

Review articles

Accuracy of screening instruments in identifying central auditory processing disorders: an integrative literature review

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ABSTRACT

Purpose: to assess the literature about the accuracy of screening instruments for identifying the Central Auditory Processing Disorders (CAPD).

Methods: search strategies were performed in the following databases: CINAHL, LILACS, PubMed /MEDLINE, Scopus, Speechbite and Web of Science. A search was also carried out in the grey literature. Four independent reviewers selected the included articles using a two-phase process based on the eligibility criteria. Two reviewers independently collected the required information from the included articles. The diagnostic methods were minimal batteries of behavioral tests to assess auditory processing skills.

Results: from 1,366 articles found on all databases, after analysis of title and abstract, 36 were selected for the next phase, when 5 articles were finally included. It was found that the studies included were related to five instruments applied in children. The specificity was higher than 70%, but just the Mottier test and Screening Test for Auditory Processing (STAP), and Screening Checklist for Auditory Processing (SCAP) showed sensibility higher than 70%.

Conclusion: Mottier was the most accurate CAPD screening test. There was no homogeneity in the presentation of the pass/fail criterion, or in the gold reference test used to establish the presence of CAPD.

Keywords: Children; Hearing; Mass Screening; Auditory Perceptual Disorders; Hearing Test

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INTRODUCTION

The Central Auditory Processing Disorder (CAPD) is defined by the difficulty in interpreting verbal and nonverbal auditory stimuli, resulting from the presence of auditory dysfunction of the central auditory nervous system (CANS) in its afferent pathways, with bottom-up modulation, and/or in the efferent pathways, which receive top-down modulation and involve language, speech, cognition, attention, memory and fluid reasoning^{1,2}. The International Statistical Classification of Diseases and Related Health Problems (ICD-10) characterizes the Auditory Processing Disorder as an Impairment of Auditory Discrimination, under the classification “Other abnormal auditory perceptions” (H93.25)³.

Currently, there is an understanding that there is a correlation between CAPD and other developmental disorders in children, such as Autism Spectrum Disorder, Dyslexia and specific language impairment¹. Thus, there are gaps in the literature regarding evidence of purely auditory deficit in children diagnosed with CAPD², since this alteration can manifest itself as a co-occurrence of other disorders. These changes in the Central Auditory System can cause several damages to the development and learning process of children⁴, impacting the performance of personal activities and quality of life¹.

In the literature, it is possible to categorize auditory processing screening instruments into various types, such as tests with recorded stimuli⁵, questionnaires and checklists⁶, scales⁷, software⁸ and online program⁹ and tests with uncalibrated sounds¹⁰.

In the study by Volpatto et al.¹¹, it is possible to see, through a systematic review, the questionnaires, and checklists most used in Brazil for auditory processing screening available in Portuguese. Among the translated and/or adapted tools, the Auditory Processing Domains Questionnaire (APDQ) is the only questionnaire that has been validated¹¹. Another review that focused on analyzed studies that applied CAPD screening in schoolchildren did not use the eligibility criterion studies of comparing the CAPD screening with diagnosis procedures in CAPD including behavioral assessment battery tests¹². This eligibility is necessary for measuring the accuracy of the CAPD screenings protocols. So, this gap in literature remains.

The broad spectrum of alterations inherent to the diagnosis and clinical implications of the CAPD makes it very important that the screening instruments have diagnostic validity for them to be apt to quickly and

effectively detect this disorder. The more valid the screening of CAPD is, greater are the chances of the subject to be properly identified as with a high or low probability to have CAPD and be effectively referred for diagnostic evaluation when necessary.

Therefore, it is of great importance to screen, as early as possible, the central auditory processing disorders. It is important that the process of improving, or even developing methods of auditory screening be approached with caution¹³, as it is the moment when the professionals collect information on the subjects' health, education and well-being, which are important parameters for them to perform their daily tasks¹⁴. Based on the identification, the child can be adequately diagnosed and, afterwards, referred for intervention¹³.

In this way, this review aimed at studying what is referred to in the literature regarding the accuracy of screening instruments in identifying the CAPD.

METHODS

This integrative literature review was guided by the question: “What is the accuracy of the screening instruments in identifying the CAPD?”. After the question had been developed in the first phase, the second phase of the integrative review was begun, involving the survey of the literature in six databases, namely, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Literature in the Health Sciences in Latin America and the Caribbean (LILACS), PubMed (including MEDLINE), Scopus, SpeechBITE and Web of Science, in addition to two grey literature databases, Google Scholar and OpenGrey.

