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Online Auditory Abilities Screening in Elderly: Initial Considerations

Evaluación en línea de habilidades auditivas en la tercera edad: consideraciones iniciales

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Abstract

Objective. To analyze the results of AudBility's online screening in the elderly to assess its viability.

Methodology. The study included 40 elderly participants (mean age 67.4 years). They underwent online AudBility screening and completed a self-assessment questionnaire along with tests assessing seven auditory skills: sound localization (SL), dichotic digits task, speech perception in noise, auditory closure, staggered dichotic words test (SDW), temporal resolution, and temporal ordering. Descriptive data analysis considered AudBility's reference parameters: <50% = abnormal, 51-79% caution, >80% = normal.

Results. The tests with the highest frequency of abnormalities were SL and temporal ordering frequency (TOF), both with 22.5%. On average, these tests were considered as "caution" (SL = 72.75%; TOF = 67.5%). The self-assessment questionnaire had the highest frequency of "caution" results (52.5%), followed by SDW (35%) and TOF (32.5%). On average, the self-assessment questionnaire and TOF showed caution values (74.41% and 67.5%, respectively). SDW had normal average values (81.5%). No test showed abnormal average values.

Conclusion. Auditory screening using AudBility can serve as an entry point for assessing auditory and cognitive health in the elderly population, guiding referrals and therapies before in-person interventions.

Declaration of interests
The authors have declared that there is no conflict of interest.

Data availability
All relevant data is in the article.
For futher information, contact the corresponding author.

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Statement of Responsibility
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Contribution of the authors
Marina Englert: Conceptualization, data curation, formal analysis, investigation, methodology, project administration, writing – original draft.
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Keywords
Auditory perception; old age assistance; aged; geriatric assessment; audiology.

Resumen

Objetivo. Analizar los resultados del cribado en línea de AudBility en ancianos para evaluar su viabilidad.

Metodología. El estudio incluyó a 40 ancianos (edad media de 67.4 años). Se sometieron a un cribado en línea de AudBility y completaron un cuestionario de autoevaluación y pruebas que evaluaban siete habilidades auditivas: localización del sonido (LS), tarea dicótica de dígitos, percepción del habla en ruido, cierre auditivo, prueba dicótica de palabras escalonadas (PDE), resolución temporal y ordenamiento temporal. El análisis de datos descriptivos consideró los parámetros de referencia de AudBility: <50% = anormal, 51-79% = precaución, >80% = normal.

Resultados. La prueba con la mayor frecuencia de anomalías fue LS y ordenamiento temporal frecuencia (OTF), ambas con un 22.5%. En promedio, estas pruebas se consideraron como "precaución" (LS = 72.75%; OTF = 67.5%). El cuestionario de autoevaluación tuvo la mayor frecuencia de resultados de "precaución" (52.5%), seguido por PDE (35%) y OTF (32.5%). En promedio, el cuestionario de autoevaluación y OTF mostraron valores de precaución (74.41% y 67.5%, respectivamente). PDE tuvo valores promedio normales (81.5%). Ninguna prueba tuvo valores promedio anormales.

Conclusión. Utilizar AudBility para el cribado auditivo puede servir como punto de partida para evaluar la salud auditiva y cognitiva en la población anciana, orientando derivaciones y terapias antes de las intervenciones presenciales.

Palabras clave
Percepción auditiva; asistencia a los ancianos; anciano; evaluación geriátrica; audiología.

Introduction

The aging population is an undeniable reality in Brazil, reflected in the significant increase in the elderly population. According to estimates from IBGE (2023) [1], this segment of society already reaches 14.7% of the total population, corresponding to 31.2 million individuals aged 60 and above. Projections indicate that by 2050, this proportion will increase to 29.3%, encompassing 66.5 million seniors. Life expectancy at birth is also on the rise, reaching 77.3 years in 2023, with projections to reach 81.2 years by 2050.

The socioeconomic impact of this aging is evident, especially in the health context. The World Health Organization (WHO) [2] reports that costs related to the health of the elderly population are 2 to 3 times higher compared to younger adults. In this scenario, it becomes essential to address specific issues such as hearing loss and central auditory processing (CAP) alterations, which directly impact the quality of life of the elderly.

