

## Review articles

# Behavioral assessment tests for central hearing skills in individuals with sensorineural hearing loss: an integrative review

Letícia Antunes Dias Sousa<sup>1</sup><https://orcid.org/0000-0001-8366-8927>Ayellen do Nascimento Andrade Batista Costa<sup>1</sup><https://orcid.org/0000-0001-8615-4147>Rodrigo Dornelas<sup>1</sup><https://orcid.org/0000-0002-9710-5751>Silvana Maria Monte Coelho Frota<sup>1</sup><https://orcid.org/0000-0003-3439-9681>

<sup>1</sup> Universidade Federal do Rio de Janeiro - UFRJ, Rio de Janeiro, Rio de Janeiro, Brasil.

Conflict of interests: Nonexistent



## ABSTRACT

**Purpose:** to identify the most used tests and the changed hearing skills in the central auditory processing of individuals with sensorineural hearing loss.

**Methods:** an integrative literature review conducted between March and August 2021 in PubMed/MEDLINE, LILACS, SciELO, IBECs, and Index Psi Scientific Journals. The review included studies addressing central hearing skills with central auditory processing behavioral tests in subjects with mild to moderate sensorineural hearing loss. Two independent reviewers made the study selection, data extraction, and qualitative synthesis. The selection aimed at verifying whether the studies answered the research question.

**Literature Review:** 39 studies were found for full-text reading; after applying the eligibility criteria, 13 studies were included in the review. Participants diagnosed with sensorineural hearing loss predominantly had hearing changes in verbal tests, in comparison with normal standards for individuals without hearing loss. Thus, the most changed skills are the ones that depend on speech sound discrimination.

**Conclusion:** the Staggered Spondaic Word Test predominated among the most used behavioral tests, while the most researched central auditory skills were binaural integration and binaural separation.

**Keywords:** Hearing; Hearing Loss; Auditory Perception; Hearing Disorders; Central Auditory, Diseases

Received on: March 25, 2022  
Accepted on: September 30, 2022

**Corresponding address:**

Silvana Maria Monte Coelho Frota  
Hospital Universitário Clementino  
Fraga Filho  
Rua Professor Rodolpho Paulo Rocco,  
255 - Cidade Universitária da Universidade  
Federal do Rio de Janeiro  
CEP: 21941-617 - Rio de Janeiro,  
Rio de Janeiro, Brasil  
E-mail: silfrota@gmail.com

## INTRODUCTION

Changes in auditory system integrity can interfere with people's quality of life, with consequences to their affective, professional, and social lives<sup>1</sup>. Sensorineural hearing loss can result from changes in the structures of the organ of Corti, which consequently lead to neural code dysfunction<sup>2</sup>.

Central auditory processing (CAP) is the set of mechanisms and processes responsible for sound lateralization and localization, auditory discrimination, auditory pattern recognition, temporal aspects of hearing (integration, discrimination, ordering, and temporal masking), and hearing skills with competitive and degraded acoustic signals. The objective of the CAP behavioral test is to assess the effectiveness with which the central nervous system uses auditory information<sup>3</sup>.

Hence, CAP disorder (CAPD) is a hearing change with an impaired ability to analyze and interpret sound patterns, characterized by poor performances in one or more central hearing skills<sup>3</sup>.

Audiological practice routinely uses pure-tone threshold audiometry to establish the type and degree of peripheral hearing changes. To investigate the functioning of the central auditory pathways, CAP behavioral tests and specific electrophysiological tests are recommended<sup>4</sup>.

Auditory-evoked potential tests objectively furnish important information on possible anatomical or functional changes in the central auditory pathways. Behavioral tests, in their turn, measure aspects related to the functioning of hearing skills<sup>5</sup>.