Mesh terms, keywords, and other free terms related to “questionnaires”; “hearing tests”; “mobile application”; software; “mass screening hearing”; “auditory perception”; and “auditory perceptual disorders” were used with Boolean operators (e.g. OR and AND) to combine searches. Additional information on the search strategies are provided on the Appendix 1. The lists of references of included studies were also hand-searched to identify additional relevant studies¹⁵. Experts were also consulted by email to improve search findings.

Studies of the accuracy screening instruments applied for identification of the CAPD were included. For this end, it was necessary that the study had compared CAPD screening instruments either already validated or with a battery of tests for the diagnosis

of CAPD. The inclusion of studies had no restrictions regarding language, age, gender, and time of publication.

Studies excluded from the analysis were: 1 - Studies whose subjects had hearing loss; 2 - Studies presenting any other screening protocol, whose focus was not the CAPD; 3 - Studies not using the reference standard, which could be either a battery of behavioral tests for the auditory processing assessment, or instruments validated for the diagnosis; 4 - Studies not presenting accurate measurements (sensitivity and specificity), or not presenting sufficient data to calculate them; 5 - Case-control studies, cohort studies, clinical trials, conference summaries, personal opinions, congress annals, reviews, editorials, and letters to the editor; and 6 - Unavailable complete articles. Those criteria were applied on screening stage and full text analyses.

The search was conducted on December 12, 2018 and updated on August 17, 2020. The references were administered, and the duplicated files were removed with the help of the Mendeley© software (2008 Glyph & Cog, LLC.), version 1.19.4. The online data manager Rayyan.qcri (Rayyan, Qatar Computing Research Institute)¹⁶ was used to enable, between the reviewers, the blind reading of the titles and abstracts.

In the third phase of the review, four reviewers selected the articles blindly and independently. On the screening stage, these four reviewers examined the titles and abstracts of all the studies through the Rayyan.qcri (Rayyan, Qatar Computing Research Institute)¹⁶ applying eligibility criteria. Then the same four reviewers evaluated the full text with eligibility criteria. The four reviewers cleared any disagreement in both stages by discussing and getting to a mutual agreement. When they could not get to a consensus, the fifth reviewer was asked to make a final decision.

Two reviewers blindly and independently collected from the selected articles author, year and country of publication of the study, sample size, mean age in years, characteristics of the subjects and other alterations, screening instruments, auditory processing skills, sensitivity and specificity values, pass/fail criterion, and the diagnostic method used. Any disagreement was settled by discussion and mutual agreement between the two reviewers. The sixth author was involved, as necessary, to make possible for the final decision to be formulated.

LITERATURE REVIEW

The search on the databases returned 1,366 studies, as shown on the diagram (Figure 1). After the duplicated files had been removed, the first selection of 1,174 articles was conducted (stage 1), through the reading of title and/or abstract. Following the eligibility criteria, 1,144 studies were excluded. Of the 30 remaining articles, three could not be obtained, even though the authors of the articles had been contacted by e-mail in different days and hours to make possible for the articles to be obtained in full. Neither were the articles available in full text on the repositories to which the researchers' university of origin has access, nor was there availability for them to be acquired. The search on the grey literature identified 1,864 studies; the first 100 results from each database were taken into consideration in the initial title and abstract analysis. None of these met the eligibility criteria. It is also important to highlight that, after the reference lists had been sought through and the articles had been solicited to the experts, no additional study was included.

With the update of the searches, 114 were analyzed based on the title and abstract. Three articles met the eligibility criteria and went on to analyze the full text. Therefore, 33 articles passed on to the stage 2, when the full texts were read, and 28 of them were excluded following the same eligibility criteria (shown in Appendix 2). Lastly, five studies remained and were included in the qualitative analysis.

The five studies included had been published in the United States¹⁷, in Germany¹⁸, in the United Kingdom^{19,20} and in Hong Kong²¹. The sample size of the studies varied from 81 to 201 subjects, aged from 6 to 16 years.