Studies indicate that among the elderly, 70% to 80% have some degree of hearing loss, a situation that increases with age, reaching 90% in individuals over 80 years old. This loss can be classified into different types of presbycusis: sensory, neural,

metabolic, and mechanical. Sensory presbycusis is associated with damage to the hair cells in the inner ear. Neural presbycusis originates from the auditory nerve or brainstem. Metabolic presbycusis involves changes in the stria vascularis, affecting the ionic composition of the endolymph. Mechanical presbycusis is related to changes in the mechanical properties of the cochlea, such as stiffening of the basilar membrane [2,3]. Additionally, aging affects CAP, responsible for the analysis and interpretation of sounds by the brain, manifesting challenges such as difficulty in understanding speech in noisy environments and problems with spatial sound localization [4,5].

Given this context, the early assessment of auditory skills in the elderly is crucial. However, the conventional assessment of CAP presents challenges, as it requires hearing within normal thresholds [4], limiting its application in elderly individuals with hearing loss. Ferguson et al. (2023) [6] underscored the critical association between cognitive impairment and hearing loss, emphasizing the importance of early detection in managing these conditions for effective healthcare decision-making. Their scoping review identified prevalent preferences among clinicians for short, accessible tests such as the Mini-Mental State Exam and Montreal Cognitive Assessment for cognitive impairment, and pure-tone audiometry for hearing loss in healthcare settings. However, they also noted inherent limitations in these methods when applied to an aging population. In response, Ferguson et al. [6] advocate for the incorporation of electrophysiological measures alongside standard assessments, proposing that this comprehensive approach may offer more reliable information for clinical recommendations, especially in cases of concurrent cognitive and hearing impairment. This recommendation aligns with the growing concern regarding the relationship between hearing loss, CAP alterations, and dementia, as highlighted by various studies [3,7-12]. Recognizing these challenges and insights, it is imperative to explore and implement advanced assessment tools that cater to the unique needs of the elderly population, ultimately aiming for better healthcare outcomes in this demographic.

To facilitate this process, AudBility emerges as an online tool for screening auditory skills, available in Brazilian and European Portuguese at https://www.audbility.com.br/. Comprising quick and simple tests, AudBility assesses various aspects of hearing, such as sound discrimination, and spatial sound localization [13]. Its viability for the elderly stands out, being easily accessible and usable, and applicable to seniors with varying levels of technology familiarity.

The proposed study aims to analyze the results of online screening of auditory skills with AudBility in the elderly population, intending to verify its effectiveness as a tool for early identification of auditory and CAP problems. This article contributes to the understanding of these challenges and proposes an innovative approach to assess auditory skills in a population that requires increased attention.

Methods

The study was approved by the Ethics and Research Committee (number 4343-20 at *Plataforma Brasil* with CAAE 37763220.7.0000.0071). Forty individuals aged 60 to 75 years participated in the study (mean age 67.4 years, SD = 4.51, 12 men and 28 women). All subjects were invited to participate through announcements at a senior physical activity center and/or direct contact with the researchers. Those who agreed to participate signed an online Informed Consent Form (ICF).

Initially, the invited individuals and those interested in participating in the study answered identification questions, reported any hearing complaints, disclosed whether they used hear-

ing aids, and were classified as athletes, active, or sedentary using the modified Baecke questionnaire for the elderly [14]. All questions were presented through an online questionnaire provided via Google Forms to those interested in participating in the study.

The inclusion criteria were being between 60 and 75 years old; being a native speaker of Brazilian Portuguese language; having controlled chronic diseases; being independent and autonomous; having a hearing level compatible with social conversation, regardless of using hearing aids; and understanding the instructions of the auditory tests to be performed. Exclusion criteria included individuals with neurological diseases, sequelae of strokes, disorders affecting speech intelligibility, individuals with less than four years of formal education, unilateral anacusis, and cognitive deficits.

