Revista CEFAC

eISSN 1982-0216

DOI: 10.1590/1982-0216/20242613823 | Rev. CEFAC. 2024;26(1):e3823

Review articles

Central auditory processing and aphasia: A scoping review

Raquel de Oliveira Bezerra[1]
Ana Cecília de Brito Vidal Santos[1]
Daviany de Oliveira Lima[2]
Ivonaldo Leidson Barbosa Lima[3]
Marine Raquel Diniz da Rosa[2]

[1] Centro Universitário de João Pessoa, João Pessoa, Paraíba, Brasil.
[2] Universidade Federal da Paraíba - UFPB, João Pessoa, Paraíba, Brasil.
[3] Universidade Federal do Rio Grande do Norte - UFRN, Natal, Rio Grande do Norte, Brasil.

ABSTRACT

Purpose: to report scientific evidence on the impact of aphasia on central auditory processing and map the contribution of auditory training to aphasic individuals.

Methods: a scoping review approaching national and international databases (SciELO, LILACS, PubMed, Scopus, and Cochrane Library) and the gray literature (Google Scholar and Open Grey). The inclusion criteria covered articles that addressed the interface between central auditory processing and aphasia, excluding duplicates, literature reviews, and scientific abstracts.

Literature Review: the review comprised 13 articles that met the eligibility criteria for this study. Seven of the selected articles assessed central auditory processing, four used electrophysiological examinations (such as auditory brainstem response and long-latency auditory evoked potentials) to assess the auditory pathway, and only one analyzed the intervention in aphasic individuals with auditory training.

Conclusion: scientific evidence points to an important change in aphasic people's central auditory processing, with impaired figure-ground, auditory closure, temporal resolution and ordering, and binaural integration. Moreover, it is relevant to assess auditory processing, given the contribution of auditory training in speech-language-hearing therapy for a better prognosis in the rehabilitation of aphasia.

Keywords: Auditory Perception; Auditory Pathways; Acoustic Stimulation; Aphasia

A study conducted at the Centro Universitário de João Pessoa, João Pessoa, Paraíba, Brazil.

Financial support: Nothing to declare.

Conflict of interests: Nonexistent.

Corresponding author:
Raquel de Oliveira Bezerra
Rua Valdomiro Figueiredo de Souza, 52
CEP: 58073178 - João Pessoa, Paraíba, Brasil
E-mail: raquelbezerra12@gmail.com

Received on: May 13, 2023
Accepted on: October 23, 2023

INTRODUCTION

Central auditory processing (CAP) is the neural processing of auditory stimuli and how the nervous system contributes to the use of auditory information. It is what a person does with what they hear[1]. After detected by the inner ear, the sound goes through several physiological and cognitive processes, so that it is decoded and understood in the brain. These processes comprise a set of auditory skills on which the individual depends to interpret the sound message[2].

The auditory skills that make up the CAP are sound localization and lateralization (the ability to identify the sound source), auditory discrimination (the ability to differentiate one sound from another), auditory pattern recognition (the ability to perceive similarities and differences between acoustic patterns), temporal aspects of hearing (the ability to process acoustic stimuli as a function of time), figure-ground (the ability to focus on the message in the presence of competing stimuli), auditory closure (the ability to recognize speech when parts are being omitted or distorted), and binaural aspects of hearing (the ability to process acoustic stimuli presented to both ears)[2].

Therefore, having intact hearing thresholds is not enough; the acoustic signal must also be analyzed and interpreted to transform it into a meaningful message – which makes the organic and functional integrity of the entire auditory system essential[3,4]. The efficient communicative performance begins with detecting and perceiving the auditory stimuli, followed by linguistic analysis of the message in the cerebral cortex[5,6].

Hence, auditory and language processing are known to be mutually dependent to perform their functions, and impairment in either of them, caused by intrinsic or extrinsic factors, such as strokes, traumatic brain injuries, and tumors, can affect both auditory information processing and language understanding and expression[7,8].

Aphasia is language impairment acquired after brain damage, of which the most common is a stroke in the left hemisphere. As a result of the injury, aphasic individuals may have changes in different linguistic skills, such as comprehension, repetition, naming, fluency, reading, and writing[9]. Aphasic individuals' language symptoms have been grouped into aphasic syndromes or types of aphasia[10]. The best-known classification worldwide is the one that divides them into fluent and non-fluent ones. In fluent ones, the aphasic person produces linked speech, with relatively intact sentence structure, but with gaps in meaning. In non-fluent aphasia, speech is produced with pauses, effort, and morphosyntactic impairment, but the content of the words may be preserved[10].

As language is a brain function, the neurological lesions that characterize aphasia can result in a partial or total loss of linguistic skills and impair attention, discrimination, memory, and integration skills[11,12]. These skills are important for language and participate in the process of detecting and interpreting the sound events involved in CAP[13]. Broadly speaking, processes in the central auditory system influence both verbal and non-verbal signals and contribute to higher functions, including language[14,15].