The screening instruments used were a Screening Test for Auditory Processing Disorders (SCAN)¹⁷; auditory processing behavioral test battery¹⁸, Children's auditory performance scale (CHAPS)¹⁹, the SCAN-3 subtest Auditory Figure-Ground (AFG) in the signal/noise relations of +8 dB and 0 dB²⁰, the Screening Test for Auditory Processing (STAP) and the Screening Checklist for Auditory Processing (SCAP)²¹. The pass/fail criterion was presented in four articles, and they were the signal-noise relation of 0 dB in the AFG²⁰; failing in two or more tests of the battery conducted, with score of 1 to 1.5 SD below average¹⁹; the parameters recommended by Keith⁵, i.e., 1 SD below average composite score of the subtests¹⁸; and a cut-off score criteria of 6 on the SCAP. In the articles from 2000¹⁸ and 2014²¹, there was the need of support from another study to present this information^{5,22}. It should be noted

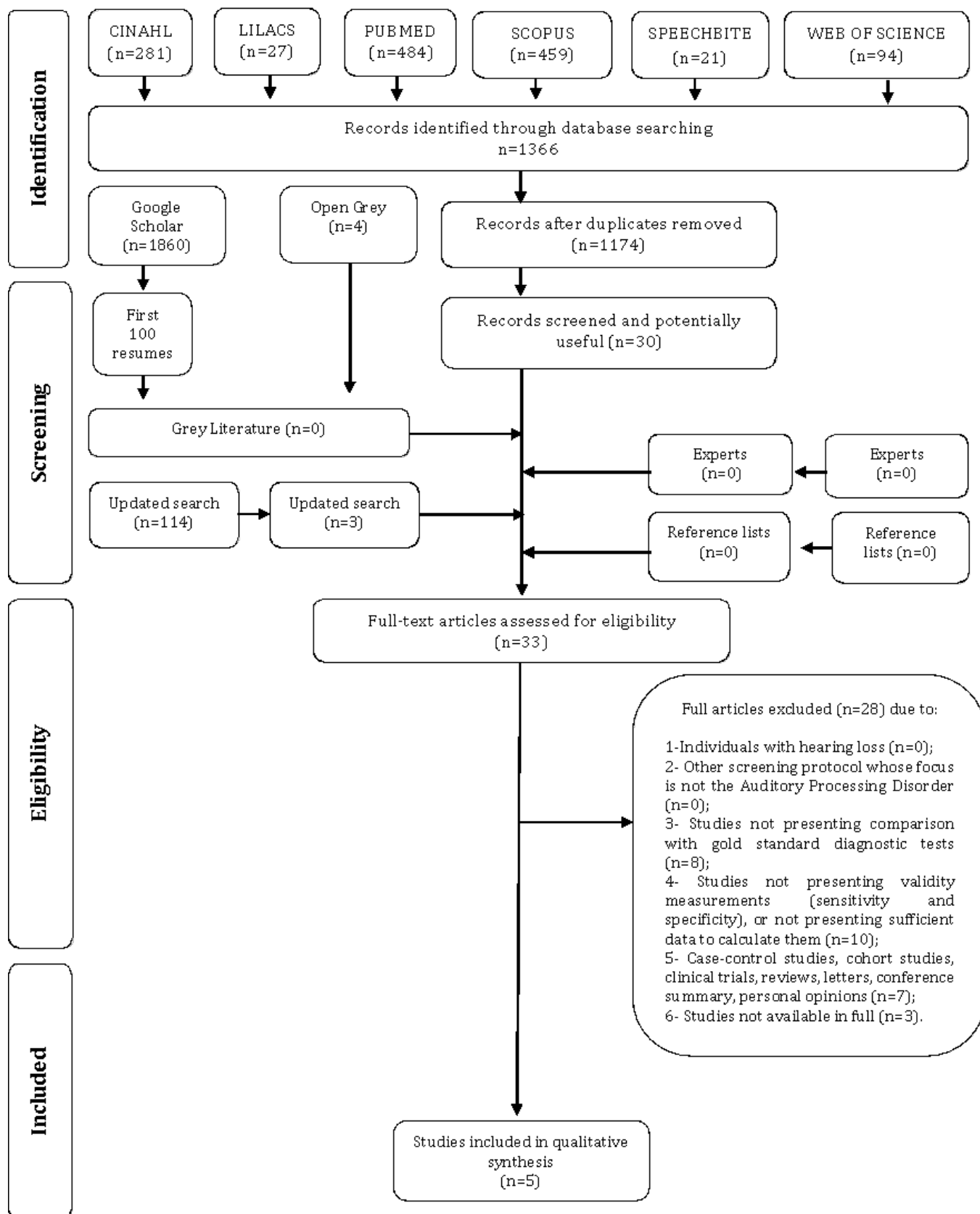


Figure 1. Flow diagram of literature search and selection criteria¹

that article of 2014²¹ did not mention the parameters of the STAP.