Lesions in the organ of Corti affect hearing acuity. Such peripheral damages may cause a series of changes in auditory system skills, hindering acoustic and speech signal processing, and affecting communication. Hearing loss can have significant perceptual effects, such as increased hearing threshold, reduced dynamic field, discrimination loss, and greater sensitivity to noise. Thus, hearing skill difficulties can coexist with peripheral hearing loss<sup>6</sup>, as central pathway activities can be changed due to cochlear damage.

CAP is widely studied to clarify hearing difficulties of individuals with hearing perception complaints, despite their normal hearing thresholds. Central hearing skills occurring in the afferent and efferent pathways are essential because they help understand the sound message. Difficulties in one or more hearing skills, researched with CAP behavioral tests, can be secondary to peripheral hearing pathway changes<sup>7,8</sup>.

There is a gap in knowledge of hearing skills in individuals with sensorineural hearing loss (SNHL), which hinders the use of robust criteria to seek auditory training tools. Some studies investigated the central processing of sound information in individuals with SNHL; however, no consensus has been reached about which tests should be used and which skills should be researched<sup>4,7,8</sup>.

This study aimed at identifying the most used tests and the changed CAP hearing skills in individuals presented with SNHL.

## METHODS

An integrative review of the literature was conducted to answer the following research question: "Which CAP hearing skills are assessed in individuals with mild to moderate SNHL?"

The question was constructed based on the PCC acronym, in which P – Population, C – Concept, and C – Context. Thus, in this research, P stood for individuals with SNHL; C, for CAPD; and C, for audiological tests.

Original articles that answered the research question were searched between March and August 2021 in PubMed/MEDLINE (Medical Literature Analysis and Retrieval System Online), LILACS (Latin American and Caribbean Health Sciences Literature), SciELO (Scientific Electronic Library Online), IBECS (Spanish Bibliographic Index of the Health Sciences), Index Psi Scientific Journals, and CUMED (Cuban National Center for Medical Science Information). The descriptors "hearing loss" and "central auditory processing" were used in combination with the Boolean operator AND. MEDLINE was accessed via PubMed.

The inclusion criteria were as follows: studies researching central hearing skills with CAP behavioral tests in subjects with mild to moderate SNHL. Studies whose sample had cognitive changes or syndromes that might interfere with the CAP behavioral test results were excluded.

Two independent researchers blindly selected the studies, with no restriction on language, date of publication, or study design. The selection process had three stages (title, abstract, and full-text reading) to verify whether the article answered the research question and met the inclusion and exclusion criteria. No problems occurred in retrieving full-text studies; therefore, their authors did not have to be contacted. The stages in the integrative review are shown in Figure 1.

After selecting the studies, the following data were extracted: author, year of publication, method,

population, intervention, and CAP behavioral test results, which were then organized in an Excel spreadsheet. The qualitative synthesis analyzed the methodology and outcomes of the selected articles. The extraction instrument was adapted from previous studies.

## LITERATURE REVIEW

The search strategy identified 1,574 records. After reading their titles and abstracts, 805 articles were excluded for not meeting the inclusion and exclusion criteria. After removing duplicates, 39 articles remained for full-text reading, of which 24 were excluded for not meeting the inclusion criteria. Hence, 13 articles were eligible. This integrative review of the literature aimed at identifying the most used CAP behavioral tests and the most changed central hearing skills in individuals with SNHL.

The analysis of data extracted from all articles showed an increase in scientific production addressing the topic, which however only took place in the last 10 years.

The present study sample comprised 13 articles retrieved from the databases (Chart 1). There was variability in the participants' age ranges; nine articles researched adults aged 19 to 59 years<sup>9-13,15-17,19</sup>, except for four studies, which had wider age ranges<sup>12,15,17,19</sup>. One article included not only adults but also older adults up to 80 years old to verify, with a greater number, the influence of CAP on speech intelligibility in patients with SNHL<sup>13</sup>. Another three articles (23%) approached a different age range, recruiting participants from 9 to 12 years old<sup>8,17,19</sup>, whose maturational development was enough to be exposed to CAP behavioral test tasks<sup>4</sup>.