Thus, it can be stated that language and auditory processing are strongly associated with the anatomical-physiological structures of the central auditory pathway. These structures correspond to the brainstem (where the initial phase of auditory processing occurs through signal modulation and integration) and the thalamo-cortical circuit (where the most advanced integration processes occur, and sensory stimuli generate emotional, cognitive, and linguistic responses)[16].

The auditory cortex, which is part of this pathway, has the role of auditory perception and sensation, as well as connection with Wernicke's area, responsible for understanding linguistic aspects. The connection between the auditory cortex and Wernicke's area constitutes the language association cortex, whose function is to interpret meanings and help understand and recognize spoken language[17].

Since neurological injuries are a risk factor for changes in auditory processing, aphasic people are more susceptible to this condition[14]. Therefore, it is greatly important to better understand the association between aphasia and CAP, as the relationship between these skills may contribute to these individuals' diagnosis and speech-language-hearing intervention.

Thus, this study aimed to report scientific evidence of the impact of aphasia on CAP and map the contribution of auditory training to aphasic people.

METHODS

This scoping review followed the step-by-step recommendations of PRISMA-extension for scoping reviews (PRISMA-ScR)[18]. The following research questions were developed to meet the study objective, guide the review, and select the articles: "Is there a relationship between aphasic changes and CAP performance? Can auditory training improve language and CAP skills?".

The research questions were developed based on the elements of the PCC strategy (P – participant, C – content, and C – context), with P (participant) being individuals with aphasia, C (content) being CAP, and C (context) being auditory training.

The research had the following search strategies: selecting descriptors to obtain studies; searching in national and international databases (such as SciELO, LILACS, PubMed, Scopus, and Cochrane Library) and the grey literature (Google Scholar and Open Grey); applying eligibility criteria; reading titles and abstracts; and, lastly, reading the selected studies' full text. There was no restriction on the time of publication to gather all the evidence that met the objective of the study. The Google Scholar search strategy for the grey literature used the first 100 references in the database for all crossed terms. Filters were applied for articles in English and Portuguese, with no restriction on time, to retrieve free articles available in full text. The searches used the AND, OR, and All Fields markers, crossing the English and Portuguese descriptors obtained from the Health Sciences (DeCS) and Medical Subject Heading (MeSH). Chart 1 presents the search strategies used in the databases.

Chart 1. Search strategies used in each database

DATABASE	SEARCH CONDUCTED IN AUGUST 2023
PUBMED	("Aphasia" [All Fields] OR "Processing Auditory" [All Fields] OR "Perception auditory" [All Fields] OR "Auditory Pathways" [All Fields] OR "Auditory Cortex Disorder" [All Fields] OR "Auditory Perception Disorders" [All Fields] OR "Acoustic Stimulation" [All Fields] OR "Auditory Perception correction" [All Fields] OR "Neuronal Plasticity")
LILACS	("Aphasia" AND "Processing Auditory" AND "Perception auditory" AND "Auditory Pathways" AND "Auditory Cortex Disorder" AND "Auditory Perception Disorders" AND "Acoustic Stimulation" AND "Auditory Perception correction" AND "Neuronal Plasticity" AND "Percepção auditiva" AND "Afasia" AND "Processamento auditivo" AND "Vias Auditivas" AND "Transtorno do cortex auditivo" AND "Distúrbios da percepção Auditiva" AND "Estimulação Acústica" AND "Correção da percepção Auditiva" AND "Plasticidade neuronal")
SCOPUS	("Aphasia" AND "Processing Auditory" AND "Perception auditory" AND "Auditory Pathways" AND "Auditory Cortex Disorder" AND "Auditory Perception Disorders" AND "Acoustic Stimulation" AND "Auditory Perception correction" AND "Neuronal Plasticity")
COCHRANE LIBRARY	("Aphasia" AND "Processing Auditory" AND "Perception auditory" AND "Auditory Pathways" AND "Auditory Cortex Disorder" AND "Auditory Perception Disorders" AND "Acoustic Stimulation" AND "Auditory Perception correction" AND "Neuronal Plasticity")
OPEN GREY	("Aphasia" AND "Processing Auditory" AND "Perception auditory" AND "Auditory Pathways" AND "Auditory Cortex Disorder" AND "Auditory Perception Disorders" AND "Acoustic Stimulation" AND "Auditory Perception correction" AND "Neuronal Plasticity" AND "Percepção auditiva" AND "Afasia" AND "Processamento auditivo" AND "Vias Auditivas" AND "Transtorno do cortex auditivo" AND "Distúrbios da percepção Auditiva" AND "Estimulação Acústica" AND "Correção da percepção Auditiva" AND "Plasticidade neuronal")
SCIELO	("Percepção auditiva" AND "Afasia" AND "Processamento auditivo" AND "Vias Aditivas" AND "Transtorno do cortex auditivo" AND "Distúrbios da percepção Auditiva" AND "Estimulação Acústica" AND "Correção da percepção Auditiva" AND "Plasticidade neuronal" AND "Auditory Pathways" AND "Acoustic Stimulation" AND "Auditory Perception Correction" AND "Neuronal Plasticity")
GOOGLE SCHOLAR	("Percepção auditiva" OR "Afasia" OR "Processamento auditivo" OR "Vias Aditivas" OR "Transtorno do córtex auditivo" OR "Distúrbios da percepção Auditiva" OR "Estimulação Acústica" OR "Correção da percepção Auditiva" OR "Plasticidade neuronal" OR "Auditory Pathways" OR "Acoustic Stimulation" OR "Auditory Perception Correction" OR "Neuronal Plasticity")

Source: the authors, 2023.