All the studies achieved the primary outcome, proving the accuracy of the instruments analyzed. The values of sensitivity ranged from 42.1% to 97.2%, whereas those of specificity reached between 65.5%

and 100%. The CAPD diagnostic methods observed were minimum batteries of behavioral tests aimed at assessing all the auditory processing skills, or the SCAN test battery aimed at diagnosing. The detailed characteristics of the studies included are shown in Table 1.

Table 1. Summary of descriptive characteristics and outcomes of interest of the included studies (n = 5)

Author, year; country	Number of subjects (n), Mean age (years) ± SD	Characteristics of the subjects and other alterations	Reference gold diagnostic method	Index test	Definition of positivity in the screening test	Sensitivity	Specificity
Ahmed and Ahmed, 2016; United Kingdom ¹⁹	109 9.33 ± 1.40 6 - 11 years	Male: 67 Other alterations – NR	Batteries SCAN-C: FW, AFG +8 dB, CW, CS and IMAP (assesses auditory cognitive function). Diagnostic criteria for CAPD: performance 1SD and 1.5 SD below the mean in at least two CAPD tests (i.e. SCAN-C and IMAP tests)	CHAPS	Failure in two or more tests, from 1 to 1.5 SD below average	53.3%	75%
Ahmed, 2017; United Kingdom ²⁰	201 10.5 ± 2.8 6 - 16 years	Male: 115 - Language disorder (17.4%) - ADHD (2.9%) - ADHD and language disorder (38.3%)	Battery of SCAN-3 diagnostic tests: FW, AFG +8 dB, CW, CS, AFG 0, TCS. Diagnostic criteria for CAPD: percentile score ≤10 in two or more SCAN-3 subtests	subtest of the SCAN-3 battery – AFG with S/N ratio = +8 dB	percentile score ≤10 on AFG with S/N ratio = 0	42.1%	80%
				subtest of the SCAN-3 battery – AFG with S/N ratio = 0 dB		56.3%	100%
Domitz, Schow, 2000; USA ¹⁷	81 8 - 9 years	Male: 40 - Learning difficulty (14%) - ADHD (9%) - Language and speech alterations (4%) - One or more overlapping diagnoses (20%)	Battery MAPA: mSAAT; Frequency pattern tests; Dichotic Digits and Competing Sentences. Diagnostic criteria for CAPD: performance 2 SD below the mean in at least one test	SCAN	Parameters recommended by Keith (1986): score of up to 1 SD below composed score average	45%	95%
Kiese-Himmel, Nickisch, 2015; Germany ¹⁸	178 8.44 ± 0.99 7 - 10 years		Battery of auditory processing diagnostic behavioral tests (German). Diagnostic criteria for CAPD: raw scores as the cut-off point based on the maximum value of Youden's index Mottier test: 17,5 HSET IS subtest: 21,5 PET ZFG subtest: 25,5 Göttinger speech-in-noise audiometry: 82,5 Dichotic words comprehension: 82,5 HLAD phoneme identification: 18,5 Step (PaTsy): 80,0 HLAD phoneme differentiation: 19,5 Monaural threshold classification (PaTsy): 225,5 HLAD phoneme analysis: 8,5	Mottier test	NR	90.1%	93.1%
				HSET IS subtest	84.6%	97.7%	
				PET ZFG subtest	84.6%	79.3%	
				Göttinger speech-in-noise audiometry	71.4%	88.5%	
				Dichotic words comprehension	63.7%	95.4%	
				HLAD phoneme identification	81.3%	74.4%	
				Step (PaTsy)	80.5%	74.4%	
				HLAD phoneme differentiation	63.7%	81.6%	
Monaural threshold classification (PaTsy)	75.9%	65.5%					
HLAD phoneme analysis	64.8%	73.5%					

Author, year; country	Number of subjects (n), Mean age (years) ± SD	Characteristics of the subjects and other alterations	Reference gold diagnostic method	Index test	Definition of positivity in the screening test	Sensitivity	Specificity
Yathiraj; Maggu, 2014; Hong Kong ²¹	152 8 - 13 years	Normal hearing Distribution of subjects according to age and other alterations - NR	Battery of diagnostic tests: SPIN-IE, DCV, GDT and RAMST-IE. Diagnostic criteria for CAPD: Children who failed on only one diagnostic test – performance 2 SD below the mean Children who failed more than one diagnostic test – performance 1 SD below the mean	STAP Subtests: - SPIN - DCV - GD - AM SCAP SCAP + STAP	RE / LE 6 / 6 words 4 / 4 consonant-vowel pairs per ear 2 consonant-vowel pair answered simultaneously 4 / 4 triads of 300 msec white noise 12 words Cut-off score = 6 Parameters already presented above	76.6% 74.1% 83.8%	72% 50% 76.2%

