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Validation of the Central Auditory Processing Skill Self-Perception Scale (CAPSSPS) for adults

Validação da Escala de Autopercepção de Habilidades do Processamento Auditivo Central (EAPAC) para adultos

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ABSTRACT

Purpose: To validate a self-report questionnaire to assess the central auditory processing in adults. **Methods:** The instrument was tested and validated with 123 university students aged 18 to 59 years, without hearing changes or history of treatment for central auditory processing disorder. The participants were submitted to the Gaps-in-Noise and speech-in-white-noise tests. The cutoff scores for changes, sensitivity, and specificity were defined with statistical analysis. **Results:** The instrument was developed with 21 questions related to health history, life habits, and hearing and learning complaints. After factor analysis, the questions related to life habits and health conditions were removed because they had a low factor loading. Thus, the final version of the scale comprised 13 questions. The first-order constructs and the diagnostic indicator achieved the required levels of reliability. The cutoff scores to indicate abnormal results in the Gaps-in-Noise and speech-in-white-noise tests were defined respectively as 6 and 5. **Conclusion:** The scale obtained valid, reliable, and consistent results and enabled professionals to make inferences about auditory processing.

Keywords: Validation Studies; Psychometry; Self report; Auditory perception; Adult; Hearing, Speech-language pathology

RESUMO

Objetivo: validar um questionário autorreferido para avaliação do processamento auditivo central para adultos. **Métodos:** o instrumento foi testado e validado com 123 estudantes universitários de 18 a 59 anos, sem alteração auditiva e sem histórico de tratamento para transtorno do processamento auditivo central. Os participantes realizaram os testes *Gaps in Noise* e Fala com Ruído. Por meio da análise estatística, foi definido o ponto de corte para alterações, a sensibilidade e a especificidade. **Resultados:** o instrumento foi elaborado contendo 21 questões relacionadas ao histórico de saúde, aos hábitos de vida, às queixas auditivas e de aprendizagem. Após a análise fatorial, as questões relacionadas ao hábito de vida e condições de saúde foram retiradas por apresentarem carga fatorial baixa. Assim, a versão final da escala foi composta por 13 questões. Os constructos de primeira ordem e o indicador diagnóstico apresentaram níveis de confiabilidade exigidos. Foram definidos os pontos de corte 6 e 5 que indicassem alteração nos testes *Gaps in Noise* e Fala com Ruído branco, respectivamente. **Conclusão:** a escala apresentou resultados válidos, confiáveis e consistentes e foi capaz de realizar inferências sobre o processamento auditivo.

Palavras-chave: Estudos de validação; Psicometria; Autorrelato; Percepção auditiva; Adulto; Audição; Fonoaudiologia

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INTRODUCTION

In adults, as well as in children and adolescents, central auditory processing disorders (CAPD) may have countless triggering factors and coexist with learning difficulties and language, behavioral, and cognitive function changes. These lead to deficits in communication and restrictions in their personal, academic, social, and emotional life[1].

There is scarce scientific production in the national literature investigating these disorders and their consequences to adults' life and communication. Nevertheless, it is important to draw attention to changes in this target audience, since adults are likewise affected[2].

Some studies have researched CAPD with auditory skill investigation questionnaires[3]. The questionnaires enable health and education professionals, as well as the patient, to identify which skills are at risk of suffering changes and develop learning and hearing health promotion strategies[3].

The study by Zanchetta et al.[4] aimed to translate and culturally adapt the Amsterdam Inventory for Auditory Disability and Handicap (AIADH) to Portuguese and analyze its reliability, validity, and acceptability results. The instrument assesses the result measures reported by the patient, which allow them to present, based on their perceptions, the impact of hearing loss on their daily activities. The study showed that the self-report questionnaire is adequate to distinguish people with hearing loss. Thus, by measuring the self-perceived hearing difficulties, the instrument presented important data on the auditory skills and performance of people in daily activities that depend on hearing.

According to the international literature, the results of auditory investigation questionnaires – e.g., the Speech, Spatial, and Qualities of Hearing Scale (SSQ), Amsterdam Inventory for Auditory Disability (Modified), and Hyperacusis Questionnaire (HQ) – are correlated with the results of central auditory processing (CAP) behavioral assessment tests. This suggests that questionnaires can indicate the same aspects investigated in formal tests[5].

