were determined. It is essential that the population and equipment are considered when analyzing the results of this procedure.
Keywords: Elderly; speech perception; neuronal plasticity; *Frequency Following Response*.

INTRODUCTION

The Brazilian population is predominantly formed by young people, but currently, there is a significant growth in the number of elderly people, as well as a greater life expectancy (TRAVASSOS, 2020). This increase occurs worldwide today and entails the need to provide better health care for this population, both structurally and trained professionals, and for this assistance to be beneficial, important knowledge about senescence is required (HUANG, 2022)

There may be difficulties in evaluating the central auditory system of the geriatric population, since both peripheral hearing loss and changes in cognitive function can interfere with the results of such evaluations (JAYAKODY, 2018). In this sense, the relevance of electrophysiological tests is evident, objective procedures that assess the neuroelectric activity of the auditory pathway and that corroborate the measurement of the functional capacity of individuals in the performance of different auditory tasks (BEZ, 2021).

Among the electrophysiological evaluations, the Frequency-Following Response (FFR) stands out for being a different potential, as it presents a response that almost physically replicates the stimulus, demonstrating the integrity of the auditory processing of sound stimuli, as well as providing a response from the subcortical region with probable cortical contributions (COFFEY et al, 2019; MALAVOLTA et al., 2022; WHITE-SCHWOCH T, KRAUS N; 2017).

The FFR has a different clinical scope than the click-evoked Auditory Brainstem Evoked Potential (ABR) (TESSELE, 2022). Click ABR will reflect the neural activity in the auditory pathway from the distal portion of the auditory nerve to the lateral lemniscus, demonstrating with specificity the function of each structure (JACXSENS, 2022). FFR, on the other hand, brings a neurophysiological response at subcortical and cortical levels that precisely reflects the continuous dynamics of the speech sound and can reveal central auditory processing deficits (KRIZMAN, 2019). The clinical potential of FFR is different from BAEP, offering new possibilities in hearing health.

This research is justified by the pertinence of studying the elderly population, diagnosing accurately, in order to rehabilitate with excellence and based on scientific evidence. There is evidence of damage in acoustic signal processing, related to changes in the central auditory pathway in the nervous system due to aging (SARDONA, 2019; TESSELE et al, 2022). Still, there is a need for this study due to the cognitive influences on behavioral responses in this population, which sometimes may not demonstrate the actual performance of individuals.

In this sense, the present research aimed to describe the values for latency, amplitude, slope and interpeaks of the FFR, for elderly people, in the equipment: "*Smart EP*" of the brand: *Intelligent Hearing Systems* (IHS).

METHODOLOGY

STUDY DESIGN

Prospective, quantitative and cross-sectional study, approved by the Research Ethics Committee, under number CAAE 78740117.3.0000.5346. The procedures were performed at the Audiology outpatient clinic of a university hospital, in the pre-pandemic period.

All participants in the sample agreed to participate voluntarily, by explaining and signing the Free and Informed Consent Term and only after participating in the study. It is noteworthy that the research followed all ethical precepts, according to resolution 466/12 of the National Health Council.

The sample calculation was based on a large study in 2015 (SKOE, et al 2015) (standard deviation of the D wave=0.61ms), demonstrating that the use of a sample of 18 subjects would be sufficient.

SAMPLE COMPOSITION

The subjects were invited to socialize groups for elderly people in the city, and the following eligibility criteria were established:

Inclusion criteria:

- Ages 60 and over;
- Both genders;

- Right hand preference;
- Brazilian Portuguese as mother tongue;
- Normality in the Mini Mental State Examination (MMSE);
- No alteration in the assessed auditory skills;
- Minimum three years of schooling, mentioned;
- Tonal auditory thresholds within normal or average standards of 500, 1000, 2000 and 4000 Hz (Hertz) of up to 50 dB (decibels)
- moderate hearing loss, according to the classification of the World Health Organization (World Health Organization-WHO, 2020);
- Symmetrical hearing - difference of up to 10 dB between the auditory thresholds of the right and left ears (NEWTON; ROWSON, 1988).

Exclusion criteria:
- Middle ear alteration;
- History of head or brain trauma (CT), cerebrovascular accident (CVA), evident speech, psychiatric or neurological disorders;
- Perception of chronic tinnitus, configuring a tinnitus disorder;
- Complaint of dizziness;
- Continuous exposure to noise;
- Elderly people who used or use Individual Sound Amplification Devices.

