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Self-assessment instruments for measuring listening effort in Cochlear Implant users: scope review

Instrumentos de autoavaliação para mensuração do esforço de escuta em usuários de Implante Coclear: revisão de escopo

Instrumentos de autoevaluación para medir el esfuerzo de escucha en usuarios de Implantes Cocleares: revisión del alcance

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Abstract

Introduction: Speech listening in challenging conditions as in the presence of reverberation and noise increases cognitive demand, posing difficulties for cochlear implant users. This listening effort can be understood as a mental effort, involving the task of listening in unfavorable environments. **Objective**: To review the national and international literature and identify the main self-report instruments to measure listening effort in Cochlear Implant users. **Method**: Bibliographical survey of scientific publications published between 2014 and 2024, considering the English, Spanish and Portuguese languages, and delimiting the application of questionnaires to measure Auditory Effort in adults. Articles available in the following electronic databases were selected: Cochrane, SciELO, Scopus and BVS, composed of the LILACS and MEDLINE databases. Our protocol was developed using the PRISMA Core Items for Reporting Systematic Reviews and Meta-Analyses for Scoping Review. Publications were considered through metadata analysis, based on the title and abstract, to identify relevance to the research. Studies published more than ten years ago, repeated and discrepant on the topic were excluded. **Results**: From the

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Authors' contributions:
NPS: study conception; methodology; data collection; article design.
MVSGG: study conception; methodology; data collection; article design; critical revision and orientation.

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electronic search, 600 available articles were identified, with a total of 21 articles included in this study. **Conclusion**: Ten instruments used to assess listening effort were identified, 4 questionnaires, 5 scales and one qualitative technique. The LEQ-CI is the first and only questionnaire developed specifically to measure the perception of listening effort in daily life situations in adult users and candidates for cochlear implants.

Keywords: Cochlear Implant; Listening Effort; Hearing Loss; Patient-reported outcome measures; Questionnaire and Adult.

Resumo

Introdução: A percepção da fala em ambientes desafiadores, caracterizados por reverberação e ruído, demanda maior esforço cognitivo, o que pode ocasionar dificuldades significativas para indivíduos usuários de implante coclear. O conceito de esforço de escuta refere-se ao esforço mental requerido para compreender mensagens auditivas em condições adversas. **Objetivo:** Revisar a literatura nacional e internacional, identificar os principais instrumentos de autoavaliação empregados na mensuração do esforço de escuta e verificar aqueles especificamente desenvolvidos para usuários de implante coclear. **Método:** Foi realizado um levantamento bibliográfico de publicações científicas no período de 2014 a 2024, nos idiomas inglês, espanhol e português, com enfoque na aplicação de questionários para avaliação do esforço de escuta em adultos. Os artigos foram selecionados nas bases Cochrane, SciELO, Scopus e BVS (LILACS e MEDLINE). O protocolo de revisão seguiu os critérios do PRISMA para Scoping Review. A triagem inicial considerou título e resumo, visando à identificação de pertinência ao tema, sendo excluídos estudos com mais de dez anos, duplicados ou fora do escopo da pesquisa. **Resultados:** A busca eletrônica resultou em 600 artigos, dos quais 21 atenderam aos critérios de inclusão. **Conclusão:** Foram identificados dez instrumentos destinados à avaliação do esforço auditivo, incluindo quatro questionários, cinco escalas e uma técnica qualitativa. Destaca-se o LEQ-CI como o primeiro e único questionário desenvolvido para mensurar a percepção do esforço de escuta em situações do cotidiano em adultos candidatos ou usuários de implante coclear, constituindo ferramenta relevante para pesquisas e práticas clínicas voltadas à reabilitação auditiva.

Palavras-chave: Implante Coclear; Esforço de Escuta; Perda Auditiva; Medidas de Resultados Relatados pelo Paciente; Questionário e Adultos.

Resumen

Introducción: Escuchar habla en condiciones desafiantes como cuando reverberación y ruído están presentes, aumenta la demanda cognitiva, generando dificultades en usuarios de implante coclear. El esfuerzo auditivo se refiere al esfuerzo mental implicado en escuchar en condiciones desfavorables. **Objetivo:** Revisar la literatura y reconocer los principales instrumentos de autoinforme utilizados para medir el esfuerzo auditivo en usuarios de implante coclear. **Método:** Se realizó una revisión bibliográfica de publicaciones entre 2014 y 2024, en inglés, español y portugués, centrada en estuios que aplicaran cuestionarios para evaluar el esfuerzo auditivo en adultos. Se consultaron las bases de datos Cochrane, SciELO, Scopus y BVS (incluyendo LILACS y MEDLINE). El protocolo siguió las directrices PRISMA para Scoping Review. Se seleccionaron estudios mediante análisis de título y resumen, excluyendo aquellos duplicados, no pertinentes o con más de diez años de antigüedad. **Resultados:** De los 600 artículos identificados, se incluyeron 21 en esta revisión. **Conclusión:** Se encontraron diez instrumentos para evaluar el esfuerzo auditivo: 4 cuestionarios, 5 escalas y una técnica cualitativa. El LEQ-CI es el primer y único cuestionario diseñado específicamente para medir la percepción del esfuerzo auditivo en situaciones cotidianas de adultos usuarios y candidatos al implante coclear.

