Clinical Practice Patterns with Pediatric Loudness Perception Measures

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ABSTRACT

Purpose: Obtaining a patient's loudness discomfort level (LDL) can assist the audiologist in defining their dynamic range so that the hearing device fitting can ensure that low-level sounds are audible, average-level sounds are comfortable, and more intense sounds are loud but not too loud. A 2016 survey showed that 67.5% of 350 pediatric audiologist reported to never or rarely measure LDLs with pediatric patients (Moodie et al., 2016). The purpose of this study was to identify factors influencing this previously-reported limited use of LDL measures.

Method: Sixty-two pediatric audiologists in the United States were surveyed using a questionnaire that sought to improve our understanding of the (non)use of loudness perception measures with pediatric patients and to assess familiarity with various loudness perception measurements. In addition, the questionnaire gathered information about the needs of pediatric audiologists in relation to LDL measures.

Results: Audiologist report being largely unfamiliar with methods of assessing loudness perception in children, with categorical loudness scaling being the method with which they are most familiar. In addition, audiologists reported being more willing and able to measure LDLs in older compared to younger pediatric patients. Limited use of pediatric loudness perception measures appears to be driven by a lack of familiarity with measurement methods and the belief that loudness perception measures may not be useful for clinical practice.

Conclusions: Findings highlight audiologists' need for further information regarding the relevance of loudness perception measurements with pediatric patients and the need for easy-to-implement LDL measurement procedures for pediatric patients of all ages.

Loudness is the "perceptual strength of a sound ranging from very soft (or quiet) to very loud" (Florentine et al., 2011, p.3). Understanding an individual's perception of loudness is important when defining their dynamic range, a critical step in the goal of mapping cochlear implants, fitting hearing aids, and ultimately attempting to normalize loudness perception (American Academy of Audiology (AAA), 2013). The dynamic range is described as the range between the threshold of audibility and the threshold of discomfort, also referred to as the loudness discomfort level (LDL). A person's dynamic range varies depending on their hearing sensitivity. For example, individuals with a hearing loss have higher thresholds of audibility but little to no change in LDLs (Bentler & Cooley, 2001), creating a compressed dynamic range. In addition to improving audibility, hearing aids and cochlear implants are programmed to restore normal or near-normal loudness perception (Cox, 1999; Mueller, 1999; Palmer et al., 1999). For adult patients who do not achieve normalized loudness growth with their hearing devices, speech perception may be compromised (Fu & Shannon, 2000).

It may be particularly important to consider the impact of abnormal loudness perception on daily life for children, as they do not often have the freedom to remove themselves from an environment that is deemed too loud. A recent study examined relative loudness judgements in children with and without hearing loss by asking children (6-15 years of age) to judge which of two visual scenarios (e.g., metal vs plastic bowl falling off a table) would be accompanied by a louder sound (Tak & Yathiraj, 2021). Results showed that children with hearing loss who use cochlear implants, but not those who use hearing aids, demonstrate abnormal relative loudness judgements. Although this study did not report if the mapping processes used objective (e.g., evoked stapedial reflex) or subjective (e.g., loudness scaling) methods, these findings suggest that the process of defining the dynamic range incorporated within the cochlear implant mapping process may not be adequately normalizing loudness perception for some children with cochlear implants.

Best-practice protocols for fitting hearing aids and mapping cochlear implants with adults and children recommend including subjective assessments of loudness perception with pediatric patients who are able to participate in testing (AAA, 2013, 2019; Messersmith et al., 2019; Ontario Infant Hearing Program (OIHP), 2019; Valente et al., 2006). These loudness perception measures can be made using subjective methods (e.g., questionnaires; Cox et al., 1997) or estimated based on the patient's thresholds of audibility. Importantly, a study of more than 300 patients with hearing loss (ages 11 to 97 years) found that LDLs of patients with the same threshold can range 50-60 dB (Bentler & Cooley, 2001). Given this large across-listener variability, audiologists should be using subjective loudness perception measurement with adult and pediatric patients. Furthermore, including measured LDLs in the hearing aid fitting process with adult patients has been found to require half the number of post-fitting adjustments by the audiologist when compared to fittings using estimated LDLs (Shi et al., 2007). We are not aware of research that directly examines the value of including measured LDLs into pediatric hearing aid fitting/cochlear implant mapping; however, excessive loudness may be associated with limited or inconsistent device use (Ching et al., 2010).