When scores suggestive of hearing change are identified in questionnaires such as the abovementioned ones and abnormal results are found in at least one CAP assessment test, the person must be referred for rehabilitation, with strategies developed from the two assessment methods[5].

There are few instruments in the national literature developed and aiming to screen CAP skill changes in Brazilian adults, which motivated this research. Its objective was to validate the Central Auditory Processing Skill Self-Perception Scale (CAPSSPS), developed in the study by Silva et al.[6] for auditory investigation.

The present study presents the instrument developed to identify possible disorders or the need for CAP assessment in adults, encompassing the CAPSSPS validation data, with sensitivity, specificity, and cutoff scores defined with psychometric analysis.

METHODS

This study was approved by the Research Ethics Committee of the Federal University of Minas Gerais, under evaluation report no. 913.923. All study sample participants signed an informed consent form (ICF), which followed the recommendations of the National Health Council – CNS 466/2012[7].

The research was conducted in two stages: 1) development and construction of the instrument named Central Auditory Processing Skill Self-Perception Scale (CAPSSPS), in which the steps necessary to construct a health measurement instrument were followed and the first version of the scale was produced and tested in a pilot study by Silva et al.[6]; 2) application and validation of the instrument, in which the psychometric measures were tested.

In the first stage, the instrument was analyzed by judges and applied to a sample of university students, who analyzed its writing and semantics. The necessary adjustments were made, including the development of questions related to clinical factors and reduction in answer options[6]. The validity of the instrument was based on face validity (presentation of the instrument, instructions on how to answer it, and ease of reading), content (clarity, relevance, appropriateness, and coverage), and construct.

Sample

The participants selected for the research were students aged 18 to 59 years, of any race and sex, regularly enrolled in the target public institution and attending at least their second term, with no history of undergoing speech-language-hearing therapy for CAPD. Students with any type and degree of hearing loss diagnosed before the study, who did not correctly answer the research instrument, or did not finish the testing were excluded. The individuals were invited to participate in the study via e-mail and were randomly selected. Along with the invitation, the participants received the CAPSSPS questionnaire and ICF.

Altogether, 32,390 higher education students enrolled in the Federal University of Minas Gerais were invited. Of these, 1,246 answered the instrument, although 342 were excluded for not meeting the study inclusion criteria. Hence, 904 individuals correctly answered the questionnaire and were apt to participate in the research.

A sample calculation was made, considering a simple random sampling without replacement, to make up the final sample, which would be selected for hearing assessment. The premises were 88% confidence interval with an approximately 0.05 margin of error. The calculation was based on the information that the proportion of students who perceived any difficulty related to the auditory skills was 0.85. This datum was obtained from the pilot study of this paper[6].

Hence, considering the population eligible for this study, it was inferred that 123 answered scales and standardized assessments would be necessary to estimate, with a precision of 0.05, the proportion of students who would perceive any difficulty related to the auditory skills. This was the total number of participants who comprised the final sample.

There were 69.1% males and 30.9% females among the included individuals; their ages ranged from 18 to 51 years, with a mean age of 24.61 years. Concerning their undergraduate programs, 60.16% were studying Health Sciences; 10.56%, Applied Social Sciences; 8.94%, Engineering; 8.13%, Linguistics, Languages, and Arts; 6.5%, Exact and Earth Sciences; 4.06%, Human Sciences; and 0.8%, Biological and Agricultural Sciences.

Procedures

After the invitation and selection of the final sample, the individuals were submitted to an audiological assessment with otoscopy, pure-tone threshold audiometry, speech audiometry, tympanometry, acoustic reflex testing, and auditory processing behavioral assessment, using the speech-in-white-noise (SWN) [(8)] and Gaps-in-Noise (GIN) tests (Auditec©). The SWN and GIN tests were used to verify the validity of the questions that investigated hearing-related difficulties requiring less involvement of language and indispensable hearing skills to good speech perception. Thus, it was identified whether the instrument would point out individuals with underlying CAPD. The auditory examinations were selected for being the gold standard to characterize peripheral hearing and auditory processing.