Palabras clave: Implante Coclear; Esfuerzo de Escucha; Pérdida Auditiva; Medición de Resultados Informados por el Paciente; Cuestionarios y Adultos.

Introduction

The Cochlear Implant (CI) is one of the most important technological advances today for the habilitation and rehabilitation of patients with severe to profound sensorineural hearing loss.

Unfortunately, the technology does not mimic all aspects and pathways of the auditory system, meaning that speech comprehension in environments with noise, distance, and reverberation still represents a great challenge even for patients who are well-adapted to the technology and have good auditory performance in quiet environments[1].

In 1973, Kahneman developed the Capacity Theory, demonstrating that human beings have a limited capacity for information processing[2]. Thus, when the cognitive demand in a task increases, it is assumed that more resources are allocated to perform it, and, consequently, performance decreases in tasks that are being carried out simultaneously.

Similarly, listening effort (LE) is a specific form of *mental effort* that occurs when the task of listening to speech becomes difficult to analyze, requiring more cognitive and attentional resources to be recruited for comprehension to occur[3-4]. In this scenario, technology has focused on audiological solutions to help reduce the negative impacts on comprehension for patients with hearing impairments when faced with challenging acoustic environments.

Word/sentence recognition tests have been used to evaluate the impact of technology in solving this difficulty and in an attempt to measure LE. However, the literature shows that the percentage of intelligibility achieved in these tests, when applied in isolation, does not significantly translate the contribution of the technology and is not able to provide information about attention and the cognitive resources used[5].

Thus, three methodological approaches to measuring LE standout: physiological, behavioral and self-assessment measures[6] .

The most used physiological measures are pupillometry, heart rate variability, skin conductance and temperature, and electromyographic activity (EMG). Variations in these measures suggest possible signs of LE[7].

Studies have identified that during the increased demand for working memory (WM) and selective attention, there is an increase in skin conductance[8], pupil dilation in the presence of LE[9] and that among all the physiological measures used, heart rate proved to be the most robust physiological indicator of LE, sensitive to task complexity and noise[10].

Regarding behavioral measures, the Dual Task Paradigm (DTP)[11] stands out. The DTP is an assessment composed of two tasks performed simultaneously. The Primary Task (PT) involves speech perception tests, such as word and/or sentence recognition, in silence and with manipulation of the signal-to-noise ratio.

Meanwhile, the Secondary Task (ST) involves visual and motor tasks, and may involve WM[11-12].

The hypothesis of some studies with DTP involving working memory in ST is that patients with greater WM ability will have less LE when performing the speech perception task, that is, the factors, LE and WM, would be inversely proportional[12-13].

Finally, the self-assessment measure includes scales and questionnaires that measure LE using, for example, the descriptive visual analogue scale (VAS) (no effort or maximum effort) and/or numerical (for example, 0 to 100). Subjective methods constitute a versatile way of evaluating an individual's perception of LE and have high validity[14].

However, although there is no clear consensus on the best way to measure it[4,15] studies indicate that all measures are valid[3,5]. Researchers suggest that LE is a multidimensional[16] construct and that available measurement tools can capture different aspects of this phenomenon[17].

Thus, the literature increasingly defines the proposal that there is not just one single way to measure LE, and in this scenario, it is observed that Patient-Reported Outcome Measures (PROMs) can make a great contribution due to their speed and ease of application[14].

However, a significant part of the self-assessment instruments is generic, being less sensitive to specific populations and without presenting specificity in relation to the individual's disease and/or treatment. In this sense, instruments for a specific population can provide more precise data, since the items that make up the questionnaire are elaborated to contemplate aspects related to a specific disease and/or treatment[18].

Therefore, the objective of the present article is to review national and international literature and identify the main self-assessment instruments

for measuring listening effort and which ones are dedicated to CI users.

Method

The study was approved by the Ethics and Research Committee under opinion no. 7.398.795.

This is a scoping review carried out in accordance with the PRISMA-ScR extension for Scoping Review. The research question developed for the present review respected the PCC acronym (P - participant, C - concept and C - context) with the following question: "What are the self-assessment instruments available in the scientific literature for measuring listening effort in adult CI users?". According to the PCC, adult CI users were included as participants, the evaluation of LE was the concept, and the scientific literature was the context.