A total of 136 individuals responded to the questionnaire; 15 did not meet the inclusion criteria and were excluded. The remaining 121 participants were invited to participate through email. Several participants did not respond to the invitation emails, some responded choosing not to participate, and 40 subjects were scheduled and participated in the study.

The 40 participants underwent AudBility, an online screening of central auditory function behavior, conducted entirely using the Google Meet platform. AudBility was validated with approximately 200 users in the free trial model and became commercially available in March 2020. Reference parameters flagged on the platform were defined for the age range of 9 to 12 years [15]. The platform also presents a color-coded selection, where less than 50% equals red; between 51% and 79%, yellow; above 80%, green. In the results of this study, researchers made an analogy in which red was considered abnormal, yellow was considered cautious, and green was considered normal.

The AudBility platform includes tests for screening auditory skills, allowing the mapping of performance in the following abilities and mechanisms: sound localization, dichotic digit integration test, dichotic digit separation test, speech perception in noise, auditory closure, sequential dichotic listening, temporal resolution, and temporal ordering. Additionally, there is a self-assessment questionnaire in which participants respond to the frequency of certain auditory behaviors in their daily lives [16].

AudBility is a product from the company ProBrain (https://www.probrain.com.br/inicio) that operates as an online program accessible at the following website: https://afinandoocerebro.com.br/painel/login. Its terms of use are available online by the company at https://termos.probrain.com.br/pub/policies/policies_eng.pdf?. As a screening tool for auditory skills, only speech-language pathologists and/or medical professionals are authorized to administer it. The software requires a stable internet connection with a minimum bandwidth of 1 Mbps for optimal performance. It is compatible with computers, tablets, and mobile devices running on Windows, macOS, iOS, or Android operating systems. The program supports the latest versions of web browsers, including Chrome, Firefox, Safari, and Edge. Additionally, the tool utilizes secure data encryption protocols to ensure patient confidentiality.

When accessing AudBility, the researcher registered the participant by entering anonymized identification data, date of birth, presence or absence of auditory complaints, presence or absence of learning complaints, handedness, and education level. Subsequently, the screening process began.

The screening was conducted through an access link sent via email to the participants. During the assessment, the participants shared their screen with the researcher via Google Meet. For each test, the researcher guided the participants and demonstrated examples available in each activity to explain the tasks. The screening duration ranged from 40 minutes to

2 hours, depending on the individual's ease of understanding and performing the tasks. Participants were required to use headphones and be in a quiet environment.

The data from each test were descriptively analyzed using mean, median, standard deviation, minimum, and maximum in the R Studio program. The results of each test were categorized based on the color-coded parameters of the AudBility platform, where less than 50% equaled red; between 51% and 79%, yellow; and above 80%, green.

Results

Table 1 presents participants categorized by gender, handedness, presence of auditory and learning complaints, education level, physical activity level, and hearing aid use.

Table 1. Sample Characteristics Considering Gender, Handedness Dominance, Presence of Auditory and Learning Complaints, Educational Level, Physical Activity Level, and Hearing Aid Use.

	N	%
Gender		
Male	12	30
Female	28	70
Handedness		
Right	38	95
Left	2	5
Auditory Complaint		
Yes	13	32.5
No	27	67.5
Learning Complaint		
Yes	1	2.5
No	39	97.5
Education Level		
Undergraduate	23	57.5
Postgraduate	17	42.5
Physical Activity Level		
Athlete	3	7.5
Active	7	17.5
Sedentary	30	75
Hearing Aid Use		
Yes	1	2.5
No	39	97.5

Note. N = number.

The Sound Localization and Temporal Ordering Frequency tests were the ones that most frequently displayed red values (i.e., altered according to the Audbility scale) were the, with results below 50% for nine elderly individuals (Table 2). According to the data in Table 3, these tests ranged between 51% and 79% accuracy on average, which is considered cautious (i.e., yellow colored).

Table 2. Frequency of Tests with Normal, Caution, and Altered Results.