Although early studies including children with hearing loss found loudness perception difficult to measure (Israelsson et al., 1995; Lucker et al., 1996), more recent studies show that children with hearing loss do appear to provide reliable responses on pediatric-adapted loudness scaling measures (Crukley & Scollie, 2012, 2014). Like adults with hearing loss, loudness growth functions for children with a hearing loss are steeper and more variable than those obtained from children and adults without hearing loss (Serpanos & Gravel, 2000, 2004).

Unfortunately, research examining appropriate subjective methods for measuring loudness perception in children is plagued by issues associated with small sample sizes, wide age-ranges of children, and varying methodology (Aazh et al., 2018; Collins & Gescheider, 1989; Ellis & Wynne, 1999; Kawell et al., 1988; Khalfa et al., 2004; Macpherson et al., 1991; Serpanos & Gravel, 2000, 2004; Teghtsoonian, 1980).

Given the limited and variable pediatric evidence-based measurement methods, it is not surprising that the majority of pediatric audiologists do not routinely use these measures (Moodie et al., 2016). In a survey of 350 pediatric audiologists, Moodie et al. found that 67.5% reported to 'never' or 'rarely' measure LDLs with their patients. Reasons cited for 'never' or 'rarely' using this testing included constraints on appointment time and expectations that testing procedures would be challenging for the child. Surprisingly, only 8% of audiologists reported routinely measuring LDLs with pediatric patients. Authors noted that respondents reported to obtain LDL measures to frequency-specific tones and/or speech only when a child or caregiver reported loudness issues; however, no further information was provided by Moodie and colleagues regarding which methods were used when LDLs were measured.

This study sought to further understand clinical practice patterns of pediatric audiologists with respect to loudness perception measures. Using the survey conducted by Moodie and colleagues (2016) as a guide, we created an online survey to further examine (a) reasoning behind the (non)use of loudness perception measures with children and (b) audiologists' self-reported familiarity with evidence regarding loudness perception in children. This survey was intended to improve our understanding of which loudness perception measurement methods (if any) are being used clinically and for what purpose these measures are serving. Finally, we sought to understand if there are unmet needs of audiologists in relation to measuring loudness perception in children.

Methods

Survey Distribution

Audiologists were recruited via an email invitation submitted to list serves maintained by the American Speech-Language-Hearing Association and the Educational Audiology Association and to social media websites frequently visited by pediatric audiologists. The invitation included a letter explaining the study, an acknowledgement of informed consent, and a link to the online survey. The invitations were extended on November 16, 2020. The link to the survey was active through December 16, 2020. Participants were eligible if they were licensed to practice audiology in the United States and if they currently see pediatric patients. This study was approved by the Institutional Review Board at the University of Utah. The responses to this survey were anonymous.

Questionnaire

The online survey was created using REDCap software (Harris et al., 2009, 2019). The survey was based on a prior assessment of the literature surrounding loudness perception in children and the recent finding that audiologists rarely or never assess LDLs in pediatric patients (Moodie et al., 2016). Audiologists were asked to complete the survey, which was expected to take five to ten minutes to complete. The online survey consisted of two parts: (a) general demographics and (b) a section pertaining to loudness measurements in pediatric patients. Survey respondents self-identified various aspects of their job, including the percentage of pediatric patients seen with sensorineural hearing loss, the highest degree acquired, and the number of years they had been practicing audiology. In addition, they provided information about their current work setting and the specific tasks they perform with their patients. Survey respondents were asked to report on their assessment of LDLs in pediatric patients with sensorineural hearing loss. The familiarity with and regularity of use was also obtained for specific loudness measurements (categorical loudness scaling, cross-modal matching, magnitude estimation/production, and equal loudness matching). Finally, we aimed to describe pediatric audiologists' familiarity with the loudness perception research by assessing respondent agreement with three specific statements: (1) "There is evidence to show that children perceive loudness similarly to adult listeners who have the same audiometric profile," (2) "There is evidence to show that children are able to provide consistent reports of their loudness perception," and (3) "There is evidence to show that average data are adequate for estimating LDLs in children." A copy of the survey can be found in the Appendix.