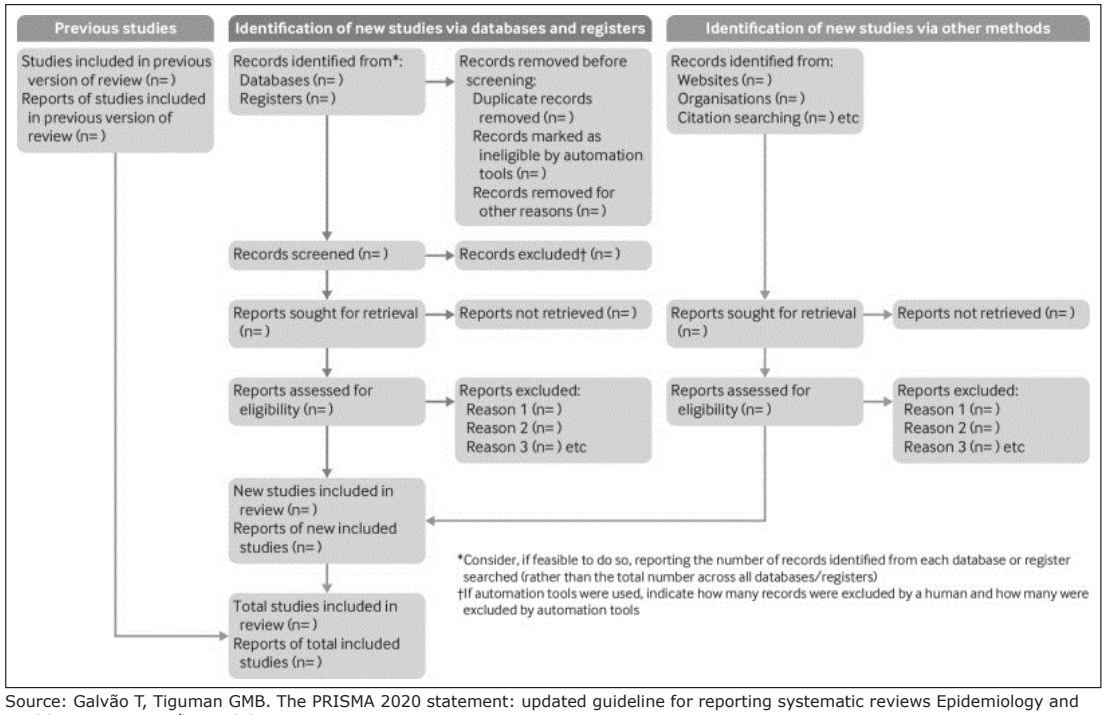
The search strategy was adapted according to the protocols of each database, using a combination of six descriptors indexed in the Health Sciences Descriptors (DecS). The descriptors were combined and grouped into at least two keywords (Table 1) using the Boolean operator AND. The search was performed in Portuguese, Spanish, and English. The scientific databases searched were: Cochrane, SciELO, Scopus, and BVS, which includes the LILACS and MEDLINE databases. All articles published between 2014 and 2024 were analyzed.

Table 1. Search strategies for queries and number of articles found in databases according to the combination of descriptors

Search Strategy	VHL	Cochrane	Scopus	Web of Science
"listening effort" AND "cochlear implant"	112	13	135	177
"listening effort" AND "cochlear implant" AND "adult" AND "Patient Reported Outcome Measures"	14	1	19	20
"listening effort" AND "cochlear implant" AND "hearing loss" AND "Patient Reported Outcome Measures"	8	1	11	11
"listening effort" AND "cochlear implant" AND "adult" AND "questionnaire"	20	4	28	26

Regarding the eligibility criteria for inclusion or exclusion of articles, the information contained in the title and abstract were used. However, if the information was not clear and doubts arose, the article would be read in its entirety to meet the inclusion criteria. The inclusion criteria were articles that used self-assessment methods, questionnaires, and subjective scales to evaluate LE in adult individuals with cochlear implants. Articles published more than 10 years ago, which measured listening effort exclusively by behavioral methods, for example, dual-task paradigms, and studies with measurements through physiological exams were excluded. LE research with children was not included.

After the searches, the records were imported into a free reference and citation manager, Zotero, to eliminate duplicate publications. The research was then selected manually, without the use of automation tools, based on reading the title and abstract. The research strategy followed the PRISMA 2020 flowchart model for systematic reviews (Figure 1)[20]. The article selection stage by screening titles and abstracts was carried out by two independent evaluators, and disagreements were resolved by a third reviewer, while the full-text reading and data extraction were carried out by the first author.