Captions: S/N - Signal/Noise; NR - Not report; ADHD - Attention-deficit/hyperactivity disorder; AFG - Auditory Figure-Ground (Speech-in-Noise); FW - Filtered Words, CW - Competing Words, CS - Competing Sentences, TCS - Time-Compressed Sentences; CHAPS - Children's Auditory Performance Scale; IMAP - Institute of Hearing Research Multicenter Auditory Processing; SCAN - A Screening Test for Auditory Processing Disorders; MAPA - Multiple Auditory Processing Assessment; mSAAT - monaural Selective Auditory Attention Test; STAP - Screening Test for Auditory Processing; SPIN - Speech Perception in Noise; DCV - Dichotic Consonant Vowel; GD - Gap Detection; AM - Auditory Memory; SPIN-IE - Speech Perception in Noise in Indian English; GDT - Gap Detection Test; RAMST-IE - Revised Auditory Memory and Sequencing test in Indian English; SCAP - Screening Checklist for Auditory Processing.

The five studies included in this review used different procedures for screening auditory processing and were conducted with children. There was no homogeneity in the presentation of the pass/fail criterion, or in the gold reference test used to establish the presence of the CAPD.

All the articles included presented the sensitivity and specificity measurements of the screening instruments¹⁷⁻²¹. The instruments used were two versions of the SCAN^{17,20}, Mottier test¹⁸, STAP and SCAP used separately and in combination²¹, and the questionnaire CHAPS¹⁹, in spite of the questionnaires, especially those developed more recently based on psychometric characteristics, being promising screening instruments to detect subjects at risk of CAPD⁶. A systematic review with questionnaires for Brazilian Portuguese found only one validated instrument, the APDQ, indicating that there was a rate of 100% in the sensitivity and specificity measurements¹¹. This datum indicates that it is a tool apt to detect all the subjects who actually have CAPD (sensitivity), as well as exclude the subjects without alteration (specificity)²³.

Despite this, the values of sensitivity and specificity of the SCAP may reflect that the use of questionnaires by other professionals, such as teachers, tends to

correctly identify CAPD in suspected children. However, they are likely to be over-referred. Screening becomes more accurate when there is an association between two types of tools, such as the use of tests that involve recorded sound stimuli²¹.

Sensitivity and specificity vary across studies. Nevertheless, some studies have used similar instruments, they could belong to different categories, such as the SCAN^{16,19} which has variations. Probably the different characteristics from tests can interfere on the task executed by the child, and consequently on sensitivity and specificity measures. CAPD complex nature¹ could reflect different results for different symptoms, too.

Five instruments applied in children for CAPD screening were identified: CHAPS, AFG, SCAN, Mottier, SCAP and STAP. The specificity of all the instruments CHAPS, AFG, SCAN, Mottier test, STAP and the associated use between SCAP and STAP were higher than 70%, but just the Mottier and STAP test, and SCAP showed sensibility higher than 70%.

The Mottier test was the instrument with better specificity and sensibility. This test assesses memory, which is only worked on in the STAP tests. This gives greater sensitivity to the instrument since this is one of the most

affected skills in this population²¹. In addition, memory is linked to sequences of meaningless syllables which makes the test more difficult.

Among the articles included in this review, it is possible to verify that there is no strong relationship between questionnaires and CAPD screening tests. Questionnaires can provide information on comorbidities and behavioral issues that allow them to know the individual in the educational, social and communicative contexts. Meanwhile, the performance-based screening tools present varied tasks that focus on different listening skills and some of them may have more consistent results to determine the CAPD or the need for a detailed behavioral assessment²⁴.