Data Analysis

A Microsoft Excel document was exported from the REDCap survey software and the data were separated using tabs within Microsoft Excel to individually analyze each question. For each survey question, the percentage of respondents selecting the same category (e.g., Always, Almost Never) was calculated. Answers to open-ended questions were analyzed via consensus by both authors to identify common themes.

Reported agreement with the three statements was analyzed using a Friedman's test (Friedman, 1937, 1940) to determine if the distribution of reported level of agreement differed when considering patients of different ages. Paired comparisons were made using Wilcoxon signed-rank tests (Wilcoxon, 1947) when the Friedman's test indicated a significant difference in distributions. To compare differences in level of agreement across reports for the three age groups and to account for the possibility of a Type I error, Bonferroni correction for multiple comparisons was used to evaluate the statistical significance of Wilcoxon signed-rank tests - significance was accepted at the $p < .0167$ level.

Results

Data were obtained from 62 licensed audiologists who practice in the United States with pediatric patients (≤21 years of age). Several survey respondents chose not to answer all questions. For survey questions yielding <62 responses, sample sizes are reported with the corresponding data. The most common degree held by survey participants was Doctor of Audiology (AuD, n=49), followed by Doctor of Philosophy (PhD, n=9), and Masters (n=4). All but one survey respondent reported more than one year practicing as a licensed audiologist.

Respondents represented a variety of work settings, predominantly hospitals, university clinics, and schools. All survey respondents reported seeing pediatric patients for at least one year. Years of pediatric experience were reported to be 1-5 years by 29% of respondents, 6-10 years by 18% of respondents, 11-20 years by 26% of respondents, and >20 years by 27% of respondents. Percentage of practice that includes pediatric patients was reported to be <40% for 21 respondents and >61% for 37 respondents - with one respondent reporting 41-60% of their practice was with pediatric patients. Three respondents did not provide an answer indicating the amount of their practice that includes pediatric patients.[1] Survey respondents were asked to

[1] Although these three participants did not provide a breakdown of their practice, they did report to see pediatric patients on a previous question (see Appendix). Because we had no hypothesis regarding (non)use of loudness perception measures in clinicians with differing caseloads of pediatric patients, their data are included here.

report the percentage of their total practice that includes patients ranging in age from birth to <3 years, 3 to <7 years, 7 to <14 years, and 14-21 years. In general, the majority of survey respondents reported to work with a wide variety of patient ages, with any specific age group comprising <61% of their practice. Eight respondents reported that patients aged birth to <3 years comprised >61-100% of their practice. This same percentage of practice was reported by one respondent for patients 14-21 years-old and for four respondents reporting for patients age ranges 3 to <7 years and 7 to <14 years (two respondents per age group).

LDL Measurement

Five of the 62 respondents indicated that they were unable or unwilling to answer questions about loudness perception measures, and thus are not included in the survey results pertaining to loudness perception measures. Figure 1 shows the frequency of LDL testing used with pediatric patients of various age groups. As expected, the proportion of respondents who reported to never measure LDLs with their pediatric patients reduced with increasing patient age. LDL measures were primarily reported to be used prior to fitting hearing devices (i.e., unaided LDLs during the hearing aid evaluation, to facilitate hearing aid programming) as well as during the fitting process (i.e., adjustment of the hearing aid MPO or mapping of cochlear implants). Several survey respondents reported using LDL testing during the fitting follow-up to evaluate loudness normalization and to troubleshoot issues with loudness sensitivity or intolerance of the device. Forty-three respondents rated their level of ease/difficulty when assessing LDLs in patients of varying age groups. Figure 2 shows reported level of ease/difficulty for three patient age groups. As patient age increased, ratings of ‘very easy’ and ‘easy’ increased and ratings of ‘very difficult’ and ‘difficult’ decreased.