	Normal		Caution		Altered	
	N	%	N	%	N	%
Questionnaire	18	45	21	52.5	1	2.5
Sound Localization	24	60	7	17.5	9	22.5
DDI	39	97.5	0	0	1	2.5
DDS	-	-	-	-	-	-
LE	34	85	1	2.5	5	12.5
RE	35	87.5	0	0	5	12.5
Sequential Dichotic Test	24	60	14	35	2	5
Auditory Closure						
LE	38	95	2	5	0	0
RE	39	97.5	1	2.5	0	0
Speech in Noise	-	-	-	-	-	-
LE	26	65	10	25	4	10
RE	33	82.5	6	15	1	2.5
Temporal Resolution	39	97.5	1	2.5	1	1
Temp. Order. Intens	30	75	4	10	6	15
Temp. Order. Freq.	18	45	13	32.5	9	22.5
Temp. Order. Duration	25	62.5	9	22.5	6	15

Note. N = number, DDI = dichotic digit integration test; DDS = dichotic digit separation test; LE = left ear; RE = right ear; Temp. Order. Intens. = Temporal Ordering Intensity; Temp. Order. Freq. = Temporal Ordering Frequency; Temp. Order. Duration = Temporal Ordering Duration.

Tests with the highest frequency of yellow values within the platform were the self-assessment questionnaire (21 participants), the Sequential Dichotic test (14 participants), and the Temporal Ordering Frequency test (13 participants) (Table 2). In terms of average values, the self-assessment questionnaire (74.41%) and the Temporal Ordering Frequency test (67.5%) showed values in caution range (yellow), while the Sequential Dichotic test exhibited normal average values (81.5%) (Table 3).

Considering the average score of each test, none had an average value below 50% (Table 3).

Table 3. Mean Values for Each AudBility Test.

	%	Standard Deviation (SD)	Minimum Score (%)	Maximum Score (%)	N Total
Questionnaire	74.41	10.74	45	91.67	40
Sound Localization	72.75	24.13	6	100	40
DDI	94.93	6.82	60	100	40
LE	92.87	13.42	20	100	40
RE	97	4.5	85	100	40
DDS	-	-	-	-	-
LE	88.37	22.34	0	100	40
RE	92.75	17.39	40	100	40
Sequential Dichotic Tes	81.5	10.78	57.5	100	40
Auditory Closure	-	-	-	-	-
LE	90.25	8.91	60	100	40
RE	93	8.82	60	100	40
Speech in Noise	-	-	-	-	-
LE	77.5	17.93	10	100	40
RE	86.5	13.31	50	100	40
Temporal Resolution	95.15	6.77	72	100	40
15ms	98.43	5.79	75	100	40
10ms	99.68	1.97	87.5	100	40
8ms	98.12	6.66	62.15	100	40
5ms	96.87	7.88	62.5	100	40
2ms	80.31	28.57	25	100	40
0ms	93.5	20.57	10	100	40
Temp. Order. Intens	79.5	20.99	20	100	40
LE	76	25.29	20	100	40
RE	83	21.02	20	100	40
Temp. Order. Freq.	67.5	26.18	20	100	40
LE	70	29.69	0	100	40
RE	65	26.31	20	100	40
Temp. Order. Duration	77.75	21.18	10	100	40
LE	74.5	27.54	0	100	40
RE	81	23.94	20	100	40

Note. N = number, DDI = dichotic digit integration test; DDS = dichotic digit separation test; LE = left ear; RE = right ear; Temp. Order. Intens. = Temporal Ordering Intensity; Temp. Order. Freq. = Temporal Ordering Frequency; Temp. Order. Duration = Temporal Ordering Duration.

Discussion

The present study aimed to analyze the results of an auditory skills screening in the elderly population to assess its viability for use in this demographic.

During the initial phase of online participant recruitment, we observed a response rate of only 40 out of 121 invited individuals, underscoring the challenges discussed by Peek et al. [17]. Their systematic review on the acceptance of electronic technologies among older adults highlighted concerns such as high costs, privacy implications, and usability issues, indicating the hesitancy of elderly individuals, especially when encountering technology for the first time. These concerns align with the observed lack of response in our study, emphasizing the need to address technological apprehensions and tailor interventions to enhance the acceptance of online screenings among older adults. This parallel insight suggests that interventions addressing these concerns could potentially increase participation in online assessments, particularly if preceded by in-person contact. However, it is essential to note that our data collection occurred during the COVID-19 pandemic in 2020, discouraging in-person contact. Future studies should explore this different approach and assess if participants engage more with online assessments when preceded by in-person contact.