Eligibility criteria

The eligibility criteria for this review were as follows: articles addressing CAP's interface with aphasia and designed as original research and clinical case studies. As exclusion criteria, duplicates, literature review articles, and scientific abstracts were removed.

Moreover, the review did not consider studies on aphasia and CAP not specifying electrophysiological assessments and examinations, studies on aphasia not showing its relationship with auditory processing, or studies on therapy and intervention not presenting the auditory training format. Only research using auditory training was included, as it is the scientifically proven form of intervention for CAP changes in aphasic individuals[19].

The study selection process had four stages. In the first one, which began in November 2022, with an update in August 2023, a search was carried out using the descriptors for all databases, applying the filters related to the inclusion criteria. The next stage selected articles whose titles addressed the relationship between aphasia and auditory processing, then, proceeding to the third stage, the article abstracts were read. In the last stage, the articles selected in the previous one were read independently in full text to verify whether they met the research criteria and answered the research question.

Thus, after collecting from the databases and excluding duplicates, two reviewers (ROB and ACBVS) screened the articles independently. They first selected the studies by reading their titles and abstracts. Then, the same reviewers read the full text and analyzed the content of the articles. Two other reviewers (DOL and MRDR) were available to reach a consensus with the first two in cases of disagreement regarding either abstracts or full texts. Another reviewer participated in the last phase to discuss and resolve any existing conflicts.

LITERATURE REVIEW

The process of searching and choosing articles in this review is presented in a flowchart (Figure 1). It shows the extracted data and the results of crossing health descriptors in the databases, presenting the strategy used for the review and bringing the quantitative findings in the literature on the study topic.

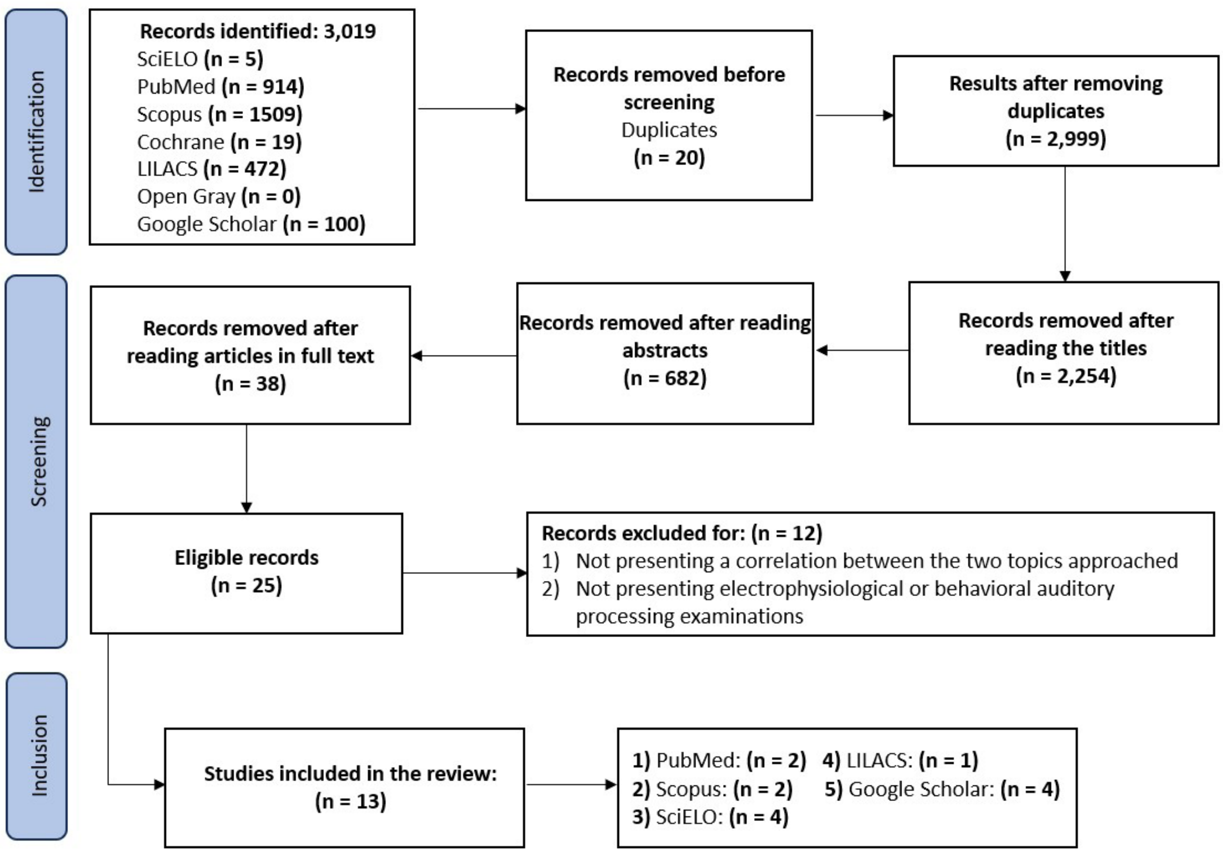

Figure 1. Flowchart with the different review stages, based on the 2020 PRISMA guidelines for new systematic reviews, including the search in databases, records, and other sources