Figure 1. Frequency of use reported for loudness discomfort level (LDL) testing with pediatric patients of various age groups.

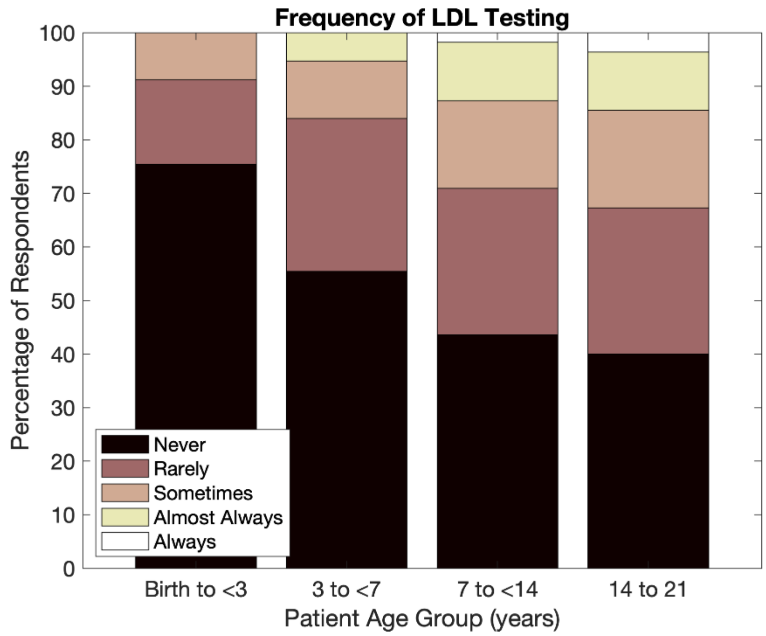
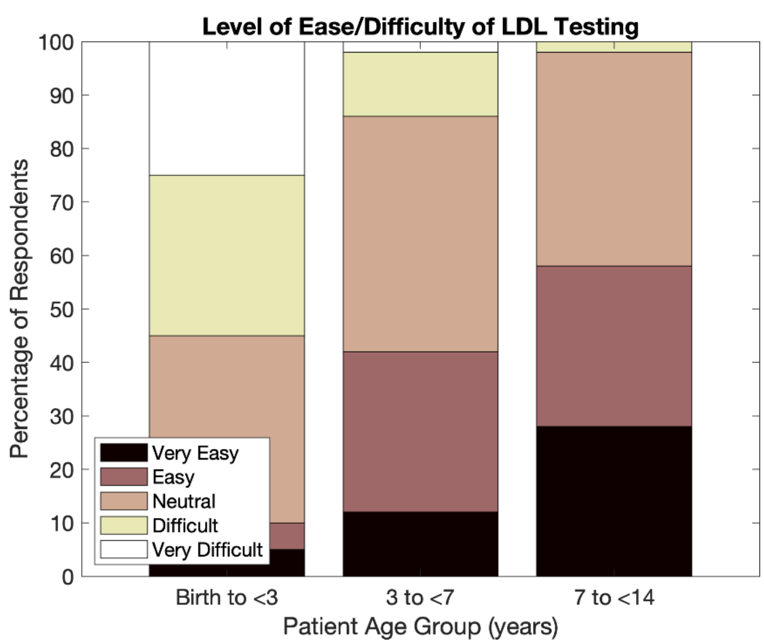


Figure 2. Reported level of ease/difficulty when measuring LDLs in pediatric patients of various age groups.