The tests were conducted in an acoustically treated room with a two-channel audiometer manufactured by Interacoustics (Denmark), model Ad629B, calibrated according to ISO 8253-1[(9)].

In pure-tone audiometry, the air-conduction pure-tone audibility thresholds were determined with the descending technique at 250 to 8000 Hz. The bone-conduction testing at 500 to 4000 Hz was performed when the air-conduction threshold was equal to or higher than 25 dB. The result was considered normal when the mean at 500, 1000, and 2000 Hz was equal to or lower than 25 dB HL[(10)].

The speech recognition percentage index (SRPI) test comprised 25 monosyllable words recorded 40 dB SL above the mean pure-tone threshold at 500, 1000, and 2000 Hz, presented separately to each ear. Results between 88% and 100% correct identifications were considered normal[(11)]. The recorded list[(8)] was used as the reference in the SWN test.

The equipment used in the tympanometry and acoustic reflex testing was also manufactured by Interacoustics (Denmark), model At235h, calibrated according to ISO 8253-1[(9)]. The results were considered normal when there was a type A tympanogram and acoustic reflexes following the classifications by Jerger[(12)], Jerger and Jerger[(13)].

The SWN test assessed auditory closure, using the main message with a list of 25 monosyllable words and an ipsilateral white noise competing message, at -5 dB signal-to-noise ratio (SNR). The number of correct answers was multiplied by 4% to obtain the percentage of correct answers. The criteria proposed in the test manual were used to define normal results – i.e., a percentage of correct answers higher than 72% and a maximum difference in the percentage of correct answers between the SRPI and SWN of 20%.

The GIN test assessed temporal resolution and determined the gap detection threshold (silence interval) in 6-second white noise stimuli. Two stimulus tracks of the test were used. The gap threshold was considered the shortest interval perceived by the subject in at least four of the six times it was presented. The test result was presented in milliseconds (ms). The threshold expected from students aged 18 years or older was up to 5 ms.

Statistical analysis

The data were entered into an Excel® spreadsheet. To create a diagnostic indicator for adults, the number of dimensions of the instrument was first verified, using the acceleration factor (AF). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was used to verify whether the sample was adequate for factor analysis. This measure ranges from 0.0 to 1.0; the closer to 1,0 (unit), the more adequate the sample.

To analyze the quality and validity of the constructs, the dimensionality, reliability, and convergent validity were verified. The dimensionality – which can also be explained as one item's strong association with another, thus representing a single concept – was verified with AF. The Cronbach alpha (AC) and composite reliability (CR) were used to measure reliability. Both CA and CR must have values higher than 0.70 to indicate construct reliability, or higher than 0.60 in the case of exploratory research, such as this paper. Convergent validity was verified with the mean percentage of shared variance between the latent construct and its items. This criterion ensures the convergent validity for average variance extracted (AVE) values – or mean percentage of shared variance between the construct and its indicators – above 50%, or 40% in the case of exploratory research.

The diagnostic indicator for adults between the variables was compared with the results of the standardized tests using the Mann-Whitney test. Logistic regression was adjusted to establish the diagnosis for students based on the results of the GIN and SWN tests and the diagnostic indicator for adults. The Receiver Operating Characteristic (ROC) curve was obtained with the regression model to determine the cutoff score – i.e., the necessary indicator value to diagnose an adult with change based on the GIN and SWN tests. The R software (version 3.2.4) was used in the analyses, and the significance level was set at 5%.

RESULTS

The descriptive analysis of the students' perceptions showed that 46.74% had some CAP-related complaint, and 63.61%, some academic difficulty.

AF was used to create the diagnostic indicator for adults and verify the number of dimensions of the instrument – which, based on this method, were found to be two. The degree of discrimination of the items was investigated through factor analysis with a tetrachoric correlation matrix, as all items were binary. Table 1 presents the factor analysis of these two constructs. Items Q16 in the first construct and Q13, Q14, Q15, Q17, Q18, Q19.I, and Q20.I in the second one were removed from the model because they did not have factor loadings above 0.50. On the other hand, although item Q7 had a factor loading of 0.39, it was not removed from the model because this condition did not prevent the validation of its respective construct. Construct items Q1 to Q21 were described in Appendix 1.