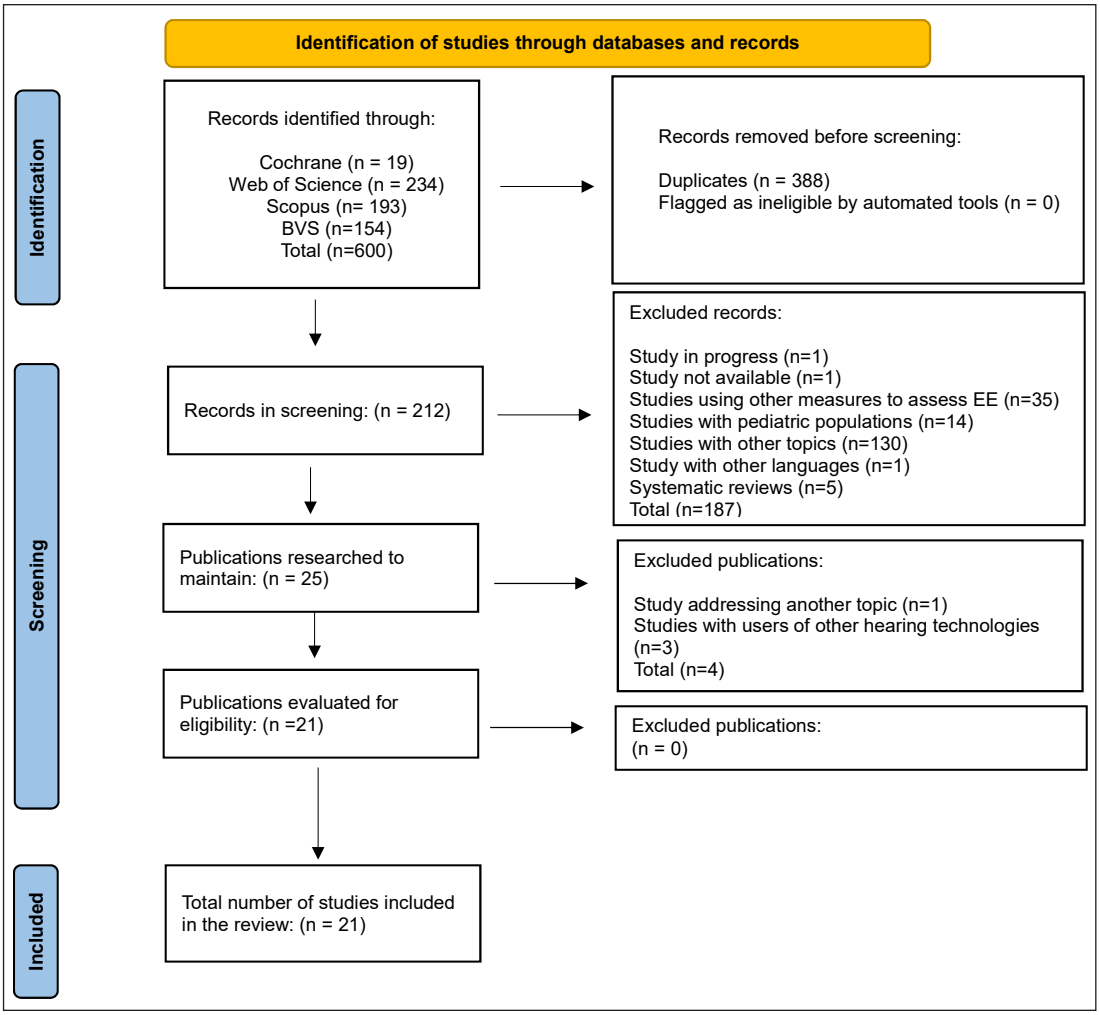


Source: Galvão T, Tiguman GMB. The PRISMA 2020 statement: updated guideline for reporting systematic reviews Epidemiology and Health Services, Brasília, 31(2):e2022107, 2022.

Figure 1. PRISMA 2020 flowchart model for systematic reviews

Results

The electronic search resulted in 600 articles, of which 388 were removed for being duplicates. Subsequently, the title and abstract of 212 studies were manually analyzed, and from this, 25 were selected for full-content reading. After this reading, 4 more studies were excluded from the sample for not contemplating the objective of this review and for not being studies with CI users, ending with 21 articles included in the review. The article selection process is described in Figure 2.



Source: Adapted by the study authors

Figure 2. Flowchart of the selection process of included studies

Chart 1 presents the publications selected for this review that refer to studies that used self-assessment measures to quantify LE in patients using CIs, detailing these studies by first author, year of publication, instrument used to evaluate LE, application format, and study objective.

Chart 1. Characterization of the selected publications regarding the first author, year of publication, instrument used, application format and objective of the study