Various studies assessed both men and women. Only three articles used this variable as a comparison parameter – males participated in two of them<sup>11,20</sup>, and females in one of them<sup>15</sup>. It was concluded that sex did not influence the test results.

Two studies were selected regarding age groups<sup>12,17</sup> whose results can be filtered to include only participants who met the criteria and dismiss results of participants younger than 9 years or older than 59 years. The results of children less than 9 years old may be influenced by immaturity, and those of older adults can have possible aging effects on the central auditory nervous system, besides the SNHL<sup>7,21</sup>.

<sup>23</sup>. Since this study did not aim to observe only the effects of presbycusis on hearing skills, the age filter was rather encompassing to demonstrate that possible

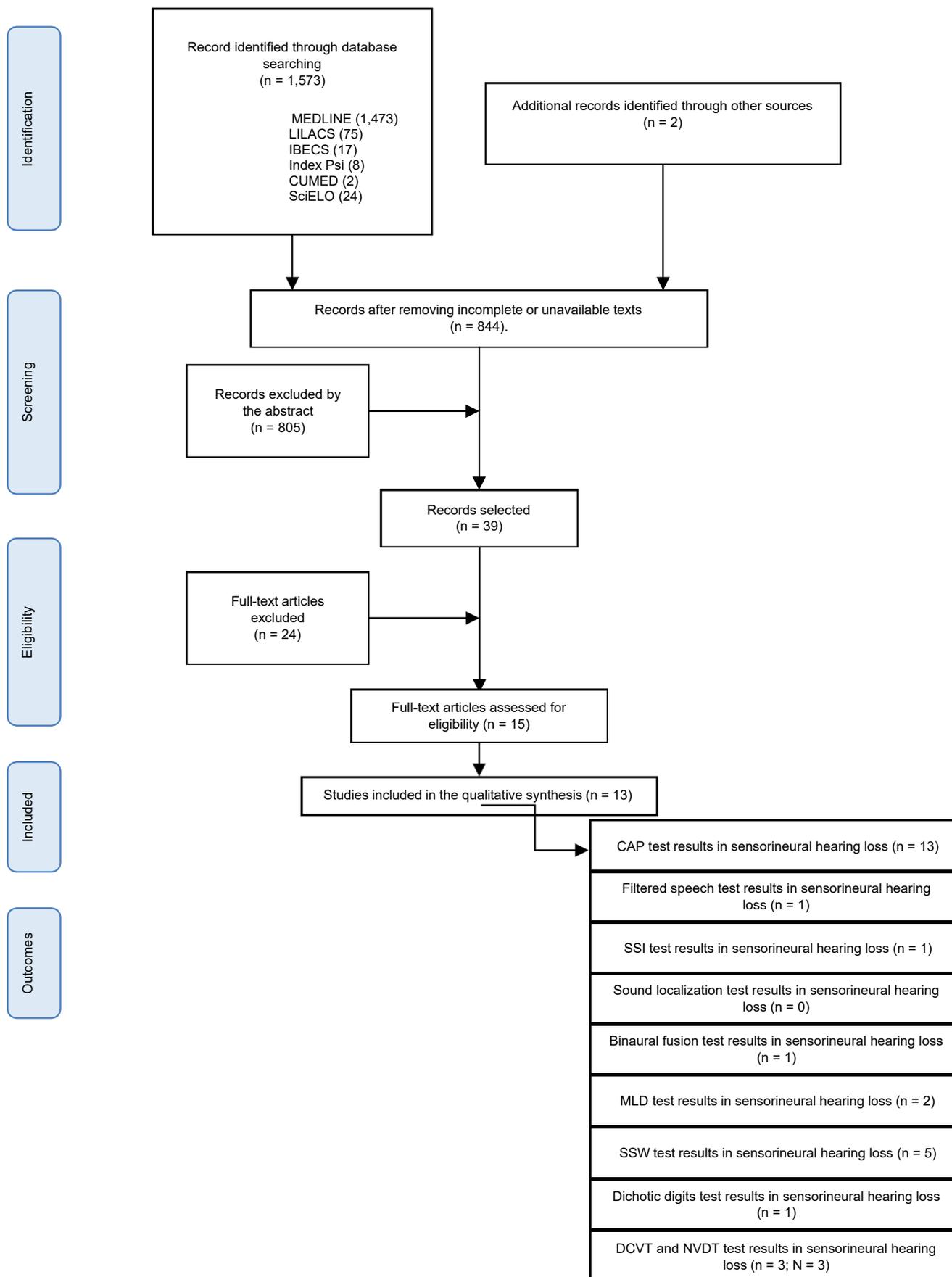
abnormal results in CAP behavioral tests are not explained only by the aging of the peripheral hearing system. Thus, it shows that young and adult individuals with mild to moderate SNHL may have abnormal behavioral test results<sup>12-20</sup>.