The validity and quality measure analyses of the two factors showed that the two constructs presented convergent validation (AVE > 0.50), Cronbach alpha, or composite reliability above 0.60 – i.e., all of them had the required levels of reliability. The fit of the factor analysis was good, as all KMO were equal to or higher than 0.50. Both constructs were unidimensional according to AF.

In the verification of the validity and quality measures of the second-order construct, it showed convergent validity (AVE > 0.50) and composite reliability above 0.60 – i.e., it had the required levels of reliability. The fit of the factor analysis was good, as all KMO were equal to or higher than 0.50. The construct was unidimensional according to AF (Table 2).

Table 1. Factor analysis of the first-order constructs

Constructs	Items	Initial model			Final model		
		FL¹	Com.²	Weight	FL¹	Com.²	Weight
Factor 1	Q1	0.97	0.84	0.32	0.98	0.85	0.32
	Q2	0.97	0.84	0.32	0.97	0.84	0.32
	Q3	0.81	0.42	0.23	0.80	0.41	0.23
	Q4	0.62	0.22	0.16	0.61	0.21	0.16
	Q7	0.39	0.07	0.09	0.39	0.07	0.09
	Q16	0.21	0.02	0.05		Excluded	
	Q21.I	0.79	0.44	0.23	0.80	0.45	0.24
Factor 2	Q5	0.60	0.25	0.17	0.61	0.26	0.18
	Q6	0.70	0.36	0.20	0.72	0.38	0.22
	Q8	0.40	0.11	0.11	0.41	0.11	0.12
	Q9	0.80	0.50	0.24	0.82	0.52	0.25
	Q10	0.88	0.61	0.26	0.89	0.63	0.28
	Q11	0.70	0.36	0.20	0.73	0.39	0.22
	Q12	0.81	0.51	0.24	0.83	0.54	0.26
	Q13	-0.01	0.00	0.00		Excluded	
	Q14	0.03	0.00	0.01		Excluded	
	Q15	0.19	0.02	0.05		Excluded	
	Q17	0.21	0.03	0.05		Excluded	
	Q18	0.36	0.09	0.10		Excluded	
	Q19.I	0.44	0.13	0.12		Excluded	
	Q20.I	0.23	0.03	0.06		Excluded	

Subtitle: FL¹ = factor loading; Com.² = communality; Q = Question

Table 2. Validation of the first- and second-order constructs

Validation of the first-order constructs						
Factors	Items	CA¹	CR²	Dim.³	AVE⁴	KMO⁵
Factor 1	6	0.72	0.80	1	0.62	0.72
Factor 2	7	0.74	0.70	1	0.53	0.80
Validation of the second-order construct						
Constructs	**Items**	**CA¹**	**CR²**	**Dim.³**	**AVE⁴**	**KMO⁵**
Diagnosis for adults	2	0.40	0.68	1	0.63	0.50

Subtitle: CA¹ = Cronbach alpha; CR² = composite reliability; Dim.³ = dimensionality; AVE⁴ = average variance extracted; KMO⁵ = Kaiser-Meyer-Olkin measure of sampling adequacy

Once validated, the diagnostic indicator for adults was created based on the sum of the subject's answers, which is the most recommended method to obtain generality and transfer capacity. Considering that the indicator was created based on the sum of the two 13-item factors, ranging from 0 to 1, it was situated on a scale ranging from 0 to 13. Hence, the indicator had a mean of 6.10 [5.91; 6.31] and a standard deviation of 2.99.

The Mann-Whitney technique was used to compare the diagnostic indicator for adults with the auditory and auditory processing assessments. It revealed that there was no significant difference between the indicator and the variables (Table 3).

Logistic regression was fitted to establish the diagnosis for adults with the GIN and SWN tests based on the diagnostic indicator for adults. The ROC curve was obtained with the regression model to determine the cutoff score – i.e., the necessary indicator value to diagnose an adult with change based on the GIN and SWN tests. Moreover, some quality measures of the model fitting were also calculated, namely: Pseudo R^2 and Hosmer-Lemeshow test.