First Author and Year	Questionnaire or Tool used	Application format	Objective of the study
Devocht et al. (2016)[21]	13-point Likert scale	LE was assessed during the Dutch Matrix Test with sentences in noise.	To evaluate monaural beam formation in bimodal users.
Devocht et al. (2017)[22]	13-point Likert scale	The LE classification was performed using the Likert Scale with the application of the Dutch Matrix Test in the following scenarios (only CI and AASI + CI).	Investigate the benefits of bimodal combination.
Alhanbali et al. (2017)[23]	Effort Assessment Scale (EAS)	The EAS scale was applied together with the Fatigue Assessment Scale (FAS) questionnaire.	To investigate and compare the levels of listening effort and fatigue reported by adults with different types of hearing impairment compared to adults with normal hearing.
Perreau et al. (2017)[24]	SSQ - PLE (3 QUESTIONS)	LE was assessed through behavioral measures such as PDT and Reading Span Test (MT Test) and also through self-assessment.	To compare listening effort between adults with normal hearing and cochlear implant (CI) users, using objective and subjective measures.
Hughes et al. (2018)[25]	Focus group proceedings	The study explored the perceptions and experiences of LE in adults before and after cochlear implantation.	Develop a new self-assessment measure (PROM) for LE.
Sladen et al. (2018)[26]	Categorical Ease of Listening Scale (CELS)	EE was assessed using two measures: behavioral, PDT (reaction time) and self-assessment.	What is the impact of using omnidirectional versus directional microphones on speech recognition and listening effort in noisy environments?
Buchner et al. (2019)[27]	Visual Analogue Scale (VAS)	The LE classification was made by applying the OLSA Test to different signal-to-noise ratios.	To evaluate the effect of microphone directionality, i.e., beamforming, on speech understanding in noise with the SONNET audio processor.
Bracker et al. (2019)[28]	Visual Analogue Scale (VAS)	Auditory performance and sound perception were assessed using various tests. LE was assessed using a visual analogue scale with varying background noise.	Reduce the discrepancy between clinical results and real-life hearing performance.
Dwyer. et al (2019)[29]	Amsterdam Checklist for Hearing and Work	The LE assessment was performed using 5 modified items from session 2 of the Amsterdam Checklist for Hearing and Work and the LE classification was made on a Likert Scale (0-4)	The primary objective was to investigate the relationship between cortisol levels throughout the day and subjective perceptions of listening effort and fatigue in adults with cochlear implants. Cortisol is a hormone associated with stress, and its daily variations may reflect the impact of listening effort on individuals with hearing loss.
Hughes et al. (2019)[17]	LEQ-CI	Application of the LEQ-CI questionnaire to 350 CI users in the United Kingdom.	To conduct the first psychometric evaluation of the measurement properties of the LEQ-CI questionnaire.
Zinfollino et al. (2019)[30]	Speech, Spatial, and Qualities of Hearing (SSQ) scale – LE Domain	The study evaluated the LE from the optimization of the mapping using the SSQ.	To evaluate the effects of optimizing the mapping of cochlear implants (CIs) in adult patients who had been using unchanged settings for at least 12 months.
Hughes et al. (2021)[31]	LEQ-CI	Questionnaire applied to 330 patients using CI from 5 CI centers in the United Kingdom.	To improve the accuracy of the LEQ-CI questionnaire measurements and their psychometric measurement properties.
Lopez et. al (2021)[32]	Speech, Spatial, and Qualities of Hearing (SSQ) scale – LE Domain	Speech recognition test in silence with words and sentences in noise was applied before and after CI.	To evaluate the impact of the use of CIs on the listening effort perceived by adults and children with unilateral or asymmetric hearing loss, comparing the perceptions of listening effort with and without the use of CI.

First Author and Year	Questionnaire or Tool used	Application format	Objective of the study
Stronks et al. (2021)[33]	9-point Likert scale	LE was assessed in each speech presentation using the Dutch Matrix Test, subjectively using a rating scale, and objectively using pupillometry.	To evaluate whether the SoftVoice algorithm improves speech perception at low sound intensity levels and reduces listening effort, both subjectively and objectively, in adult users of Advanced Bionics CI.
Abdel-Latif et al. (2022)[34]	Adaptive Categorical Listening Effort Scaling (ACALES)	The LE assessment was also performed using the PDT behavioral measure. The ACALES scale was administered using the OLSA Speech Recognition Test.	To compare speech recognition and LE in CI users and normal-hearing listeners of the same age, considering possible influential factors such as cognitive abilities.
El Mahallawi et al. (2022)[35]	Hospital Anxiety & Depression Scale (HADS)	EE was assessed using two measures: PDT and Memory Tests and self-assessment measure.	To investigate the listening effort in adults with sensorineural hearing loss who use unilateral CI, comparing them with adults with normal hearing.
Kurz et al. (2022)[36]	Adaptive Categorical Listening Effort Scaling (ACALES)	The ACALES scale was applied based on the presentation of sentences from the OLSA Test in the presence of noise.	Evaluate the contribution of the technology offered in the Sonnet 2 processor to LE mitigation.
Lambriks et. al (2023)[37]	13-point Likert scale	LE was assessed using sentences from the Dutch Matrix Sentence Test.	To evaluate the effects of image-based frequency mapping on CI users, compared to standard mapping.
Hornsby et al. (2024)[38]	Effort Assessment Scale (EAS)	Other questionnaires were used in the research, such as the Vanderbilt Fatigue Scale and Hearing Handicap Inventory before and after CI.	To assess longitudinal changes in listening-related fatigue in adults newly implanted with CIs. To compare fatigue levels between new and experienced CI users. To examine demographic and audiological factors that may influence listening-related fatigue.
Wagner. et al (2024)[39]	Adaptive Categorical Listening Effort Scaling (ACALES)	The ACALES scale was applied based on the presentation of two sentences extracted from the OLSA Test.	Evaluate the contribution of Forward Focus technology in reducing LE.
Wesarg et al. (2024)[40]	Adaptive Categorical Listening Effort Scaling (ACALES)	The LE was evaluated according to the presentation of the OLSA Test sentences in two configurations: frontal and with noise generated at 90, 180 and 270 degrees.	To evaluate speech perception and LE in CI users using 3 different microphone technologies in single-piece processors.

Five scales, one qualitative method, and four questionnaires were identified to measure LE in CI patients. The description of each tool can be seen in Chart 2, considering the characteristics of the instrument, whether it was developed specifically for the evaluation of LE in CI users, and which target audience it is intended for.