The research included elderly individuals with hearing complaints or hearing aid users (Table 1) to ensure comprehensive representation, considering that approximately 70% of the elderly may experience hearing loss or report hearing difficulties [8]. Many older individuals might consider such complaints as commonplace or underestimate the extent of their hearing issues, resulting in a tendency to underreport [18]. Screening results from AudBility provide clinicians with an online assessment tool that can map elderly individuals' auditory performance, aiding in directing CAP evaluation and subsequent stimulation of central auditory functions.

The CAP stimulation holds potential benefits for elderly individuals with hearing loss, improving communication through enhanced sound perception and refined processing via auditory training [19]. Considering Maidment et al.'s [20] systematic review, which highlights the positive impact of alternative listening devices on behavioral measures, there is a plausible hypothesis that auditory training may similarly enhance behavioral measures in individuals with mild hearing loss. This proposition gains significance in cases where hearing aids are not utilized, potentially offering an alternative and beneficial intervention. Furthermore, for those facing barriers to hearing aid adoption, such as cost or waitlists, engaging in auditory training may serve as a viable means to improve overall quality of life and communication. Future research should explore the specific benefits of auditory stimulation on behavioral measures to further substantiate these hypotheses.

When alterations in auditory screening are identified, the initial step is to assess for hearing loss [4]. Thus, conducting screening before audiometry may facilitate referrals for resistant elderly individuals who believe they have good hearing. AudBility's auditory screening can be conducted entirely online, eliminating the need for elderly individuals to travel to clinics. This is particularly beneficial for those with limited mobility and helps streamline referrals to specialists.

Despite the potential benefits, this initial study with 40 participants did not segment subject groups based on manual dominance, presence of hearing or learning complaints, education level, physical activity level, or hearing aid use. However, researchers aim to increase the sample size for group analysis to guide referrals for each type of elderly profile and establish

normal values for this population. The analysis in this study considered the 40 elderly participants as a single group, as presented in Tables 2 and 3.

The Sound Localization and Temporal Ordering Frequency tests were frequently identified as altered (Table 2). It is known that hearing loss may negatively impact the ability to locate sounds and aspects of spatial hearing [21,22], particularly in cases of asymmetric hearing loss. Therefore, an alteration in sound location suggests a high likelihood of hearing loss, which could be due to earwax blockage or a CAP alteration at the brainstem level, specifically at the olivary complex. It's important to note that normal sound location does not rule out the possibility of hearing loss, which could be mild or asymmetrical. However, if the test fails, there is certainly a problem, either in acuity or in processing.

On the other hand, failures in Temporal Ordering Frequency in the naming modality may indicate alterations in auditory processing in the right hemisphere and/or alterations in interhemispheric integration [23].

No test had an average value considered altered; however, three had average values in caution range (Questionnaire, Sound Localization, and Temporal Ordering Frequency), and two had average values between normal and caution (Left Ear Background Noise and Temporal Ordering Duration) (Table 3). Therefore, a prevalent challenge emerges in Temporal Ordering tests, aligning with previous investigations focusing on central auditory processing disorders in the elderly [24]. The outcomes of this particular study, using the Right Hemisphere Language Battery (RHLB-PL) and the Brain-Boy Universal Professional (BUP), revealed statistically significant relationships between emotional prosody and factors such as spatial hearing, reaction time, and the recognition of frequency and duration patterns. Additionally, noteworthy correlations were observed between linguistic prosody and pitch discrimination, recognition of frequency and time patterns, as well as emotional prosody. These insights underscore the age-related decline in functions associated with frequency differentiation and temporal pattern recognition that contribute to the diminished perception of both emotional and linguistic prosody, impairing communication quality in the elderly. Consequently, utilizing AudBility for screening these abilities can serve as an initial step for appropriately stimulating this population, ultimately enhancing the overall quality of life for the elderly.