The search initially found 3,019 articles by crossing descriptors in the databases. The studies were filtered according to the stages previously defined and listed in the text, following the exclusion and inclusion criteria. After removing records by title and abstract reading (stages two and three), 25 studies were selected for full-text reading and analysis. Twelve of them were excluded for not relating aphasia with CAP or not presenting methods on the behavioral assessment battery, electrophysiological examinations, or auditory training as a form of intervention. Hence, the final sample had 13 articles that met the objective of this review.

Thus, eight (61.53%) out of the 13 articles selected from the literature assessed auditory processing with behavioral assessments, while four (30.76%) did so with electrophysiological assessments – two of them (15.38%) with auditory brainstem response (ABR) and three (23.07%) with long-latency auditory evoked potentials (LLAEP). Furthermore, only one (7.69%) of the articles used auditory training as a form of intervention. A chart was created to present a synthesis of the studies, including the article title, year of publication, author, objective, methods, and main results (Chart 2).

Chart 2. Data extracted from the articles selected for the review

Author and year of publication	Title	Study type	Methodological design	Outcome
Purdy et al. (2016)[20]	Aphasia and auditory processing after stroke through an international classification of lens functionality, disability, and health	Clinical case study	A 37-year-old aphasic person with difficulty processing auditory information and speaking at the same time. The CAP test used did not require verbal responses, such as behavioral assessments and a battery of standardized tests.	Behavioral and electrophysiological measures of auditory processing indicated that the participant had difficulty with temporal spectrum discrimination and cortical auditory processing of slow speech stimuli.
Nascimento (2012)[21]	Habilidades auditivas e afasia: um estudo comparativo (Auditory skills and aphasia: A comparative study)	Comparative study	The study encompassed 32 individuals, 16 with (G1) and 16 without aphasia (G2). CAP tests included monotic and dichotic listening tests with sentences, Dichotic Digit Tests, Filtered speech, and Binaural Fusion.	The PSI test result demonstrated that the group with aphasia obtained values lower than those considered normal. The aphasic group performed worse in the filtered speech test. In the binaural fusion test, there was a difference between the average number of correct answers in the group with aphasia and the control group, with a predominant worse performance in the aphasic group.
Silva et al. (2016)[22]	Processamento auditivo da informação em sujeitos com afasia (Auditory information processing in subjects with aphasia)	Cross-sectional study	Ten people with aphasia participated in the battery of assessments. CAP assessment used sound localization tests, sequential memory for verbal and non-verbal sounds, frequency pattern and duration tests, dichotic digits tests, compressed speech, and PSI.	All subjects had changes in most auditory skills, having greater difficulty with verbal tasks.
Ortiz et al. (2008)[23]	Comprehension of competitive messages in aphasic patients	Cross-sectional study	Twenty aphasic individuals with a neurological and speech-language-hearing diagnosis of aphasia were evaluated. They were submitted to the monotic and dichotic Listening Test with PSI sentences - proposed for the Brazilian population.	The results of the aphasic and control groups revealed significant differences in both contralateral and ipsilateral messages. Performances differed in ipsilateral messages, identifying a greater difficulty.
Zeigelboim et al. (2010)[24]	Neurophysiologic evaluation of auditory pathways and the balance in Broca's aphasia: presentation of illustrative case	Clinical case study	The CAP assessment included the stages of sound localization; sequential memory for syllables; dichotic listening of alternating disyllables; monotic listening test; and random gap detection test.	CAP results indicated difficulties in binaural integration, sound localization, and binaural interaction tests. The SSW test proved to be useful in the topographic diagnostic investigation of patients.
Dokoza et al. (2020)[25]	Auditory processing in people with chronic aphasia	Case-control study	Two groups underwent the tests. Group I had 23 individuals with aphasia, and group II had 17 individuals with no neurological pathology. The auditory processing test was carried out in four subtests: filtered words test, speech in noise, and dichotic words.	Statistically lower results were observed in monaural tests, which indicates worse word recognition.
Shanks et al. (1976)[26]	A comparison of aphasic and non-brain-injured adults in a CV-syllable dichotic listening task	Comparative study	A CV-syllable dichotic listening task was administered to a group of 11 adults without brain injury and a group of 11 aphasic adults to compare their dichotic performances.	The results were analyzed in terms of a functional auditory processing model. The bilateral deficit in the aphasic group's dichotic performance was explained by their lesion in the dominant left hemisphere.