Chart 2. Description of questionnaires and scales identified for measuring listening effort in terms of their characteristics, development for assessment of listening effort in cochlear implant users and target audience

Instrument	Features	Developed for assessment of listening effort	Developed for cochlear implant users	Target audience
Adaptive Categorical Listening Effort Scaling (ACALES)[41]	This is an adaptive categorical scale, adjusting the difficulty of the test or the intensity of the auditory stimulus based on the participant's responses.	Yes	No	Applicable to Adults and Children
Likert Scale [42]	Technique used to measure attitudes based on the responses given by participants when expressing their level of agreement or disagreement with a series of statements.	No	No	Applicable to Adults and Children with reservations
Speech, Spatial, and Qualities of Hearing (SSQ)[43]	It is an instrument used to assess the quality of hearing in terms of speech perception, spatial localization of sounds and general hearing qualities.	No	No	Applicable to Adults and Children
Visual Analogue Scale (VAS)[44]	A widely used instrument to measure subjective perceptions of the intensity of sensations, such as pain, discomfort, fatigue, and others. It is a continuous scale usually represented by a straight line, where the ends of the line represent the minimum and maximum intensities of a sensation or experience.	No	No	Applicable to Adults and Children
Effort Assessment Scale (EAS)[16]	This is a subjective scale used to measure perceived listening effort during listening tasks. It is typically administered after completing an auditory task (such as listening to sentences in noise), and participants indicate how much effort they felt they had to put in to understand.	Yes	No	Applicable to Adults and Children with adaptations
Focus Group Proceedings[45]	These are focused group discussions. In healthcare, they help uncover patients' opinions on treatment outcomes, allowing for a nuanced understanding of patient experiences, which can inform clinical practice.	No	No	Applicable to Adults and Children with adaptations
Amsterdam Checklist for Hearing and Work (ACHW)[46]	It is an instrument developed to assess the difficulties faced by people with hearing impairments in the workplace.	No	No	Applicable to Adults only
Categorical Ease of Listening Scale (CELS)[47]	CELS focuses on the listener's experience in terms of how easy or difficult it is to listen in different situations, taking into account cognitive load and personal perception of effort to understand speech. It is a form of qualitative assessment.	Yes	No	Applicable to Adults and Children with adaptations
Hospital Anxiety & Depression Scale (HADS)[48]	It is a screening instrument created to assess symptoms of anxiety and depression in hospitalized and outpatient patients.	No	No	Applicable to Adults only
Listening Effort Questionnaire – Cochlear Implant (LEQ-CI)[31]	It is a self-reported measurement instrument, developed specifically to assess the listening effort perceived by adults with severe to profound hearing loss who use cochlear implants.	Yes	Yes	Applicable to Adults only

Discussion

The present study aimed to identify in the literature what self-assessment instruments are used to measure LE in adult CI users. LE is a phenomenon that has a significant negative impact on the quality of life of patients who use hearing technologies, causing complaints related to social functionality, well-being, and interpersonal relationships[30].

Because it is not necessarily proportional to the degree of hearing loss, depending on the linguistic arsenal, auditory processing, and cognitive resources, understanding how to measure it is essential to promote more effective technologies and therapeutic interventions. In the context of the last ten years (2014-2024), this topic has become a subject of interest in the global scientific community. However, despite the significant number of articles, it is still a challenge to describe what the ideal tools for its measurement are, especially the role or reliability of self-assessment measures.

With the analysis of the studies and after the elimination of duplicates, the reasons that justified the exclusion of the articles were: Study still in progress (n=1), Studies using exclusively behavioral and/or physiological measures to measure LE (n=35), Studies on LE in the pediatric population (n=14), Studies outside the prioritized theme in this research (n=130), Study using a questionnaire to evaluate LE in German (n=1), Systematic review studies (n=5) and Study not available for access (n=1).

In the clinical audiological context, some tools can provide information about the audibility of the acoustic signal, however, they are unable to provide information about the underlying processes and mechanisms of listening, as is the case with LE. In this review, ten instruments were identified, five scales, one qualitative technique and four questionnaires, used in the subjective evaluation of LE in CI patients, in addition to the application of traditional speech recognition tests.

The analysis of the studies revealed a predominance of the use of *Likert* scales (with 4, 9, and 13 points) and the *Adaptive Categorical Listening Effort Scaling (ACALES)*, both identified in four studies. The *Speech, Spatial, and Qualities of Hearing (SSQ)* questionnaire was used in three studies. The *Visual Analogue Scale (VAS)* and *Effort Assessment Scale (EAS)* scales, as well as *The Listening Effort Questionnaire-Cochlear Implant (LEQ-CI)* questionnaire, appeared in two studies each. The instruments *Focus Group Proceedings*, *Categorical Ease of Listening Scale (CELS)*, *Hospital Anxiety & Depression Scale (HADS)* and *Amsterdam Checklist for Hearing and Work (ACHW)* were identified in only one study each. The Likert scale is an important method for collecting qualitative data, capable of capturing participants' perceptions and frequently used in questionnaires. However, authors warn of the need for careful analysis in statistical methods, as simplistic approaches can produce misleading results[49-50].

Studies[21,22,33,37] that used the Likert Scale for LE evaluation applied the same speech perception test in noisy environments, the Dutch Matrix Test. The studies observed an improvement in LE associated with the use of bimodal technologies[21-22] and the use of the algorithm to reduce internal noise in the sound processor[33].