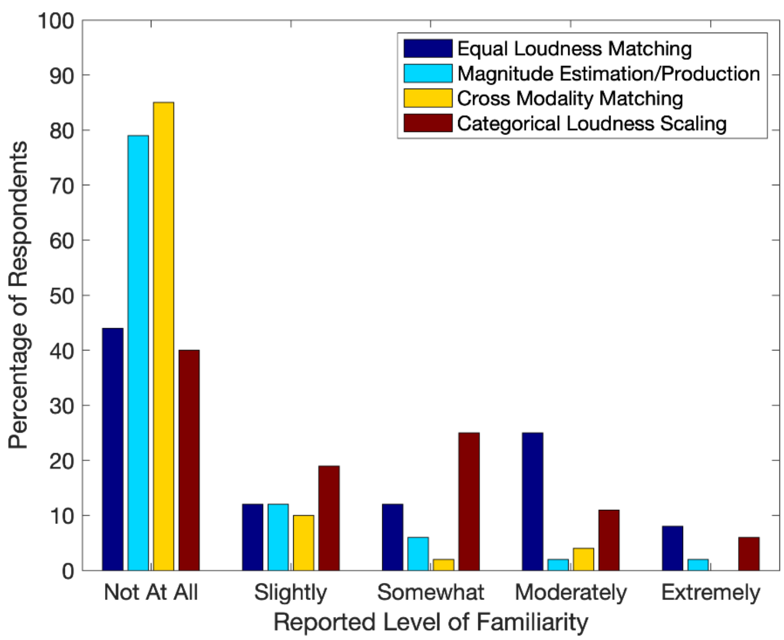


Survey respondents who reported that they never measure LDLs for a particular age group were asked to explain why. When considering patients in the age group of birth to <3 years, survey respondents shared that they mostly believed these children were not old enough for testing or may get upset with the use of loudness measurements. Poor reliability of patient responses was also noted for this age group. When considering patients in the age group of 3 to <7 years, survey respondents reported that patients in this age range were unreliable indicators of their own loudness perception and that LDL testing was of low priority or not useful in their clinical practice. Lastly, audiologists reporting no LDL measurement with patients in the age group of 7 to 21 years commonly disclosed their belief that LDL testing was not useful to their clinical practice, with a handful of respondents noting that they use probe microphone measures to monitor loudness discomfort.

Loudness Perception Measurement Methods

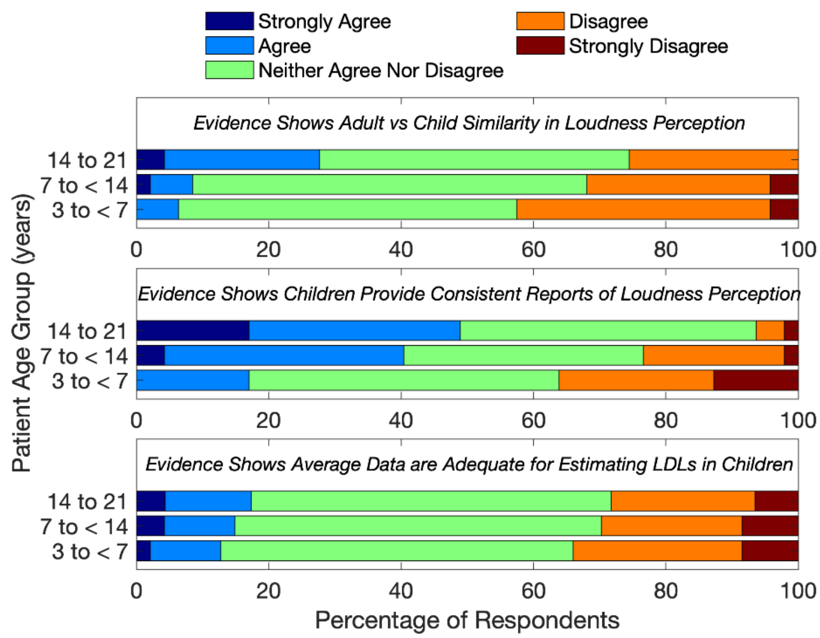
When asked to rate their level of familiarity with loudness perception measurement methods, survey respondents reported being largely unfamiliar with most testing methods. Figure 3 shows the proportion of respondents reporting their level of familiarity with four loudness perception measurement methods used previously with children. Notably, less than 20% of respondents reported being even moderately familiar with methods other than categorical loudness scaling (CLS). Despite being the measurement method that respondents reported as most familiar, only 9/56 (16%) reported to use CLS when measuring LDLs. All nine of these survey respondents reported to use a child-adapted CLS. The number of categories in these child-adapted scales were reported to range from three to nine, with two respondents reporting that the number of categories they use varies based on the skills and age of the patient. Clinicians reported that these child-adapted scales were obtained from cochlear implant manufacturers or that their clinic relies on a physical cue from the patient (e.g., pointing to a stop sign, thumbs down) for category selection. Thirty-two respondents offered explanations for their decision not to use CLS to measure LDLs with their pediatric patients. Of these, lack of familiarity with CLS was the most common (50%), with not seeing the need for or benefit of this test as the next widely-cited reason (28%). Several respondents noted that they use an informal loudness discomfort check (e.g., “When I measure LDLs, I do so more informally by asking them to tell me when it's too loud.") rather than a formal CLS.