Author and year of publication	Title	Study type	Methodological design	Outcome
Kumarsinha et al. (2019) [27]	Temporal Resolution in Stroke Patients with Expressive Aphasia	Cross-sectional study	Two groups were formed with 10 subjects each. The study group had post-stroke patients with an established diagnosis of expressive aphasia. The tests included RGDT, GIN, and TMT.	Individuals with aphasia had poor scores on all three tests. Test scores varied in the number of attempts; a poor score was seen in the first attempt and the best score, in the second attempt among normal and expressive aphasic subjects.
Mourad et al. (2017)[28]	Value of complex evoked auditory brainstem response in patients with post-stroke aphasia (prospective study)	Case-control study	The study group included 30 post-stroke aphasic patients and 30 hearing individuals without neurological deficits. All subjects underwent basic and click audiological assessment on auditory brainstem response to confirm the presence of wave V.	Aphasics had abnormal neural synchrony affecting the source elements (waves D, E, F, and O), but there was no effect on the filtering elements (transient). Auditory brainstem response was related to cortical speech processing, which was abnormal in aphasic patients.
Buriti et al. (2020) [29]	Electroacoustic and electrophysiological hearing assessment in aphasic individuals	Case-control study	Twenty individuals, 10 from the aphasic group and 10 without neurological damage participated in the cognitive potential. P300 tone-burst stimuli were used at 1000 Hz for the frequent stimuli and 2000 Hz for the rare and complex stimuli.	In the potential elicited with speech stimuli, a decrease in latency was noted in the aphasic group compared to the control group. In terms of amplitude, it can be inferred that fewer neurons were fired synchronously to form the wave.
Zanatta et al. (2016)[30]	Study of auditory evoked potentials of late latency and cognitive potential in aphasic individuals	Cross-sectional study	The study assessed 17 aphasic individuals due to stroke, using LLAEP and P3. To investigate exogenous (P1, N1, and P2 complex) and endogenous (N2 and P3) long-latency evoked potentials.	Of the 17 individuals evaluated, only 11 had the presence of waves P1 and N1. Some subjects had values above those indicated in the literature in individual latencies, possibly because of the stroke.
Samelli et al (2010)[31]	Auditory training for auditory processing disorder: a proposal for therapeutic intervention	Cross-sectional study	The study included 10 participants with abnormal auditory processing (eight males and two females). All underwent complete audiological and auditory processing evaluation. After 10 individual training sessions, their auditory processing was reassessed.	Informal auditory training proved to be effective in part of the group of individuals with processing disorders, given the significant differences in the statistics of pre- and post-auditory training assessments, which indicated improvements in abnormal auditory skills.
Szelag et al. (2014)[32]	Training in rapid auditory processing ameliorates auditory comprehension in aphasic patients: A randomized controlled pilot study	Blind randomized study	Eighteen aphasics were tested. All presented auditory comprehension deficits were evidenced through the Token Test, Phoneme Discrimination Test (PDT), and Voice Onset Time Test (VOT). Two computerized auditory training procedures were applied: temporal processing training (TT) and non-temporal control training (NT).	After TT, the average percentage of errors tended to be lower than in the pre-training assessment. In the Voice-Onset-Time Test after the TT, the best performance was found in both the voiced and deaf areas. TT in aphasic patients improved significantly for both ordering and linguistic competence – unlike the NT.

Captions: Hz = Hertz; CAP = central auditory processing; LLAEP = long-latency auditory evoked potential; PSI = Pediatric Speech Intelligibility; GIN = Gap-in-noise test; SSW = Dichotic Staggered Spondaic Word; RGDT = Random Gap Detection Test; CV = Consonant-vowel; TMT = temporal modulation transfer; TT = Temporal processing training; NT = Non-temporal control training; PDT = pattern duration test; VOT = Voie-Onset-Time test; G1 = Group 1; G2 = Group 2.

After extracting all study results to develop this discussion, their agreement and counterpoints were approached within the topic of the study objective – i.e., to report scientific evidence of the impact of aphasia on CAP and map the contribution of auditory training for the aphasic population. The results of all aphasic patients in the 13 articles selected in this review demonstrated deficits in more than one auditory skill, revealing changes in CAP performance.

A study, using an international classification of functioning, aimed to discuss the central auditory system after brain injury in aphasia disorder[20]. The use of the International Classification of Functioning, Disability, and Health (ICF) helps characterize the functional profile based on a holistic view, including health components referring to Body Functions and Structures; the dimensions of Activities and Participation; and Contextual, Environmental, and Personal Factors. It should be noted that this was the only study that approached the topic with the ICF – which indicates the need for more research, given the important difference in better understanding the complex difficulties experienced by people with aphasia.

The purpose of the said article was to look beyond the information obtained with tests and consider the broader effects of auditory processing and language difficulties on these individuals' participation in everyday activities. The results in the ICF's area of participation demonstrated that, in everyday situations, aphasia compromised the ability to speak when other people are talking or when there is background noise, characterizing auditory and linguistic skill damage and social impairment. The behavioral and electrophysiological measures and language tests also verified reduced capacity in auditory discrimination, slow cortical auditory processing, reduced word fluency, and impaired understanding of spoken sentences[20].