Although educational attainment is important to understand CAP behavioral tests highly focused on language (e.g., SSW)<sup>23</sup>, most articles did not assess it and therefore it was not included in data collection. Low cognitive and cultural reserve levels can affect comprehension in tests, but most articles did not assess this criterion. Only one article (7.6%) mentioned educational attainment in data analysis, which however did not influence test results<sup>14</sup>.

The 13 selected studies surveyed participants' medical histories and performed basic audiological assessments on them. These procedures were used as criteria in all studies – knowing the pure-tone hearing thresholds of patients submitted to behavioral tests is one of the CAP assessment prerequisites. They furnish plausible responses to auditory stimuli, which must be adjusted to the air-conduction pure-tone thresholds. Peripheral hearing loss influences the central auditory system<sup>6</sup>; thus, the medical history and basic audiological assessment results are important to understand the possible influence of the peripheral auditory system on hearing skills, based on CAP behavioral tests. CAP assessments can be made in patients with bilateral symmetric mild to moderate SNHL. These tests must be qualitatively and cautiously interpreted because of the absence of adjustments and standardization in the tests used to diagnose and assess these skills<sup>4</sup>.

Another criterion used in the 13 pieces of research was that individuals could not have cognitive or neurological impairments. Most articles selected in this study did not describe cognitive tests in their methods. Only one study used the Mini-Mental State Examination, which however did not influence the behavioral test results<sup>14</sup>. Cognitive and linguistic skills are known to be necessary to comprehend required test tasks. However, the only article with older adults<sup>12</sup> did not use cognitive assessments as a CAP assessment prerequisite. This may lead to imprecise results, as it cannot be established whether low scores were due to cognitive difficulties understanding commands or the tested skills were indeed affected by SNHL.

Two out of the 13 articles selected in this study were national ones<sup>8,11</sup>, while the other 11 were international ones. Two<sup>20,21</sup> of them used auditory brainstem response (ABR) as a participant inclusion criterion.



**Figure 1.** Flowchart with article selection stages. This review comprised 13 studies, which were divided according to the study outcomes present in them (some studies approached more than one outcome).

**Chart 1.** Characteristics of selected studies with the description of the central auditory processing assessment in individuals with sensorineural hearing loss