Figure 3. Percent of respondents reporting familiarity with four available loudness perception measures.



Evaluation of Available Evidence

Figure 4. Level of agreement with statements about loudness perception measures.



Recall that survey participants were given three statements and were asked to rate their level of agreement with each statement as it pertains to a specific patient age-range. Figure 4 shows the respondents' level of agreement for each statement and age group. In Statement 1, survey respondents evaluated the statement: "There is evidence to show that children perceive loudness similarly to adult listeners who have the same audiometric profile." Variations in agreement with Statement 1 were significantly different across age group ($\chi^2(2) = 6.66$, $p = .036$). Reported level of agreement with Statement 1 pertaining to patients in the 14 to 21 year age-group was significantly higher than those in the 7 to <14 year group ($z = -2.70$, $p = .007$) and in the 3 to <7 year group ($z = -2.89$, $p = .004$). No difference in level of agreement was found when reports evaluating this statement for patients in the two younger groups were compared ($z = -2.058$, $p = .04$). Notably, the majority of survey respondents reported that they neither agreed or disagreed with this statement when considering all age groups and 24% of participants indicated that they disagreed with the statement that 14 to 21 year-old patients and adults share similar loudness percepts.

In Statement 2, survey respondents evaluated the statement: “There is evidence to show that children are able to provide consistent reports of their loudness perception.” Differences in agreement with Statement 2 were significantly different when considering patients from varying age groups ($\chi^2(2) = 16.28$, $p < .001$). Level of agreement significantly increased as patient-age increased (3 to <7 years vs 7 to <14 years, $z = -3.015$, $p = .003$; 3 to <7 years vs 14 to 21 years, $z = -4.185$, $p <.001$; 7 to <14 years vs 14 to 21 years, $z = -2.678$, $p = .007$). Despite this increasing agreement that children provide consistent reports of loudness with increasing age, the number of respondents neither agreeing or disagreeing with this statement remained relatively unchanged across patient age-group (34-46%).

Statement 3 asked survey respondents to evaluate their agreement with the following: “There is evidence to show that average data are adequate for estimating LDLs in children.” Reported level of agreement with this statement was not different when respondents considered the different age groups ($\chi^2(2) = 2.8$, $p = .247$). A majority of respondents (53-55%) reported that they neither agree nor disagree with this statement for any age group.

At the end of the survey, participants were asked what features they would enjoy having on a future pediatric measurement of loudness perception. Survey respondents who chose to answer this question (n = 25) requested an easy, child-friendly, and time-efficient measurement. Several also noted that the measure should have evidence of reliability in children and of improved patient outcomes with use. Participants were also asked what available resources they wish they had in relation to loudness perception measurement with pediatric patients. Most of the respondents who elected to provide suggestions (n = 24) wanted more evidence to support the importance of loudness perception measurements in children and training opportunities to understand this evidence and to increase competence in administering and interpreting the tests. Several respondents also noted the desire for an objective measure of loudness perception that does not rely on patient cooperation.