The literature has shown performance below reference values in aphasic subjects' auditory skills[21-24], confirming the idea that aphasic changes are related to CAP performance. Six (46.15%) of the articles approached in this review used the Pediatric Speech Intelligibility (PSI) monaural sentence tests to assess figure-ground and the filtered words and speech-in-noise tests to assess auditory closure. PSI results showed that all aphasic individuals had changes in their figure-ground skills, also indicating a patterned advantage between the ears, with statistically significant differences. There was also a difference between performances in the ipsilateral competing message (which is a more difficult situation), identifying greater difficulty with the stimuli in the right ear – which allows us to infer that the lesion in the left hemisphere interfered with auditory information processing.

Equivalent to the previous results, evidence[21,22,24,25] corroborates the hypothesis that aphasic individuals may have abnormal results in monaural tests. Samples from this population were presented using the filtered words test and the speech-in-noise test and found that, in both monaural tests, the aphasic patients' results confirmed poorer speech comprehension, with deficits in auditory closure. This change can be explained by auditory discrimination and word recognition difficulties. Neurological damage may also interfere with it, as the literature indicates that monaural physiological mechanisms are sensitive to brainstem dysfunctions[17].

In agreement with previous studies, more CAP tests demonstrated the right ear performance of aphasic individuals[21,23,26]. These results were confirmed with dichotic consonant-vowel and dichotic digit listening. The findings showed that aphasics with lesions in the left hemisphere tend to have lower scores in the right ear and a greater advantage in the left ear. Authors[17,26] highlight that this stimulus-perception advantage between the ears is associated with the mechanisms of crossing auditory information. As most nerve fibers cross or uncross at some point in the central auditory nervous system, activity from the right ear is represented more strongly on the left side of the auditory cortex and vice versa.

Changes were also found in the dichotic listening Staggered Spondaic Word Test (SSW), whose poor performances were deemed to result from lesions in the left hemisphere. However, there was no advantage between ears, as both performed poorly[24]. This result can be explained by the limited samples of aphasics investigated. Changes were generally found in dichotic listening tests, justified by the lesion in the left hemisphere (where speech signals from both ears converge for final processing), demonstrating aphasic individuals' impaired binaural integration[24,26].

Besides these skills, temporal processing mechanisms are considered important for speech perception[27]. Studies suggest that neurological injuries can affect temporal skills. Four (30.76%) of the articles found in the databases performed the Gap-in-Noise test (GIN), Random Gap Detection test (RGDT), Frequency Pattern test (FPT), and Duration Pattern test (TPD). In view of the results found in the literature, aphasic patients presented lower scores in all temporal tasks when compared to the control group, and it can be assumed that they have impaired auditory resolution and temporal ordering. Given the results in the literature, aphasics scored lower than the control group in all temporal tasks, presuming impairments in auditory resolution and temporal ordering skills[22,24,27].

As the behavioral assessments, electrophysiological tests have likewise shown consequences in the aphasic population. The auditory evoked potential is an objective test that assesses the central auditory pathway from the auditory nerve to the cerebral cortex in response to acoustic stimuli. The ABR electrophysiological examination investigates the functioning of the auditory nerve and integrity of the auditory pathway, while LLAEP verifies the physiology of the central auditory function, auditory memory, and cognition.

Thus, studies have demonstrated an increase in ABR wave-I latency bilaterally, with a consequent decrease in I-III and III-V interpeak intervals. According to the evidence from ABR findings, aphasics have abnormal neural synchrony, affecting the source elements of the waves and causing delayed latency[20,28].

As for LLAEP, studies have shown that aphasics have greater P300 wave latency in the left ear of individuals with left hemisphere damage caused by a stroke. This suggests that absent or abnormal P300 responses may be related to linguistic changes, corroborating the sensory and cognitive difficulties in processing message decoding[29,30].

Concordantly, studies[22,28-30] in aphasic populations demonstrated increased latency or absent waves. The increase in latencies was related to the difficulty that aphasic individuals tend to have in situations involving auditory discrimination, memory, and attention mechanisms. The findings also showed an increase in P300 latency, whose results were justified by the brain injury and the assessment demand on cognitive and auditory processes. It is worth pointing out that the electrophysiological measures were within reference values, although the aphasic group performed worse than the control group.

The assessments have thus demonstrated that the behavioral findings were worse than the electrophysiological ones. This indicates that aphasic patients have greater behavioral changes than restricted functioning of the auditory pathway at the cortical level, as the greatest difficulty in behavioral assessments pointed out deficits in listening skills. This perspective highlights the importance of carrying out both assessments. However, this was a limiting factor in the present study since, among the findings, only two (23.07%) took both electrophysiological and behavioral measures. These assessments bring greatly relevant information to speech-language-hearing diagnosis and therapy so that the professional can guide the family regarding evolution possibilities and better direct the intervention[22].

The CAP changes described in the studies explain the need for auditory training to repair and improve impaired auditory skills in individuals with neurological injuries[20,31]. Neuroplasticity, which is the principle of auditory training, is the brain's ability to produce new synapses and create connections around the performance of a certain activity, being able to promote neuronal reorganization of the auditory system and connections with other systems[19,31].

Auditory training is organized into stages that address impaired hearing skills through formal or informal approaches. In formal training, acoustically controlled activities are carried out in a sound booth, whereas informal training stimulates auditory skills without requiring the acoustic control of the environment and stimuli[19,31].