Author/Year	Participants	Objective	Intervention	Outcomes
Matos GGO, Frota S (2013) <sup>9</sup>	57 individuals (20 to 59 years old) Men and women	To assess the temporal resolution skill in adults with mild to moderate SNHL and verify whether this loss influences test performance.	Gaps-in-noise detection test (GIN)	The temporal resolution skill is not influenced by SNHL in either the gap detection thresholds or the percentage of correct answers, in either ear.
Sanguibuche TR et al. (2018) <sup>10</sup>	8 participants (46 to 58 years old) Men and women	To correlate ABR findings with behavioral tests in adults with moderate SNHL.	Random Gap Detection Test (RGDT), Masking-Level Difference (MLD), and auditory brainstem response (ABR)	No statistically significant correlation was found between ABR and the behavioral tests (RGDT and MLD). This shows that the electrophysiological assessment does not depend exclusively on the tested skills. Regardless of whether they had hearing loss, RGDT and MLD results were not abnormal when respectively assessing the temporal resolution and binaural interaction skills.
Santos CCS, Juchem LS, Rossi AG (2008) <sup>11</sup>	41 military (31 to 51 years old) Group A (n = 16), without SNHL Group B (n = 25), with mild to moderate SNHL Men	To assess the CAP in the military exposed to occupational noise.	Filtered speech (FS), Staggered Spondaic Word in Portuguese (SSW), and Frequency Patter Test (FPT)	The temporal ordering skill assessed with FPT was not influenced by peripheral hearing losses. The auditory closure skill assessed with FS was influenced by SNHL, with a significant difference only in the right ear. The binaural integration skill performance assessed with SSW was abnormal in both groups.
Boboshko MY et al. (2018) <sup>12</sup>	20 participants (31 to 80 years old) with symmetrical moderate to severe SNHL Men and women	To assess the degree to which the central auditory pathway function influences speech intelligibility in patients with moderate to severe SNHL.	Binaural fusion (BF), Random Gap Detection Test (RGDT), and Synthetic Speech Intelligibility (SSI)	The tested skills were influenced according to age, degrees of speech intelligibility, and impaired hearing loss.
Best V et al. (2017) <sup>13</sup>	11 individuals without SNHL (19 to 30 years old) 8 individuals with bilateral moderate SNHL (20 to 39 years old). Men and women	To assess the binaural separation skill in hearing subjects with SNHL to verify whether this loss influences test performance.	Dichotic consonant-vowel test (DCVT)	The binaural separation skill performance assessed with DCVT was abnormal in individuals with mild to moderate hearing loss.
Fischer M et al. (2017) <sup>14</sup>	1,697 participants with and without SNHL (21 to 59 years old) Men and women	To assess binaural integration and separation skills in hearing subjects with and without mild to moderate SNHL to verify whether this loss influences test performance.	Filtered speech (FS), Staggered Spondaic Word in Portuguese (SSW), and Nonverbal Dichotic Test (NVDT)	There were substantial variations in SSW scores and insignificant variations in right-ear NVDT scores. The binaural integration skill assessed with SSW was influenced by SNHL, whereas the binaural separation skill assessed with NVDT was not influenced by SNHL.
Roverud E et al. (2016) <sup>24</sup>	14 individuals (28 to 40 years old) G1: 7 with SNHL G2: 7 without SNHL Men and women	To assess the temporal ordering skill in individuals with and without symmetrical moderate to severe SNHL.	Frequency Pattern Test (FPT)	The temporal ordering skill assessed with FPT was not influenced by moderate to severe SNHL. Abnormal performance in both groups only in the presence of masking noise.
Maeda Y et al. (2016) <sup>15</sup>	1 individual (10 years old) Woman	To assess binaural interaction and integration skills in a hearing 10-year girl with bilateral moderate SNHL.	Binaural Fusion (BF) and Staggered Spondaic Word in Portuguese (SSW)	The binaural interaction and integration skills assessed with SSW and BF were influenced by moderate SNHL.
Hedrick M et al. (2015) <sup>16</sup>	14 participants (20 to 27 years old). G1: normal hearing in the RE. G2: mild to severe SNHL. Men and women	To determine the influence of hearing loss in vowel slice perception through binaural integration assessment.	Staggered Spondaic Word in Portuguese (SSW)	The binaural integration skill assessed with SSW was influenced by moderate to severe SNHL.
Koravand A, Jutras B. (2013) <sup>17</sup>	40 participants (9 to 12 years old). G1: SNHL G2: CAPD G3: normal hearing Men and women	To assess the binaural separation skill.	Nonverbal Dichotic Test (NVDT) and Dichotic Consonant-Vowel Test (DCVT)	Individuals with SNHL had impaired binaural separation skills when recalling verbal stimuli /ba/ and /da/. Results varied according to the degrees of hearing loss. Hence, results cannot be generalized among people of this same group.