One of these authors points out that LE is an additional dimension close to speech intelligibility, being sensitive information capable of providing information about speech transmission even in subjects with high-performance[21].

Another type of scale identified in the research was the Visual Analogue Scale (VAS)[27,28] and, similarly to this tool, one of the articles used the Categorical Ease of Listening Scale (CELS)[26]. Commonly, both were used to measure LE based on the application of speech perception tests, both in silence and in noise with varying S/N ratio.

The subjective evaluations conducted with these tools indicated that microphones positioned at the entrance of the pinna, providing more natural hearing, as well as adaptive and directional microphones, led to improved speech comprehension, managing to reduce the cognitive load in CI users in noisy environments[27,28].

No discussion was identified in literature regarding the differences between the Likert Scale and the VAS. However, despite being similar, they differ in relation to the type of scale and the data generated. The VAS generates quantitative data (continuous and numerical), and qualitative data (ordinal and categorical) is generated for the Likert Scale. In terms of precision, the VAS is considered to have greater precision.

Self-reported listening effort and fatigue in adults with hearing loss are significant concerns, as these individuals generally experience greater cognitive demands when processing auditory in-

formation. The Effort Assessment Scale (EAS) is a scale used to measure perceived effort in certain tasks[23-38].

The EAS proved to be sensitive to capturing changes that occurred over time by identifying greater LE in users without CI compared to experienced CI users. However, after the cochlear implant, the EAS showed significant reductions in LE in 2 weeks, and after 3 months of CI use, no significant differences were observed between new and experienced users. The adaptation process seems to mitigate these effects over time[38].

A similar finding was observed in another study in which the EAS was applied, identifying that individuals with hearing loss, including groups of hearing aid and CI users, revealed a significantly greater LE than the control group composed of people with normal hearing thresholds[23].

The scale indicated that effort levels were similar in different types of hearing loss, suggesting that the severity of hearing loss may not predict the reported listening effort, and a weak positive correlation ($r = 0.40$) was found between effort and fatigue scores, indicating some relationship, but not a strong predictive link[23]. The scales mentioned above are very easy and quick to apply, as well as versatile. However, reliability and validity can be affected by variability in scale design and a lack of standardization in application.

The ACALES scale proves to be easy to apply in the clinic, being an instrument with high validity and reliability and with less application time when compared to the execution of a behavioral measurement task[41].

Two studies[39-40] evaluated LE from the activation of technology for background noise reduction combined with adjustments in the microphones. Using the ACALES scale, they identified an improvement in the perception of LE and concluded that this instrument is viable for evaluating LE.

Still on technological contribution, another study[36] analyzed the impact of resources to improving speech perception in noise, acoustic quality, and LE perception with the ACALES scale. The findings indicated that at a strong level of performance, these resources reduce the perception of LE and the subjects better tolerated the lower S/N ratio. The ACALES proved to be important for subjectively measuring LE, allowing a comparative analysis with objective measures and assisting in the clinical evaluation of cochlear implant users[34].

The use of the Speech, Spatial, and Qualities of Hearing (SSQ) questionnaire for LE evaluation is frequently observed in clinical practice, proving to be effective in measuring changes over time[32] and sensitive to perceiving significant improvements in the quality of auditory perception after adaptation with new mapping after a long period of using an old map[30]. However, a limiting aspect of the SSQ is its length, causing fatigue in its application and complexity of the described situations, where only 6% of the items evaluate LE[17].

One of the studies using the SSQ compared LE between individuals implanted with unilateral hearing loss versus asymmetric hearing loss using bimodal adaptation[32]. The result revealed a positive correlation between the questionnaire responses and the results obtained in the speech recognition in noise test for the group with unilateral hearing loss.

The probable hypothesis discussed is that normal contralateral hearing in cases of unilateral loss provides faster acclimatization to the use of CI, favoring better performance, unlike what occurs in asymmetric cases, in which both auditory pathways already show impairment, thus suggesting a longer period to acclimatize and to achieve benefits, and greater LE. Furthermore, the age of implantation of the group with asymmetric loss, an average of 70 years, compared to the group with unilateral loss, an average of 50 years, may have influenced acclimatization with the CI and, therefore, the LE required in challenging situations.

Differently, another study did not identify the age of implantation variable as significantly related to listening effort, but a significant factor was biological age. The elderly tend to experience greater LE[24].

The use of questionnaires not specifically related to LE was also identified in this review. One of these questionnaires was the Hospital Anxiety and Depression Scale (HADS) used with the objective of evaluating anxiety and depression associated with LE in patients with unilateral CI[35]. The patients were also submitted to objective evaluations of listening effort through the Dual-Task Paradigm (DTP) and memory tests. The group with hearing loss reported greater LE with high levels of anxiety and depression and a significant positive correlation between HADS and the primary task performed in the DTP, demonstrating an association between hearing loss and the increase in the S/R ratio with LE, anxiety and stress.