PARTICIPANTS

For sample composition, 113 elderly people were invited. However, 17 showed no interest in participating in the study, six with a history of cerebrovascular accident, three with a history of traumatic brain injury, 10 with middle ear alteration, 14 due to asymmetric hearing loss, three with alteration in cognitive screening (Mini Examination Altered Mental State), three illiterate and 32 for not showing up to finalize the assessments. Thus, a total of 25 seniors participated, aged between 60 and 81, an average of 66.88 years, 8 men and 17 women.

PROCEDURES

For better design and methodological understanding, the procedures were divided into two stages: procedures for sample composition and research procedures.

PROCEDURES FOR SAMPLE COMPOSITION

AUDIOLOGICAL ASSESSMENT

All research participants were initially submitted to a previously structured questionnaire, Visual Inspection of the External Acoustic Meatus, Threshold Tonal Audiometry (WHO, 2020), Logoaudiometry, Acoustic Immittance Measurements (tympanometry and acoustic reflexes) (JERGER, SPEAKS E TRAMEL, 1968).

ASSESSMENT OF MANUAL DOMINANCE

- **Edinburgh Manual Dominance Test:** instrument composed of 10 questions, aimed at the subject's manual preference in daily activities. The score ranges from -100 to +100 points. Subjects with scores between - 100 and - 40 are considered left-handed, mixed from - 40 to + 40 and highly right-handed are those with scores between +40 and 100 (BRITO, 1989).

COGNITIVE SCREENING

- **Mini-Mental State Examination:** applied in order to perform the screening of cognitive functions. The assessment is carried out using five categories: temporal orientation (5 points), spatial orientation (5 points), registration of three words (3 points), attention and calculation

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(5 points), short-term memory with evocation of the three words (3 points), language (8 points) and visuospatial skills (1 point). Thus, the score can vary from 0 to 30 points. For normality values in the cognitive screening, the parameters proposed by Brucki et al. (2003), from 1 to 4 years of schooling - 25 points; from 5 to 8 years of schooling - 26.5 points; from 9 to 11 years of schooling - 28 points; and over 12 years - 29 points.

CENTRAL AUDITORY PROCESSING ASSESSMENT (APAC)

The tests were carried out in the same ATL equipment, connected to a computer and applied at an intensity of 40 dB SPL plus the Tritonal Average - 500Hz, 1000Hz and 2000Hz (PEREIRA AND SCHOCHAT, 2011). For the present study, the following tests were applied: Dichotic Digits Test (DTT), Test of Identification of Dichotic Sentences (DSI), Pattern Test of Duration (TPD) and Frequency (TPF) and the Masking Level Difference (MLD), adopting as reference values those proposed by PEIXE et al., 2020.

ELECTROPHYSIOLOGICAL ASSESSMENT OF HEARING

To realize both potentials, the elderly were comfortably accommodated in a reclining chair. For the placement of the electrodes, the skin was cleaned with an abrasive paste, and they were fixed with an electrolytic paste. Regarding the placements, the reference electrodes were fixed on the left (M1) and right (M2) mastoids, the active (Fz) on the central and upper portion of the forehead, and the ground (Fpz) on the central and lower portion of the forehead. Impedance values were kept equal to or lower than 3KOhms, the number of artifacts did not exceed 10% of the number of stimuli. The equipment used was the "Smart EP" by Intelligent Hearing Systems.

Initially, the click-ABR was performed, with the stimulus presented first in the right ear, then in the left, with a recording window of 12 ms, and a speed of 27.7/s, with a low-pass filter of 3000Hz and a high-pass filter of 100Hz of the EEG, repetition rate 100.0K and a duration of 100 µsec. 2048 sweeps were used, in each stimulation, in the rarefied polarity. The application intensity was 80 dBnHL, but when necessary, it was also performed at 90 dBnHL, due to the presence of peripheral hearing loss. In the analysis of the tracings, the latency, morphology, reproducibility of waves I, III and V, the interpeak intervals I-III, III-V and I-V, as well as the interaural difference of wave V were observed (WEBSTER, 2017). As a result of the dissociation of the ABR findings from those of the FFR, as well as the lack of standardization of this potential and the need for normality in the evaluated auditory skills, the elderly who had alterations or normality in the ABR-click participated in the study (Krizman, 2019).