The description of the methodological procedures and the pass/fail criterion used in the studies was not homogeneous either. Kiese-Himmel; Nickisch¹⁸ did not present the pass/fail criterion used, making it difficult for the instrument to be concisely analyzed, and the methodological procedures to be reproduced by an independent author. The remaining four articles coherently described the criterion used^{17,19-21}. However, they diverged from one another, as the tests present their particularities, related to the use of stimuli with different acoustic characteristics and tasks. Despite the SCAN being used in two studies^{17,20}, the manner of assessment and the parameters of analysis were not the same. Domitz; Schow¹⁷ propose the screening to be conducted with all the subtests, based on the recommendations of the author of the instrument⁵. Ahmmed²⁰, in his turn, deals only with the use of the Speech-in-Noise subtest, studying the performance of the subjects in the signal/noise relations of 0 dB and +8 dB to define which of these would better reflect the actual listening difficulties.

The age range of the participants of the included studies encompass school age, the youngest being six years old^{19,20}, and the oldest, 16 years old¹⁹. Such proximity reiterates the relevance of studies with this public, since the screening can provide important information for the diagnosis. In the adult public, there is greater probability that the signs and symptoms of CAPD have not been identified or could be confounded with other health conditions. However, the results of this review evidenced the poor studies with this public, that need an adequate instrument to screening too.

Regarding the reference standard to determine the presence or absence of CAPD, there was no homogeneity. This is certainly a reflection of the complex and heterogeneous nature of the CAPD^{1,25} and, as

a consequence, of its diagnosis, whose definition presents diverging concepts.

The recommendations concerning the diagnosis indicate that the different categories composing the auditory processing - temporal processing, dichotic listening, low-redundancy speech perception, and binaural interaction - should be evaluated²⁶. The German study that investigated the accuracy of different combinations of the tests concludes that, for the diagnosis, the ideal is the combination of the ten tests of the battery studied¹⁸. Following the same line of investigation, one study from the United Kingdom uses as gold standard the SCAN-3²⁰, whereas the other study from the United Kingdom uses the SCAN-C battery as diagnostic criterion¹⁹. Although these two studies use SCAN, different versions are used, with distinct diagnostic criteria, even though the tests are similar. Another study used the MAPA battery¹⁷, and another, a combination of tests²¹, as recommended for the diagnostic assessment²⁶.

A lot of points are discussed about the definition and diagnosis of CAPD^{2,27,28}. It cannot yet be precisely stated that the CAPD is characterized as a solely auditory deficit², since the literature evidences that the intelligence, memory, attention and language characteristics in children with CAPD overlap the same characteristics in children diagnosed with specific language impairment, dyslexia, attention deficit hyperactivity disorder (ADHD) and learning difficulty. This supports the idea that the various diagnosis of disorders interrelates, forming a sort of spectrum, instead of distinct alterations, with well-defined characteristics²⁹.

There is also the premise that the CAPD goes beyond a disorder, its symptoms being a marker for the Neurodevelopmental Syndrome, which associates various auditory, speech, attention, memory, and behavioral difficulty markers. Depending on the severity and predominance of one or more markers, the child would manifest a unique development profile, with modulated unfoldment through the genetic composition, the environment to which the child is exposed, the age, and the academic demands³⁰.

For Moore²⁷, it is implausible that children with auditory difficulties (auditory inabilities, in spite of audiometry within standard normality) present a disorder in the central auditory function and it can be diagnosed only through a combination of tests. This occurs because the symptoms clinically reported in the subjects do not follow logically along with the tests used, or with an intervention based on evidence²⁷. On

the other hand, a second line of thought states that the term “auditory difficulties” is not specific enough, just as it does not contribute to the differential diagnosis. Due to its complexity, CAPD needs a thorough assessment through the central auditory processing tests and the multidisciplinary insight for the differential diagnosis to be precise and to manage to identify comorbidities, thus maximizing an effective intervention, directed to the specific processes identified through the diagnostic battery²⁶⁻²⁸.

In spite of this, all the studies included at least one test that assesses the abilities of hearing integration and/or target-to-masker listening^{17,19-21}. Filtered speech was used^{17,19}, as well as speech in noise²¹, and figure-ground²⁰, encompassing the degraded speech^{1,25,26}.

Given the particularities of each instrument, it is challenging to think which pass-failure criterion would be the most relevant. For STAP²¹, whose criteria are based on existing diagnostic tests, there is greater reliability in the result when the total score has correct answers above 50% of the stimuli presented in each subtest. The SCAN^{17,20}, which had lower sensitivity values, presented parameters involving um standard deviation below the average of the composite score¹⁷ and the percentile score ≤ 10 in the AFG subtest, both determined by reflecting more adequately to the real hearing difficulties. This comparison is also reinforced with the SCAP²¹ and CHAPS¹⁹ questionnaires. In the first, the cut-off point the score was six, with a score for each symptom related to CAPD²¹, while the second is based on a score below 1.5 standard deviation¹⁹.