The parameters of the AudBility platform lack specific validation for the elderly, establishing this study as a pioneering initiative for this population. While utilizing generic parameters in this preliminary analysis, the accuracy percentages observed in the study can be considered initial reference values for screenings among the elderly. Additionally, the World Health Organization recommends central auditory processing evaluation in cases of mild hearing loss and normal audiometry results [25]. As an online tool, AudBility can facilitate compliance with this recommendation in locations where assessment tools or specialized professionals may not be accessible.

Beyond offering the initial standards values, our research demonstrated the feasibility of online auditory skills screening for the elderly, highlighting its potential to guide referrals and assessments related to central auditory processing and auditory training. This, in turn, can enhance communication and subsequently improve the overall quality of life for elderly individuals. The application of AudBility screening holds the promise of expanding assessment options for the elderly, optimizing referrals for audiological evaluations, and enabling more precise treatments. Moreover, it can foster greater awareness among the elderly regarding their hearing difficulties, encouraging them to seek professional care, which includes referrals for hearing aids and auditory stimulation therapies.

Likewise, a study conducted by Kovalová et al. [26] focused on assessing hearing loss in individuals aged 65 and above, utilizing pure tone audiometry. This research also explored a gender-based comparison of experiences. The sensitivity of the abbreviated version of the Hearing Handicap Inventory (HHIE-S) was evaluated, a questionnaire designed to identify hearing handicaps, particularly in speech understanding. The outcomes revealed a substantial prevalence of hearing impairment in the participants, with 68.93% exhibiting some degree of hearing loss, primarily categorized as mild. The HHIE-S, with diagnostic sensitivity and specificity of 75.43% and 82.53%, respectively, is a fast, cost-effective, and concise screening tool for hearing impairment in elderly care. This underscores the significance of assessing and addressing even minor hearing impairments, as they can significantly impact social interactions and mental functioning in elderly individuals [27]. AudBility, with its comprehensive screening approach beyond a questionnaire, stands out as a potential tool to guide auditory stimulation interventions in response to these identified impairments.

In summary, AudBility screening for the elderly population can be an early identification tool for hearing loss, auditory processing failures, and cognitive aspects, optimizing referrals and guiding auditory training to be more assertive in strategies to improve communication in the elderly's social environment. Additionally, it allows for low-cost monitoring with potential to detect auditory and cognitive alterations. Although more studies are needed with this population, the preliminary results of this research suggest the feasibility of implementing screening in the elderly.

Limitations and recommendations

This study is constrained by a relatively small sample size of 40 elderly participants, limiting the generalizability of the outcomes. Future research should address these limitations by conducting studies with larger and more diverse samples to validate AudBility's effectiveness across the elderly population. Additionally, comparative analyses with traditional in-person assessments can provide a more comprehensive understanding of AudBility's reliability and acceptance among the elderly. It may be worthwhile for future studies to incorporate audiometry to supplement the screening results.

Furthermore, the self-assessment questionnaire used in this study was originally designed for children. While we did not encounter any issues with its applicability to the elderly, future research should consider developing and utilizing a questionnaire specifically tailored to the elderly population. This may also require modifications to the AudBility platform. We suggest considering the Inventory for Auditory Disability and Handicap, as it includes many questions related to the daily lives of adults. We reviewed the article on the cross-cultural adaptation of this inventory to Brazilian Portuguese and recommend its use in future adaptations and studies [28].

Conclusion

The screening of auditory skills using the online platform AudBility is feasible for the elderly population and can serve as a gateway to assess both auditory and cognitive health in this demographic. This study demonstrates that AudBility effectively identifies areas requiring further evaluation, particularly in sound localization and temporal ordering, which had the highest frequency of altered results. The self-assessment questionnaire also revealed significant cautionary results, indicating the need for comprehensive follow-up. By directing refer-

rals for specific evaluations and guiding targeted therapies, AudBility aligns with the potential outlined in the study's outcomes, supporting its role in early detection and intervention strategies for auditory and cognitive health in the elderly.

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