The ROC curve obtained with the regression model determined 0.299 as the best cutoff, which represents 6 in the indicator. Hence, it can be concluded that, for values higher than 6 in the indicator, the subject can be feasibly said to have a positive result for abnormal results in the GIN test. The sensitivity of the model was 62.0%, which means the model could accurately predict 62% of the processes with changes. The specificity of the model was 51.0%, which means the model could accurately predict 51% of the processes without changes. The area under the ROC curve was 55.0%.

The analysis of the logistic regression for the SWN test result revealed that there was no significant influence (p-value=0.538) of the diagnostic indicator for adults on the SWN test result. The model was considered good according to the Hosmer-Lemeshow test (p-value=0.168) and the indicator could explain 0.42% of the variability of the test result.

The ROC curve obtained with the regression model indicated 0.294 as the best cutoff score, which represents 5 in the indicator. Hence, it can be concluded that, for values higher than 5 in the indicator, the subject can be feasibly said to have a positive result for abnormal results in the SWN test. The sensitivity of the model was 74.0%, which means the model could accurately predict 74% of the processes with changes. The specificity of the model was 56.0%, which means the model could accurately predict 56% of the processes without changes. The area under the ROC curve was 54.0% (Figure 1).

The scale, after the statistical fitting, is presented in Chart 1.

DISCUSSION

The need for the CAPSSPS arose from the scarcity of CAP-related instruments for adults, as the topic is approached less frequently regarding this population.

In the investigated sample, the academic difficulties were more expressive than the CAP-related complaints. These

Table 3. Comparison of the diagnostic indicator for adults between the variables of the auditory assessment

Variables		N	Mean	SE	Q1	Q2	Q3	p-value[1]
Speech audiometry	Normal	114	7.04	0.31	4.00	7.00	10.00	0.203
	Abnormal	12	5.67	0.71	3.50	6.50	8.00	
Tympanometry	Normal	111	6.87	0.31	4.00	7.00	9.00	0.719
	Abnormal	15	7.27	0.81	5.50	7.00	9.50	
Ipsilateral acoustic reflex 1 kHz	Normal	53	7.26	0.45	4.00	7.00	10.00	0.333
	Abnormal	73	6.66	0.38	4.00	6.00	9.00	
Ipsilateral acoustic reflex 2 kHz	Normal	58	6.91	0.43	5.00	7.00	9.00	0.971
	Abnormal	68	6.91	0.40	4.00	7.00	9.00	
Contralateral acoustic reflex 500 Hz	Normal	54	7.15	0.45	5.00	7.50	10.00	0.414
	Abnormal	72	6.74	0.38	4.00	7.00	8.50	
Contralateral acoustic reflex 1 kHz	Normal	58	6.98	0.44	5.00	7.00	9.00	0.742
	Abnormal	68	6.85	0.39	4.00	7.00	9.00	
Contralateral acoustic reflex 2 kHz	Normal	61	6.95	0.41	4.00	7.00	9.00	0.916
	Abnormal	65	6.88	0.41	4.00	7.00	9.00	
Contralateral acoustic reflex 4 kHz	Normal	65	6.69	0.41	4.00	7.00	9.00	0.465
	Abnormal	61	7.15	0.42	5.00	7.00	10.00	
GIN	Normal	87	6.76	0.36	4.00	7.00	9.00	0.419
	Abnormal	39	7.26	0.50	4.50	8.00	9.50	
SWN	Normal	87	6.79	0.37	4.00	6.00	9.00	0.444
	Abnormal	39	7.18	0.47	5.50	7.00	8.50	

[1] Mann-Whitney test.