Author/Year	Participants	Objective	Intervention	Outcomes
Gallun F et al. (2012) <sup>18</sup>	65 participants (44 to 64 years old) 36 (study group) 29 (control group) Men and women	To assess temporal resolution, temporal ordering, binaural integration, and binaural interaction skills in individuals exposed and nonexposed to explosions.	Gaps-in-Noise Detection Test (GIN), Frequency Pattern Test (FPT), Staggered Spondaic Word in Portuguese (SSW), Dichotic Digits Test (DD), and Masking-Level Difference (MLD)	The binaural integration skill assessed with SSW is significantly influenced by SNHL. The temporal resolution, temporal ordering, binaural interaction, and binaural integration skills, respectively assessed with GIN, FPT, MLD, and DD are not significantly influenced by SNHL.
Koravand A, Jutras B, Roumy N (2010) <sup>19</sup>	26 participants (8 to 12 years old) 13 with mild to moderate SNHL 13 with normal hearing. Men and women	To assess the binaural separation skill with the DCVT and NVDT in individuals with mild to moderate hearing loss to verify whether the hearing loss influences test results.	Nonverbal Dichotic Test (NVDT) and Dichotic Consonant-Vowel Test (DCVT)	SNHL can influence a significantly poorer performance in DCVT and NVDT assessing the binaural separation skill than in individuals without hearing loss.
Zamysłowska-Szmytke E et al. (2009) <sup>20</sup>	109 participants (19 to 64 years old) G1: 59 (study group) G2: 50 (control group) Men and women	To assess the temporal resolution and ordering skills in adults with mild to moderate SNHL caused by exposure to styrene, to verify whether this loss influences test performance.	Gaps-in-Noise Detection Test (GIN), Frequency Pattern Test (FPT), and Duration Pattern Test (DPT).	The temporal resolution skill assessed with GIN is not influenced by mild to moderate SNHL. The temporal ordering skill assessed with DPT and FPT is not influenced by mild to moderate SNHL.

Captions: SSI: Synthetic Speech Intelligibility. MLD: Masking level difference. SSW: Staggered Spondaic Word. NVDT: Nonverbal Dichotic Test. DCVT: Dichotic Consonant-Vowel Test. GIN: Gap-in-Noise Detection Test. RGDT: Random Gap Detection Test. FPT: Frequency Pattern Test. DPT: Duration Pattern Test. CAP: central auditory processing. CAPD: central auditory processing disorder. SNHL: sensorineural hearing loss. ABR: auditory brainstem response

However, only one correlated it with two behavioral tests (RGDT and MLD) and concluded that no statistically significant correlation existed between them<sup>21,22</sup>. Hence, there is an evident scarcity of articles thoroughly verifying and investigating with behavioral and electrophysiological tests.

Electrophysiological and electroacoustic procedures are likewise relevant because they assess the neural pathways from the cochlear nerve to the upper regions (e.g., the auditory cortex) and favor the differential diagnosis between CAPD and other disorders.

Abnormal results due to SNHL were found in nine studies<sup>11-15,17</sup>. The analysis of these findings shows that the abnormal results in verbal behavioral tests were the only aspect they had in common. Furthermore, the seven articles without statistically

significant differences between subjects with and without SNHL were based on findings of nonverbal test results. This shows that behavioral skills assessed with nonverbal tests are not influenced by SNHL<sup>8,11,13,14</sup>.

The auditory processing SSW test is criticized because of its high focus on language and cognition and the recording problems for clinical use, which can make auditory responses uncertain<sup>23</sup>. Patients with SNHL have abnormal SSW results, but it cannot be stated whether they are due to hearing loss and language processing difficulties or a dichotic hearing

issue. No CAP test aims to confirm either hearing loss or language or cognition disorders; hence, analyzing them alone rather than in combination with other tests of the battery leads to inconclusive results.