Attention should also be called to the fact that, of the 28 excluded articles, seven were so because of the methodological design that diverged from the accuracy study, which was the focus of this review. Ten articles were excluded for not presenting all the accuracy measurements; and eight did not report the comparison with a battery of auditory processing diagnostic tests, considered as the reference standard assessment. This reflects the shortage of studies in audiology with methodological rigor to assess the accuracy of the CAPD screening instruments, and the need of primary studies presenting this scope and overcoming the difficulties with the diagnostic and the establishment of the reference standard. Only after this it will be possible to broaden the discussions and present more effective

evidence, strengthening the importance of CAPD screening in the clinical context.

The heterogeneity found in the gold reference standard test and in the index test are presented here as limitations to this study, since it makes the comparison and the conclusion less effective. Nevertheless, it reflects the complexity of the CAPD, and points to the need for further primary studies with rigorous methodology in order for them to be replicated, thus making comparisons easier. A methodological limitation of this review was the lack of access to three studies on the second phase, as they were unavailable in full text version, though all the possibilities had been tried, even requesting the corresponding author to provide the article.

Another limitation to the study was exactly the non-homogeneity of the pass/fail criteria to consider the CAPD in the screening instruments and in the diagnostic criteria. These two points wind up making evident the fragility in this field of knowledge; it is thus necessary to invest in primary studies presenting sturdier scientific methodology so as to bring about clearer and more valid scientific contributions to the clinical context of the practice of audiology in the field of the CAPD.

CONCLUSION

The CAPD screening test with the best accuracy was the Mottier test. There was no homogeneity in the presentation of the pass/fail criterion, or in the gold reference test used to establish the presence of the CAPD. The specificity of the instruments identified (CHAPS, AFG, SCAN, Mottier test, STAP and the associated use between SCAP and STAP) were higher than 70%, but just the Mottier and STAP test, and SCAP showed sensibility higher than 70%.

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APPENDIX 1

Database search strategy

Database	Search (December 12 th 2018; updated on August 17 th , 2020)
CINAHL	(«questionnaires» OR «questionnaire» OR «survey» OR «surveys» OR «questionnaire design» OR «Questionnaire Designs» OR «hearing tests» OR «hearing test» OR «mobile app» OR «mobile app based interventions» OR «mobile application» OR «mobile application technology» OR «mobile application use» OR «mobile applications» OR «mobile approach» OR «mobile apps» OR «mobile based intervention» OR «mobile based interventions» OR «softwares» OR «Mass Screening» OR «Mass Screenings» OR «Screening» OR «Screenings») AND («Auditory Perceptual Disorders» OR «Auditory Perceptual Disorder» OR «Auditory Processing Disorder» OR «Auditory Processing Disorders» OR «Psychoacoustical Disorders» OR «Acoustic Perceptual Disorder» OR «Acoustic Perceptual Disorders») AND («Hearing» OR «audition» OR «Auditory Perception» OR «Auditory Perception» OR «Auditory Perceptions»)
LILACS	questionnaires OR Surveys OR Encuestas OR Cuestionarios OR inquéritos OR questionários OR Software OR «Programas Informáticos» OR “Mass Screening” OR “tamizaje masivo” OR “programas de rastreamento” and «Auditory Perceptual Disorders» OR «Trastornos de la Percepción Auditiva» OR «Transtornos da Percepção Auditiva»
PubMed/Medline	((«questionnaires» OR «questionnaire» OR «survey» OR «surveys» OR «questionnaire design» OR «Questionnaire Designs» OR «hearing tests» OR «hearing test» OR «mobile app» OR «mobile app based interventions» OR «mobile application» OR «mobile application technology» OR «mobile application use» OR «mobile applications» OR «mobile approach» OR «mobile apps» OR «mobile based intervention» OR «mobile based interventions» OR «softwares» OR «Mass Screening»[Mesh] OR «Mass Screenings» OR «Screening» OR «Screenings») AND («Auditory Perceptual Disorders»[Mesh] OR «Auditory Perceptual Disorder» OR «Auditory Processing Disorder» OR «Auditory Processing Disorders» OR «Psychoacoustical Disorders» OR «Acoustic Perceptual Disorder» OR «Acoustic Perceptual Disorders»)) AND («Hearing»[Mesh] OR «audition» OR «Auditory Perception»[Mesh] OR «Auditory Perception» OR «Auditory Perceptions»)
Scopus	(“questionnaires” OR “questionnaire” OR “surveys” OR “questionnaire design” OR “hearing tests” OR “hearing test” OR “mobile app based interventions” OR “mobile application” OR “Mass Screening” OR “Mass Screenings” OR “Screening” OR “Screenings”) AND (“Auditory Perceptual Disorders” OR “Auditory Perceptual Disorder” OR “Auditory Processing Disorder” OR “Auditory Processing Disorders” OR “Psychoacoustical Disorders” OR “Acoustic Perceptual Disorder” OR “Acoustic Perceptual Disorders”) AND (“Hearing” OR “audition” OR “Auditory Perception” OR “Auditory Perception” OR “Auditory Perceptions”)
Speechbite	screening AND hearing Option 2 – questionnaires OR survey OR hearing test OR mass screening AND hearing AND auditory perceptual disorders OR auditory processing disorders
Web of Science	(«questionnaires» OR «questionnaire» OR «survey» OR «surveys» OR «questionnaire design» OR «Questionnaire Designs» OR «hearing tests» OR «hearing test» OR «mobile app» OR «mobile app based interventions» OR «mobile application» OR «mobile application technology» OR «mobile application use» OR «mobile applications» OR «mobile approach» OR «mobile apps» OR «mobile based intervention» OR «mobile based interventions» OR «softwares» OR «Mass Screening» OR «Mass Screenings» OR «Screening» OR «Screenings») AND («Auditory Perceptual Disorders» OR «Auditory Perceptual Disorder» OR «Auditory Processing Disorder» OR «Auditory Processing Disorders» OR «Psychoacoustical Disorders» OR «Acoustic Perceptual Disorder» OR «Acoustic Perceptual Disorders») AND («Hearing» OR «audition» OR «Auditory Perception» OR «Auditory Perception» OR «Auditory Perceptions»)
Google Scholar	Questionnaires OR questionnaire OR survey OR surveys OR «hearing tests» OR «hearing test» OR “mass screening” OR screening AND hearing OR audition OR «Auditory Perception» OR «Auditory Perceptions» AND «Auditory Perceptual Disorders»
Open Grey	Questionnaires OR «hearing tests» OR “mass screening” AND «Auditory Processing Disorders»