Subtitle: N = number; SE = standard error; Q1 = quartile 1; Q2 = quartile 2; Q3 = quartile 3; GIN = Gaps-in-Noise test; SWN = speech-in-white-noise test

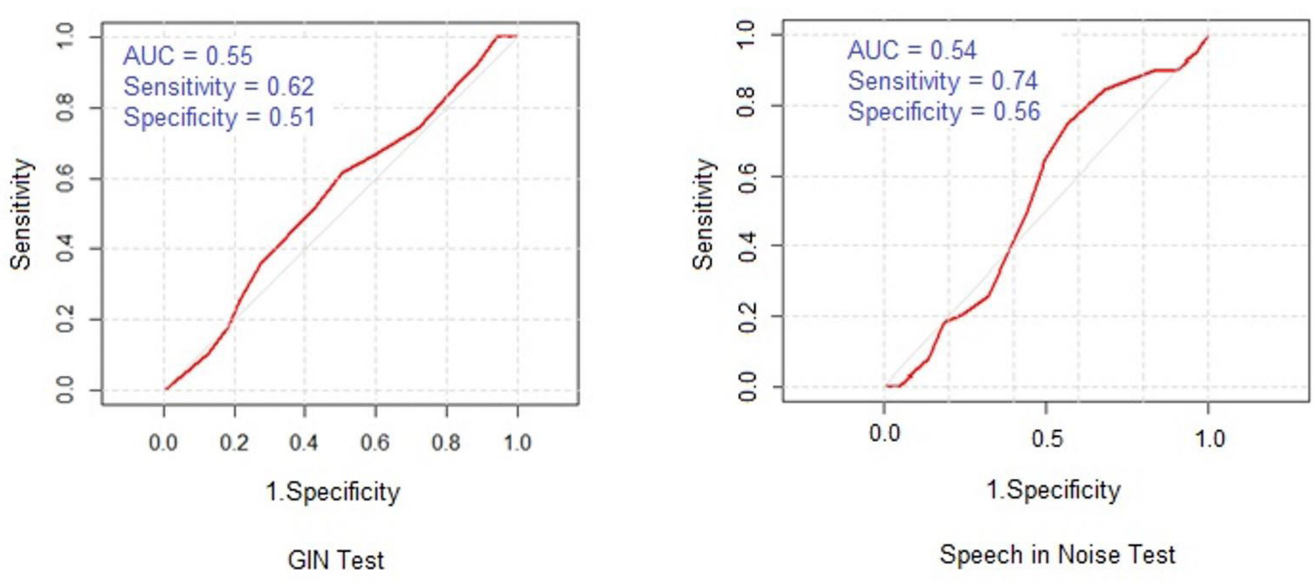

Figure 1. Gaps-in-Noise (GIN) and speech-in-white-noise ROC (Receiver Operating Characteristic) Curves
Subtitle: AUC = area under the curve; GIN = Gaps-in-Noise

Chart 1. Central Auditory Processing Skill Self-Perception Scale

CAPSSPS – CENTRAL AUDITORY PROCESSING SKILL SELF-PERCEPTION SCALE		ANSWER	
Name:	Sex: F() M()	Yes	No
Age:	Educational level:	Score	
	QUESTIONS	(1)	(0)
Q1	Do you think you have problems detecting acoustic stimuli (sounds in general, speech, etc.)?		
Q2	Do you think you have problems with sound source localization and lateralization (e.g., knowing from where someone is calling you when they are far)?		
Q3	Do you think you have problems recognizing acoustic stimuli (sounds in general)?		
Q4	Do you think you have problems discriminating acoustic stimuli (differentiating speech sounds; for instance, hearing S and Z)?		
Q5	Do you think you have problems paying selective and sustained attention to acoustic stimuli (e.g., hearing and understanding the professor speak, even with other conversations in the room or external noise)?		
Q6	Do you think you have problems with short-term memory related to acoustic stimuli (recalling things you only heard, such as classes or short texts)?		
Q7	Do you think you have difficulties perceiving sounds in time? For instance, understanding someone who speaks too fast or does not clearly articulate words.		
Q8	Do you think you have difficulties hearing and understanding people speak in noisy environments? For example, talking at the bus stop, in restaurants, etc.		
Q9	Do you have or have you ever had concentration-related academic difficulties at any moment during your higher education studies?		
Q10	Do you have or have you ever had memory-related academic difficulties at any moment during your higher education studies?		
Q11	Do you have or have you ever had planning-related academic difficulties at any moment during your higher education studies?		
Q12	Do you have or have you ever had learning-related academic difficulties at any moment during your higher education studies?		
Q13	Where did you go to high school? (Check 0 for private school or 1 for public school)		
Total SCORE			

The CAPSSPS can be answered by subjects aged 17 to 55 years; Results > or = 5 points: suggestive of a change in auditory closure; Results > or = 6 points: suggestive of a change in temporal resolution

difficulties may be associated with a wide range of aspects and are uniquely developed, based on each person's perception of them[3]. The academic difficulties must be considered because they may reflect the conditions in which knowledge is developed during undergraduate studies, impacting daily activities.