SEARCH PROCEDURE

To describe the findings on speech decoding in the elderly, the Frequency Following Response (FFR) was performed. For the FFR, the syllable /da/ of 40ms was used, provided by the equipment manufacturer, presented only in the right ear, at an intensity of 80 dBnHL. The recording window was 60ms, with a low pass filter of 3000Hz and a high pass filter of 100Hz for the EEG, with a duration of 125us, rate 10.09/s (SKOE et al., 2010) and the EEG window at 30%. The stimulus was presented in alternate polarity, averaging 6000 sweeps, from two sweeps of 3000 each. The analysis was carried out on the wave resulting from the sum of these two presentations, where we tried to mark waves V, A, C, D, E, F and O. A filter was applied to the tracing, activated as follows: Process; Filter Type; the F/R was set to 19 pnt and bandpass 100 Hz – 2000 Hz

(SANGUEBUCHE et al., 2019).

In marking the waves, latency and neural representativeness were used, with morphology being less considered. It is noteworthy that in the IHS Smart EP, when the cursor is positioned on the resulting wave tracing, the amplitude value is obtained, as well as the zero point, considered as the baseline for marking the waves. Therefore, peak V was only marked when its amplitude was positive and, consequently, valleys were only marked when its amplitudes were negative.

The impossibility of carrying out frequency analyzes on the institution's IHS equipment stands out. However, it was possible to perform latency, amplitude, interpeak (V-A, A-C, C-D, D-E, E-F, F-O, V-O) and slope V/A analyzes. To identify the amplitude of the waves, the cursor at the end of each valley was used. The interpeaks were calculated by decreasing the latency value from one wave to another, while the slope (the relationship between the duration and amplitude of waves V and A) (WIBLE, NICOL, KRAUS, 2004), was calculated by inserting the latency values and amplitude of waves V and A in the following formula, provided by Nina Kraus: (Amplitude V – Amplitude A/Latency A – Latency V).

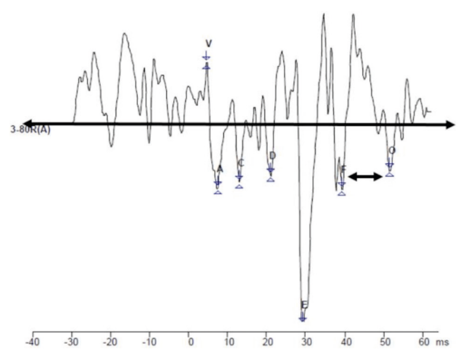

Figure 1: Visual representation of marking of FFR components, related to interpeak and amplitude. The larger arrow is located on the baseline and the smaller one on the interpeak.

Fonte: Image taken from the article by Tessele et al., 2022.

STATISTICAL ANALYSIS OF DATA

The Gauss Curve demonstrates that the use of one standard deviation represents 68.27% of the sample and two deviations represent 95.45% of the studied population. However, due to the great variability found in the elderly, the authors chose to use only one deviation. It is believed that this way, the elderly population can be represented in the best possible way.

RESULTS

The table contains a description of the reference values for latency (ms), amplitude (µV), slope (µV/ms) and interpeaks (ms), from the elderly to the FFR, considering all 25 subjects in the sample.

The description of the values for the FFR in elderly people with normal thresholds up to moderate hearing loss are presented again in charts 1 and 2, together with the standard deviation values. It is suggested the use of a deviation, in the consideration of the reference values.

FFR	Reference values - Latency (ms)	Standard deviation	Reference values - Amplitude (µV)	Standard deviation
Wave V	7,06	1,64	0,35	0,70
Wave A	9,30	2,26	-0,31	0,78
Wave C	18,10	2,00	-0,22	0,26
Wave D	24,80	3,10	-0,10	0,06
Wave E	33,20	2,5	-0,28	0,34
Wave F	41,40	2,70	-0,29	0,37
Wave O	50,90	3,10	-0,15	0,23

Table 1: Descriptive latency and amplitude values for the Frequency-following Response for the elderly population.

Subtitle: FFR: *Frequency-following Response*

FFR		Reference values	Standard deviation
Slope V-A (μV/ms)		0,27	0,45
Interpeaks (ms)	**V-A**	2,25	0,97
	A-C	8,98	2,11
	C-D	6,66	1,89
	D-E	8,73	2,47
	E-F	8,30	2,91
	F-O	9,25	2,09
	V-O	43,70	2,90

Table 2: Descriptive values for the interpeaks and slope, for the Frequency-following Response, for the elderly population.