As shown in the studies[23-25], aphasic people's auditory comprehension is affected by the extent of the cortical injury in the region of the temporal lobe and the deficit in listening skills corresponding to the ability to understand. Thus, the article on the intervention suggests that auditory training improves aphasic individuals' hearing and understanding thanks to the relationship between language and rapid auditory processing.

A study[32] tested 18 aphasic patients (nine men and nine women) with comprehension and perception deficits. Auditory comprehension was initially assessed with the Token Test, phonemic awareness, and Voice-Onset-Time Test, while perception was assessed with the auditory temporal order threshold, defined as the shortest interval between two consecutive stimuli. Two computerized auditory training procedures were applied: Temporal Processing Training (TT) and Non-Temporal Control Training (NT). Aphasic patients in both groups participated in eight 45-minute training sessions. Thus, after computerized auditory training in temporal processing, subjects in the TT group responded better in tests that evaluate language and auditory perception than in pre-training tests, while there was no significant difference in the NT group. Furthermore, the improvement in the time domain was transferred to the language domain.

Hence, temporal processing training significantly improved aphasic patients' ordering and linguistic competence, proving to be greatly important in speech-language-hearing intervention in this population[32]. The reviewed literature indicates that aphasic changes affected CAP performance, and auditory training proved to be an effective means of intervention, as it improved linguistic and CAP skills.

CONCLUSION

Scientific evidence points to an important change in aphasic patients' CAP, with notable impairments in figure-ground, auditory closure, temporal ordering and resolution, and binaural integration. The studies also demonstrate the relevance of assessing auditory processing, due to the contribution of auditory training in speech-language-hearing therapy for a better prognosis in the rehabilitation of aphasia.

Nevertheless, the literature has little data on aphasia and CAP, especially on auditory training intervention. Therefore, it is essential to conduct further research on this topic, as the findings may reflect benefits for the aphasic population and elucidate new discoveries in speech-language-hearing therapy, filling the existing gaps in the scientific literature.