Some authors[14] suggest that learning deficits may actually be executive deficits related to attention, operational memory, or inhibitory control. The subjects were probably not managing to make metacognitive analyses – i.e., were not being able to analyze the requirements of the tasks and associate them to reality[15].

The questions related to life habits and health conditions – such as sleep, consumption of alcohol and other substances, eating habits, use of medications, and history of neurological and/or psychiatric changes – were excluded from the questionnaire because they had low factor loading, although they were theoretically fitted to the construct and the dimension studied. These questions had a low saturation with the dimensions, influencing the validation of the instrument. Item Q7, despite the factor loading of 0.39, was not removed from the model because it did not impact the validation of its respective construct.

Studies show that sleep habits, such as duration and regularity of its cycles, can influence students' performance in speed tasks, quality of focused attention, and other daily activities[16]. Also, sleep disorders can affect the processing of sound information. According to Iriz et al.[17], subjects with sleep disorders, such as obstructive sleep apnea syndrome, perform worse in speech discrimination and frequency pattern and duration pattern recognition tests than those without apnea. Researchers suppose that episodes of hypoxia caused by apnea damage the auditory pathway.

The literature shows that the consumption of alcohol or other substances impairs the auditory pathway, causing sound discrimination difficulties[18], increase in auditory thresholds, absence of transient otoacoustic emissions, and presence of hearing complaints, such as difficulties understanding speech in noise[19]. A study observed changes in the auditory perception of rats and concluded that the chronic consumption of alcohol reduced such information in the nuclei of the inferior colliculus. This region is involved in motor responses that direct the head and body toward the sound source, integrating the auditory, somesthetic, and visual information[20].

Even though these life habits related to sleep and toxic substance use influence auditory functioning, the present study suggests that these aspects have little impact on auditory performance in everyday situations.

The other questions in the scale had factor loading higher than 0.5, pointing to the relevance of investigating the cognitive aspects and symptoms related to a deficit in the auditory skills[5]. Thus, after the statistical analysis, the instrument comprised 13 binary questions (yes and no; public and private), each one with a weight of up to 1 point.

Concerning the analysis of construct validity, the CAPSSPS had acceptable convergent validity values, as suggested in the literature. This shows that the scale was correlated with the auditory tests and therefore can indicate data on the subject's hearing. As for internal consistency, it was verified that the domains in the scale assess the same characteristics – i.e., the auditory skills[21,22]. Thus, the instrument proved to be precise and homogeneous.

The diagnostic indicator for adults was compared between the normal and abnormal results in the auditory assessments. However, the mean total score of the scale revealed no difference between the groups. Most of the sample had learning complaints, in contrast with hearing complaints, and the two groups were not compared regarding the scale domains. Hence, the identification of differences between the groups may have been affected. Future studies should compare the groups regarding the questionnaire domains.

According to the ROC curve results, the individuals who obtained 5 or more points on the scale had an abnormal result in the SWN test and, if they obtained 6 or more points, they also had an abnormal result in the GIN test, respectively with 74% and 62% sensitivity and 51% and 56% specificity.

The SWN and GIN tests assess auditory closure and temporal resolution. Auditory closure for verbal sounds is responsible for mentally complementing the acoustic characteristics of words when the person does not completely receive them[8]. Temporal resolution[23] detects the minimum time interval necessary to discriminate different acoustic events. In children and adolescents, changes in these skills can result in poor communication, due to impaired identification of subtle acoustic variations, causing difficulties producing and interpreting sounds. Adults are also believed to have difficulties due to such changes[23], as they are indispensable tools of the central auditory function to optimize the acquisition of knowledge at university.