This research observed that SSW was the CAP behavioral test most used to assess individuals with mild to moderate SNHL. Even though this test is no longer recommended to comprise the minimum battery<sup>23</sup>, it may have been used for being one of the oldest CAP behavioral tests. According to the test most used in the surveyed studies, binaural integration and binaural separation are the most changed CAP skills. The currently most recommended CAP behavioral assessment approach in individuals without hearing loss includes a battery of behavioral tests with at least one of them assessing monaural low-redundancy hearing, dichotic hearing, temporal

processing, and binaural integration<sup>23</sup>.

However, uniform CAP test protocols have not yet been defined to assess hearing skills in individuals with SNHL. Each study made random choices, without necessarily assessing the four recommended modalities (monaural low-redundancy hearing, dichotic hearing, temporal processing, and binaural integration), and used different numbers of tests per battery, ranging from one to five of them. Therefore, available data are

still insufficient to understand the correlation between mild to moderate SNHL and hearing skill changes.

The literature has not yet described or suggested a minimum battery of behavioral tests considered the gold standard to assess central auditory pathways in individuals with SNHL – which leads to controversies. The consequences of not having an adequate, standardized instrument to assess hearing skills in this population with hearing loss may prevent uniform research on hearing skills – which in turn hinders the progress of research on treatments and rehabilitation.

## CONCLUSION

The findings in this study show that participants diagnosed with SNHL predominantly have hearing changes in verbal tests, in comparison with normal standards established for normally hearing individuals. Thus, the most changed skills are the ones that depend on speech sound discrimination. No consensus was found in the number of tests used in the batteries, which ranged from one to five tests. SWW was the most used behavioral test, and binaural integration and binaural separation were the most researched central auditory skills.

## REFERENCES

- Teixeira CF, Griz SMS. Sistema auditivo central. In: Bevilacqua MC, Martinez MAN, Balen SA, Pupo AC, Reis ACMB, Frota S, editors. *Tratado de Audiologia*. São Paulo: Santos; 2011. p.17-27.
- Auditory neuropathy: clinical, diagnostic and therapeutic aspects [homepage on the internet]. Available at: <http://www.sborl.org.br/>. Accessed 2021 mar 1.
- Simões MB, Schochat E. Transtorno do processamento auditivo (central) em indivíduos com e sem dislexia. *Pró-Fono R Atual. Cient.* 2010;22(4):521-4.
- Lacerda CF, Silva LO, de Tavares Canto RS, Cheik NC. Efeitos da adaptação às próteses auditivas na qualidade de vida, no equilíbrio e no medo de queda em idosos com perda neurosensorial. *Int. Arch. Otorhinolaryngol.* 2012;16(2):156-62.
- Parra VM, Iório MCM, Mary MM, Baraldi GS. Testes de padrão de frequência e de duração em idosos com sensibilidade auditiva normal. *Braz J Otorhinolaryngol.* 2004;70(4):517-23.
- Magni C, Freiburger F, Tonn K. Evaluation of satisfaction measures of analogical and digital hearing aid users. *Rev Bras Otorrinolaringol.* 2005;71(5):650-7.
- Fonseca GCR, Costa-Ferreira MDO. The performance of the elderly with neurosensorial hearing loss in auditory processing tests: a longitudinal study. *Rev. CEFAC.* 2015;17(3):809-18.
- Fernandes C, Matos Silva C, Alves AR, Prata C, Rocha C, Martins JH. Central auditory processing in elderly people: preliminary results. *Gazeta Med.* 2019;6(3):147-53.
- Magni C, Freiburger F, Tonn K. Avaliação do grau de satisfação entre os usuários de amplificação de tecnologia analógica e digital. *Rev Bras Otorrinolaringol.* 2005;7(5):650-7.
- Fernandes LCBC, Gil D, Maria SLS, Azevedo MMF. Brainstem auditory evoked potential in subjects with sensorineural hearing losses. *Rev. CEFAC.* 2013;15(3):538-45.
- Santos CCS, Juchem LS, Rossi AG. Processamento auditivo de militares expostos a ruído ocupacional. *Rev. CEFAC.* 2008;10(1):92-103.
- Boboshko MY, Berdnikova IP, Garbaruk ES, Salakhbekov MA, Mal'tseva NV. The influence of central auditory processing on the intelligibility of the speech in the patients presenting with hearing impairment. *Vestnik Otorinolaringologii.* 2018;83(2):4-8.
- Best V, Mason CR, Swaminathan J, Roverud E, Kidd G. Use of a glimpsing model to understand the performance of listeners with and without hearing loss in spatialized speech mixtures. *J. Acoust. Soc. Am.* 2017;141(1):81-91.
- Fischer ME, Cruickshanks KJ, Nondahl DM, Klein BEK, Klein R, Pankow JS et al. Dichotic digits test performance across the ages: results from two large epidemiologic cohort studies. *Ear and Hearing.* 2017;38(3):314-20.
- Maeda Y, Nakagawa A, Nagayasu R, Sugaya A, Omichi R, Kariya S et al. Pediatric central auditory processing disorder showing elevated threshold on pure tone audiogram. *Auris Nasus Larynx.* 2016;43(5):570-4.
- Hedrick M, Charles L, Street ND. Vowel perception in listeners with normal hearing and in listeners with hearing loss: a preliminary study. *Cli. Exp. Otorhinolaryngol.* 2015;8(1):26.