APPENDIX 2

Excluded articles and reasons for exclusion (n=28)

Author, Year	Reason for exclusion
¹ Abramson, Lloyd (2016)	5
² Amos, Humes (1998)	4
³ Arnott, Henning, Wilson (2014)	6
⁴ Barry et al. (2015)	4
⁵ Carlin, Saniga (1997)	5
⁶ Emerson et al. (1997)	3
⁷ Garbaruk et al. (2018)	6
⁸ Lucas et al. (2007)	5
⁹ Marriage et al. (2001)	5
¹⁰ Meister, Wedel, Walger (2004)	5
¹¹ Moncrieff, Miller, Hill (2018)	4
¹² Mourad et al. (2015)	4
¹³ Nickisch et al. (2005)	3
¹⁴ Nickisch et al. (2006)	4
¹⁵ Nunes, Pereira e Carvalho (2013)	4
¹⁶ Obuchi, Kaga (2019)	4
¹⁷ O'Hara, Mealings (2018)	3
¹⁸ Preclik et al. (2008)	3
¹⁹ Rickard, Smales, Rickard (2013)	5
²⁰ Rutkowska, Lobaczuk-Sitnik, Kosztyla-Hojna (2017)	6
²¹ Shaikh, Baker and Levya (2020)	4
²² Skarzynski et al. (2015)	3
²³ Sofokleous et al. (2020)	3
²⁴ Strange, Zalewski, Waibel-Duncan (2009)	4
²⁵ Vaidyanth, Yathiraj (2014)	3
²⁶ Wilson et al. (2011)	4
²⁷ Yathiraj, Maggu (2013)	3
²⁸ Yathiraj, Maggu (2013)	5

Captions: 1- Individuals with hearing loss; 2- Other screening protocol whose focus is not the Auditory Processing Disorder; 3- Studies not presenting comparison with gold standard diagnostic tests; 4- Studies not presenting validity measurements (sensitivity and specificity), or not presenting sufficient data to calculate them; 5- Case-control studies, cohort studies, clinical trials, reviews, letters, conference summary, personal opinions; 6- Studies not available in full.

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