Another study used the Amsterdam Checklist for Hearing and Work (ACHW) to measure LE in CI patients, also observing that adults with hearing loss require greater effort and concentration when compared to adults without hearing loss, having more complaints related to fatigue[21]. The authors suggest that hearing-specific self-assessment measures are more sensitive in identifying the relationship between listening effort (LE) and auditory fatigue in cochlear implant users, when compared to generic health assessment instruments. In the study, a significant correlation was observed between self-reported LE and hearing-related fatigue only in participants with hearing loss. In contrast, generic questionnaires did not show this association, which may have limited the identification of consistent relationships between subjective measures and cortisol levels throughout the day[29].

In 2018, a group of researchers, observing the absence of standardized clinical LE measures, including Patient-Reported Outcome Measures (PROMs), proposed a qualitative study exploring the perceptions, understanding, and experiences of listening effort in adults with profound and severe sensorineural hearing loss before and after cochlear implantation, aiming to develop an instrument absent in clinical practice until then. The method used to carry out this information gathering was the Focus Group Proceedings, which refers to the process and documentation of discussions held in a small group of people gathered to discuss a specific topic under the guidance of a moderator. The rich descriptions obtained in this method illustrated the complex and multidimensional nature of LE, being described as the mental energy necessary to attend to and process the auditory signal, as well as the effort required to adapt and compensate for hearing loss[25].

The LE of most participants was motivated by the need to maintain a sense of social connection, and even with the CI alleviating the difficulties, it was seen that it does not eliminate the effort required to listen. These participants reported a restored sense of social connection after the CI and continuous acceptance of the need for listening effort[25].

Based on this first study, the same group of researchers developed The Listening Effort Questionnaire-Cochlear Implant (LEQ-CI), the first Patient-Reported Outcome Measure (PROM) for assessing the perception of LE in patients and candidates for CI. The use of PROMs in the clinic is in line with the current era of patient-centered care, in which evaluating the underlying factors is necessary if health professionals want a more holistic approach to hearing loss, to obtain data that are only felt by patients. PROMs are viable clinical measures, established in audiology, and are self-assessment tools that evaluate an individual's perceptions of the severity of their disease, symptoms, functioning, quality of life, and well-being[17].

The literature provides evidence that PROMs are capable of capturing dimensions that other measures are not capable of due to the multidimensionality of LE, thus different forms of measures can evaluate different aspects of this phenomenon[17,51].

In a recent systematic review, several PROMs were identified evaluating LE at the item or subscale level, they are: *Speech, Spatial and Qualities of Hearing Scale (SSQ), Profile of Hearing Aid Benefit (PHAB) and Communication Profile for the Hearing Impaired (CPHI).* In general, the results found limited evidence of the psychometric measurement properties of the described PROMs[17].

Notably, many of these PROM questionnaires were developed before the formulation and conceptualization of LE, resulting in a lack of congruence between the instruments and current theoretical frameworks[4], constituting a limitation for existing PROMs[17]. This is a major difference of the LEQ-CI; its origin comes after the knowledge of these frameworks.

The LEQ-CI is a unique scale composed of 21 questions in English that cover four domains for the perception of auditory effort: attention (composed of 5 subdomains), adaptation and compensation (composed of 4 subdomains), processing (composed of 4 subdomains) and motivation (composed of 4 subdomains). The 21 questions are scored on a 3 or 4-point scale, measuring severity or frequency. The minimum score is 21 and the maximum score is 75, with a higher score on the LEQ-CI indicating greater LE[51].

It is the first PROM developed, specifically, to measure the perception of LE and the only one for use with CI patients developed according to the international consensus of standards for best practices in the construction of PROMs and, elaborated from Rasch Analysis[52].

The present review made it possible to know what is currently being studied in the literature in relation to LE and what are the possibilities of

evaluation, especially in relation to the options of subjective measures. Future proposals should consider improving the understanding of LE, the importance of cognitive resources in auditory rehabilitation and in the development of technologies, and how hearing health professionals can use self-assessment tools in patient monitoring and speech recognition evaluation.

Possible limitations of this study may have occurred due to the search strategy used for the articles included in the review, however, the mapping made it possible to know the limited scenario regarding specific self-assessment instruments for the evaluation of LE in CI users, with only the LEQ-CI questionnaire being identified and still without validation and translation into Brazilian Portuguese.

Conclusion

Ten instruments were identified in the literature for subjective measurement of auditory effort, with 4 questionnaires such as: Speech, Spatial, and Qualities of Hearing (SSQ), Hospital Anxiety & Depression Scale (HADS), Amsterdam Checklist for Hearing and Work (ACHW) and Listening Effort Questionnaire – Cochlear Implant (LEQ-CI); 5 scales: Effort Assessment Scale (EAS), Likert Scale, Adaptive Categorical Listening Effort Scaling (ACALES), Visual Analogue Scale (VAS) and the Categorical Ease of Listening Scale, in addition to the qualitative method Focus Group Proceedings.

The LEQ-CI is the first and only PROM developed specifically to measure the perception of listening effort in daily life situations in adult users and candidates for CI. It is considered an instrument with the potential to be used as a research tool and in clinical practice for the evaluation of LE and with good results regarding its validity, reliability and response capacity.

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