17. Koravand A, Jutras B. Auditory temporal-organization abilities in school-age children with peripheral hearing loss. *JSLHR*. 2013;56(4):1065-74.
18. Gallun FJ, Diedesch AC, Kubli LR, Walden TC, Folmer RL, Lewis MS et al. Performance on tests of central auditory processing by individuals exposed to high-intensity blasts. *J. Rehabil. Res. Dev.* 2012;49(7):1005-24.
19. Koravand A, Jutras B, Roumy N. Peripheral hearing loss and auditory temporal ordering ability in children. *Int. J. Pediatr. Otorhinolaryngol.* 2010;74(1):50-5.
20. Zamyslowska-Szmytko E, Fuente A, Niebudek-Bogusz E, Sliwinska-Kowalska M. Temporal processing disorder associated with styrene exposure. *Audiol. Neuro-Otol.* 2009;14(5):296-302.
21. Sanguebuche TR, Peixe BP, Bruno RS, Biaggio EPV, Garcia MV. Speech- evoked brainstem auditory responses and auditory processing skills: a correlation in adults with hearing loss. *Int. Arch. Otorhinolaryngol.* 2018;22(1):38-44.
22. Cielo CA, Beber BC, Maggi CR, Körbes D, Oliveira CF, Weber DE et al. Disfonia funcional psicogênica por puberfonia do tipo muda vocal incompleta: aspectos fisiológicos e psicológicos. *Estudos de Psicologia.* 2009;26(2):227-36.
23. Conselho Federal de Fonoaudiologia. Avaliação e Intervenção no Processamento Auditivo Central [homepage on the internet]. 2020 [accessed 2021 mar 1]. Available at: [https://www.fonoaudiologia.org.br/wpcontent/uploads/2020/10/CFFa\\_Guia\\_Orientacao\\_Avaliacao\\_Intervencao\\_PAC.pdf](https://www.fonoaudiologia.org.br/wpcontent/uploads/2020/10/CFFa_Guia_Orientacao_Avaliacao_Intervencao_PAC.pdf).
24. Roverud E, Best V, Mason CR, Swaminathan J, Kidd G Jr. Informational masking in normal-hearing and hearing-impaired. Listeners measured in a nonspeech pattern identification task. *Trends Hear.* 2016;20:1-17.