REFERENCES

1. Katz J. Classification of auditory processing disorders. In: Katz J, Stecker N, Henderson D, editors. Central auditory processing: a transdisciplinary view. St Louis, Year book; 1992. p. 81-91.
2. American Speech-Language-Hearing Association (ASHA) [homepage on the internet]. (Central) Auditory Processing disorders. 2005. [accessed 2023 jan 18]. Available at: www.asha.org/policy
3. Pinheiro FH. Eficácia do programa de treinamento auditivo em escolares com distúrbio de aprendizagem [dissertation]. Marília (SP): Faculdade de Filosofia e Ciências, Universidade Estadual Paulista; 2009.
4. Jerger S, Jerger J. Alterações auditivas. Um manual para avaliação clínica. 1 ed. Rio de Janeiro: Atheneu Editora; 1989.
5. Bazilio MMM, Frota S, Chrisman JR, Meyer A, Asmus CIF, Camara VM. Processamento auditivo temporal de trabalhadores rurais expostos a agrotóxico. J. Soc. Bras. Fonoaudiol. 2012;24(2):174-80. https://doi.org/10.1590/S2179649120120002000015
6. Sitta EI, Arakawa AM, Caldana ML, Peres SHCS. A contribuição de estudos transversais na área da linguagem com enfoque em afasia. Rev. CEFAC. 2010;12(6):1059-66. https://doi.org/10.1590/S1516-18462010005000086
7. Sangtian S, Wang Y, Fridriksson J, Behroozmand R. Impairment of speech auditory feedback error detection and motor correction in post-stroke aphasia. J Commun Disord. 2021 Nov-Dec;94:106163. https://doi.org/10.1016/j.jcomdis.2021.106163 PMID: 34768093.
8. Nickisch A, Massinger C. Auditory processing in children with specific language impairments: are there deficits in frequency discrimination, temporal auditory processing or general auditory processing? Folia Phoniatr Logop. 2009;61:323-8. https://doi.org/10.1159/000252848 PMID: 19864913.
9. American Speech-Language-Hearing Association [homepage on the internet]. Aphasia (n.d.). Retrieved October, 20, 2023. [accessed 2023 nov 20]. Available at: https://www.asha.org/Practice-Portal/Clinical-Topics/Aphasia/
10. Ferreira-Donati GC, Freitas MID, Silagi ML, Pereira ACMM, Lamonica DAC. Conversando sobre afasia: guia familiar. 1. ed. São Paulo: Sociedade Brasileira de Fonoaudiologia; 2020.
11. Jacobs DH. Aphasia: e-medicine instant access to the minds of medicine. [journal on the internet] Fev. 2002. [accessed 2023 set 9]. Available at: http://emedicine.com/neuro/topic437.htm.
12. Carvalho RMM. Fonoaudiologia: Informação para a formação: procedimentos em audiologia. 1 ed. Rio de Janeiro: Guanabara Koogan; 2003.
13. Pereira L, Cavadas M. Processamento auditivo central. In: Frota S, editor. Fundamentos de fonoaudiologia: audiologia. Rio de Janeiro: Guanabara Koogan; 1998. p. 135-46.
14. Catts HW, Chermak G, Craig CH, Johnston JR, Keith R, Musiek FE et al. Central auditory processing: Current status of research and implications for clinical practice task force on central auditory processing consensus development. Am J Audiol. 1996;5:41-52. https://doi.org/10.1044/1059-0889.0502.41
15. Phillips DP. Central auditory processing: a view from auditory neuroscience. Am J Otol. 1995;16(3):338-52. PMID: 8588629.
16. Finger S. The ear and the theory of hearing. In: Finger S, editor. Origins of neuroscience: history of explication in to brain function. New York: University Press; 1994. p. 108-23.
17. Teixeira C, Griz S, Advíncula K, Caldas S. Sistema auditivo central. In: Boéchat EM, Menezes PL, Couto CM, Frizzo ACF, Scharlach RC, editors. Tratado de Audiologia. 2ed. Rio de Janeiro: Santos; 2015. p.41-8.
18. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467-73. http://dx.doi.org/10.7326/M18-0850 PMID:30178033.
19. Weihing J, Chermak GD, Musiek FE. Auditory training for central auditory processing disorder. Semin Hear. 2015;36(4):199-215. https://doi.org/10.1055/s-0035-1564458 PMID: 27587909.
20. Purdy SC, Wanigasekara I, Cañete OM, Moore C, McCann CM. Aphasia and auditory processing after stroke through an International Classification of Functioning, Disability and Health Lens. Semin Hear. 2016;37(3):233-46. https://doi.org/10.1055/s-0036-1584408 PMID: 27489401.
21. Nascimento MSR. Habilidades auditivas e afasia: um estudo comparativo [monograph]. Recife (PE): Universidade Federal de Pernambuco; 2012 [accessed 2022 out 10]. Available at: https://repositorio.ufpe.br/handle/123456789/12759
22. Folgearini JS, Biaggio EPV, Bruno RS, Oppitz SJ, Fedosse E, Santos SN et al. Processamento auditivo da informação em sujeitos com afasia. Estud.Interdiscip. Envelhec. 2016;21(3):217-34. https://doi.org/10.22456/2316-2171.80784
23. Ortiz KZ, Peroni C. Compreensão de fala em situação de mensagem competitiva em afásicos. Rev. CEFAC. 2008;10(2):226-32. https://doi.org/10.1590/S1516-18462008000200012
24. Zeigelboim BS, Klagenberg KF, Liberalesso PBN, Menezes P, Gonçalves DV. Avaliação neurofisiológica das vias auditivas e do equilíbrio na afasia de Broca – Apresentação de um caso ilustrativo. J Epilepsy Clin Neurophysiol. 2010;16(4):143-8. https://doi.org/10.1590/S1676-26492010000400005
25. Dakoza KP, Kolundzié Z, Hedever M. Auditory processing in people with chronic aphasia. Coll. Antropol. 2020;44(2):95-102. https://doi.org/10.5671/ca.44.2.5
26. Shanks J, Ryan W. A comparison of aphasic and non-brain-injured adults on a dichotic CV-syllable listening task. Cortex. 1976;12(2):100-12. https://doi.org/10.1016/s0010-9452(76)80014-7 PMID: 954446.
27. Sinha MK, Swain R, Thontadarya S. Temporal resolution in stroke patients with expressive aphasia. Int. J. Mind Brain Cogn. 2019;10(1):165-77.
28. Mourad M, Al-Ghaffar ABD, Bassiony MAA, Fawzi G. Value of complex evoked auditory Brainstem response in patients with post-stroke aphasia (prospective study). Egypt. J. Ear Nose Throat Allied Sci. 2017;18(3):217-21. https://doi.org/10.1016/j.ejenta.2017.05.006
29. Buriti AKL, Mello LA, Machado BSP, Gil D. Electroacoustic and electrophysiological auditory assessment in aphasic individuals. Rev. CEFAC. 2020;22(2):e15919. https://doi.org/10.1590/1982-0216/202022215919
30. Berticelli AZ, Grotto K, Rocha V, Brandão L, Sleifer P. Estudo dos potenciais evocados auditivos de longa latência e potencial cognitivo em indivíduos afásicos. Estud. Interdiscip. Envelhec. 2016;21(3):235-50. https://doi.org/10.22456/2316-2171.80792
31. Samelli AG, Mecca FFDN. Auditory training for auditory processing disorder: a proposal for therapeutic intervention Rev. CEFAC. 2010;12(2):235-41. https://doi.org/10.1590/S1516-18462010005000006

32. Szelag E, Lewandowska M, Wolak T, Seniow J, Poniatowska R, Poppel E et al. Training in rapid auditory processing ameliorates auditory comprehension in aphasic patients: a randomized controlled pilot study. J Neurol Sci. 2014;338(1-2):77-86. https://doi.org/10.1016/j.jns.2013.12.020 PMID: 2438843.

Authors' contributions:

ROB, ACBVS: data collection and analysis.

DOL: data analysis and supervision.

ILBL: manuscript review.

MRDR: manuscript review and research supervision.