The study by Bamiou et al.[5] likewise found an association between the SWN and GIN test results and the hearing assessment questionnaire scores. It is suggested that the inability to process temporal aspects of sound, identified in the SWN and GIN tests, is significant to the point of being perceived and reported by the subjects in real-life contexts. Moreover, as the tests and the questionnaire measure the same aspects, the deficits detected in formal tests are also pointed out in the questionnaire.

All steps in the development of this instrument were essential to the final result. From the empirical standpoint, the investigation of the discrimination power of the items and the validity and precision analyses led to the final version of the scale, which proved to be adequate in psychometric terms. The 13 final items proved to be discriminative. The precision indices obtained with Cronbach alpha for the two dimensions can be considered satisfactory for this scale, agreeing with the literature[24] and considering the methodology used[25,26], as they were above 0.50.

Thus, the CAPSSPS proved to be reliable, demonstrating, with the results obtained with psychometric analysis, that its different items correlate well (internal consistency).

The CAPSSPS results were related only to the SWN and GIN tests – i.e., to auditory closure and temporal resolution –, which is a limitation of the study. Future research should be conducted to further investigate the data obtained with the scale. There is an ongoing study administering the questionnaire to adults and addressing low-redundancy monaural speech, dichotic hearing, temporal processing, and binaural integration to observe the validity of the instrument in different contexts and broaden the comprehension of the instrument.

CONCLUSION

The psychometric assessment of the instrument revealed that the CAPSSPS had valid, reliable, and consistent results. Scale scores equal to or higher than 5 suggest changes in auditory closure, and scores equal to or higher than 6 suggest changes in temporal resolution. Hence, the instrument was able to present information on adults' auditory performance in everyday situations, helping identify possible CAPD.

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Appendix 1. Description of the questions in the first version of the Central Auditory Processing Skill Self-Perception Scale - CAPSSPS

Abbr	Description
Q1	Do you think you have problems detecting acoustic stimuli (sounds in general, speech, etc.)?
Q2	V Do you think you have problems with sound source localization and lateralization (e.g., knowing from where someone is calling you when they are far)?
Q3	Do you think you have problems recognizing acoustic stimuli (sounds in general)?
Q4	Do you think you have problems discriminating acoustic stimuli (differentiating speech sounds; for instance, hearing S and Z)?
Q5	Do you think you have problems paying selective and sustained attention to acoustic stimuli (e.g., hearing and understanding the professor speak, even with other conversations in the room or external noise)?
Q6	Do you think you have problems with short-term memory related to acoustic stimuli (recalling things you only heard, such as classes or short texts)?
Q7	Do you think you have difficulties perceiving sounds in time? For instance, understanding someone who speaks too fast or does not clearly articulate words.
Q8	Do you think you have difficulties hearing and understanding people speak in noisy environments? For example, talking at the bus stop, in restaurants, etc.
Q9	Do you have or have you ever had concentration-related academic difficulties at any moment during your higher education studies?
Q10	Do you have or have you ever had memory-related academic difficulties at any moment during your higher education studies?
Q11	Do you have or have you ever had planning-related academic difficulties at any moment during your higher education studies?
Q12	Do you have or have you ever had learning-related academic difficulties at any moment during your higher education studies?
Q13	Do you drink or have you ever drunk alcoholic beverages?
Q14	Do you use or have you ever used narcotics (cannabis, crack, or cocaine)?
Q15	Do you take or have you ever taken medications for a prolonged period?
Q16	Do you have any neurological or psychiatric disorders (dementia, brain vascular disease, hemiplegia, paraplegia, meningitis, peripheral neuropathy, facial palsy, or learning, attention and hyperactivity, behavior, mood, anxiety, psychosis, conduct)?
Q17	Do you have any neurological or psychiatric symptoms (headache, dizziness, vertigo, fainting, convulsion, other)?
Q18	Do you sleep 8 hours a night on average?
Q19	Do you consider your sleep satisfactory?
Q20	Do you regularly have three meals a day with items from the different food groups?
Q21	Where did you go to high school?

Subtitle: Abbr = abbreviation