Subtitle: FFR: *Frequency-following Response.*

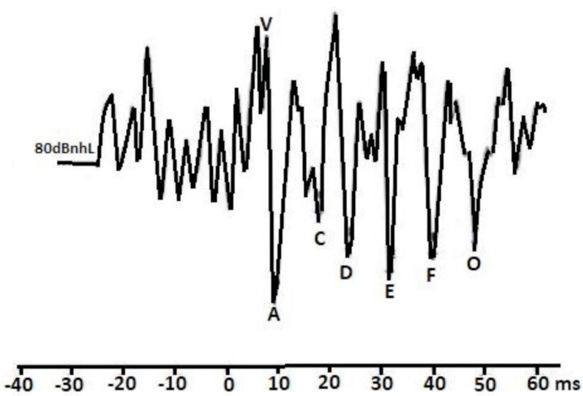

Figure 1. Graphic representation of FFR findings in the elderly population.

Source: author's personal collection

DISCUSSION

The present study is in great agreement with the specialized literature, considering that there is a lack of research aimed at measuring speech decoding in the elderly population. There is significant evidence of impairments in acoustic signal processing, as well as neurophysiological changes in the central auditory nervous system with the aging process (SARDONE, 2019; TESSELE, 2022). Also, cognitive influences on behavioral responses in this population are highlighted, which do not seem to reflect and do not represent the actual performance of individuals (JAIN, 2019; LESSA, 2016; BRUCKMANN, 2022). Thus, the need for this research is clear, which seeks to contribute to the speech therapy clinic for the objective measurement of responses related to speech decoding.

The values shown in charts 1 and 2 are in line with what the literature on the elderly deals with. This population has complaints related to the decline in speech understanding, especially in noisy environments. This type of impairment in auditory function involves several structures of the central auditory pathway and cannot be explained only by hearing loss. In this sense, there is the possibility of using electrophysiological tests, both of which reflect the aging of the central auditory nervous system, demonstrating the auditory functioning in this population (TESSELE, 2022). Thus, with the data from this study, we have evidence to use the FFR in the audiological diagnosis of the elderly.

The findings in tables 1 and 2 confirm what a recent systematic review says, which demonstrated its wide clinical applicability, in different age groups and, mainly, in the correlation with Central Auditory Processing (BASOZ, 2023). The latencies of the present study (Chart 1) are slightly higher when compared to two renowned studies that included the elderly population in their analyzes (Werff, Burns, 2011; Skoe et al., 2015), using software to perform them, using other equipment. This small disparity between the present research and the cited studies (WERFF, BURNS, 2011; SKOE et al., 2015) may be a consequence of the use of different equipment. This fact indicates that IHS can cause higher latencies. Furthermore, no software such as MATLAB and BioMARK were used here. These differences were not attributed to age or the presence of hearing loss, as both studies were carried out with the elderly, of which reference studies in the area also included alterations in auditory thresholds (Werff, Bruns (2011).

It is expected that, when the amplitudes of the elderly are compared with adults, they will be reduced, as is predicted in aging (TESSELE, 2022). However, when this comparison is performed with the amplitudes found in the same equipment, in the adult population, there are different results (Durante et al., 2020), only the D valley presented lower amplitudes (Chart 1).

Studies in the elderly, which exposed the values found for the FFR variables (WERFF, BURNS, 2011; SKOE et al., 2015) did not perform slope analysis, which is the relationship between the duration and amplitude of peak V up to the is worth A (WIBLE, NICOL, KRAUS, 2004). This relationship proves to be affected by aging, when the results are compared with the adult population (KARAWANI, BANAI, 2010; AHADI et al 2014; TAHAEI et al., 2014). Evidencing that the elderly need reference values, in the analysis of the FFR speech.

At the moment, it is not possible to explore the frequency analyzes in the IHS equipment of the institution of the present work, due to the absence of auxiliary software, however, part of the FFR pitch analysis is performed with the values of the D-E and E-F interpeaks, which are similar to the periodicity of the stimulus (CRUTTENDEN, 1997). Pay attention to the proximity of the results, these interpeaks, even when comparing the elderly in the present sample (Chart 2) with adults (DHAR et al., 2009; AHADI et al., 2014). The similarity found between the surveys suggests that the elderly did not present alterations in this analysis, but more research is needed, so that there are comparisons between the same equipment.

The importance of applying electrophysiological tests in the elderly population is evident, since all elderly people need to be carefully evaluated, since many aspects influence their performance, such as sensory deprivation, schooling and cognition, with these issues having a close connection.

CONCLUSION

It was possible to determine the descriptive values for the FFR. It is essential that the population and equipment are considered when analyzing the results of this procedure.

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