Discussion

The purpose of this study was to use an online survey to ask pediatric audiologists about their clinical practice patterns with loudness perception measures. We sought to understand the purpose for obtaining these measurements and what (if any) loudness perception measures were commonly used in clinic. Results replicate the findings from Moodie et al. (2016), showing relatively few pediatric audiologists routinely measure loudness perception in clinic. Our findings provide insight into how clinical practice patterns vary across patient age. Finally, results show this limited use is driven by a lack of familiarity with loudness measures and the belief that loudness perception measures may not be useful for clinical practice.

Our results indicate that audiologists practicing in the United States tend to be more willing and able to measure LDLs in older pediatric patients (e.g., 14 to 21 years) than younger ones (e.g., birth to <14 years). This is consistent with their reported beliefs that younger children are unable to provide a reliable response to a subjective loudness measurement. When asked why LDLs are not measured for patients in the youngest group (birth to < 3 years), one respondent reported, “I don't feel this age range could provide an accurate measure of LDL” and another shared, “I am afraid to upset the child as I cannot guarantee they understand the task.” For preschool-age children (3 to < 7 years), one survey respondent noted, “I feel I cannot reliably obtain LDLs in this age range." Although audiologists report less difficulty measuring LDLs as the age of the patient increases (see Figure 2), limited use of LDL measures in older children appears to be due to lack of evidence that this measure improves outcomes. For example, when reflecting on school-age children and adolescents (7 to 21 years), a survey respondent stated that they, "never thought of it or how/why it would be clinically useful." In sum, the reasons for limited use appear to be different for younger vs older pediatric patients – with audiologists refraining from measuring LDLs in young patients due to development-related testing barriers while the choice to not measure LDLs in older pediatric patients is due to a lack of perceived importance. The uncertainty that measuring LDLs in older pediatric patients comes with clinical value is consistent with our search of the literature, as we are unaware of any study directly evaluating the benefit of measured vs estimated LDLs in pediatric patients. Considering the benefit that has been shown when measuring vs estimating LDLs in adult patients (Shi et al., 2007), this is an important area for future research.

Survey respondents indicated that they had limited familiarity with loudness measurement methods other than CLS (see Figure 3). This lack of familiarity suggests that pediatric audiologists may not receive adequate education or training regarding various loudness perception measurements. Consistent with Moodie et al. (2016), where 67.5% of respondents within the survey reported to rarely or never measure LDLs, 62-84% of the current survey respondents said that they rarely or never measure LDLs in their pediatric patients. Once again, a lack of familiarity was cited amongst audiologists as a reason why they choose not to use CLS to measure a patient's LDLs. This highlights a gap between research and practice, as several studies of loudness perception in children have successfully used a form of CLS (Crukley & Scollie, 2012, 2014; Davidson et al., 2000, 2009; Israelsson et al., 1995; Scollie et al., 2010; Van Eeckhoutte Maaike et al., 2020; Wolfe et al., 2015).

To further evaluate respondents' use (or non-use) of loudness perception measurements, three statements were rated for relative agreement/disagreement. For statement 1, "There is evidence to show that children perceive loudness similarly to adult listeners who have the same audiometric profile," audiologists were more likely to agree that research has shown similar loudness perception in adults and children ages 14-21 years than children of younger age groups. This might suggest that audiologists believe loudness perception undergoes a prolonged developmental period extending until adolescence. There is no evidence to support this belief, as previous studies highlight that children of 5 years of age or older have similar responses on loudness perception measures when compared to adults, particularly for studies measuring LDLs (Ellis & Wynne, 1999; Kawell et al., 1988; Macpherson et al., 1991). Agreement with statement 2, "There is evidence to show that children are able to provide consistent reports of their loudness perception," also increased with the age of the patient. Although this finding seems to suggest that audiologists are aware of research illustrating improved reliability of loudness perception measures across development (Ellis & Wynne, 1999; Teghtsoonian, 1980), a significant portion of respondents (36-47%) selected that they 'neither agree nor disagree" with this statement. This is likely indicative of the lack of current research on loudness perception in children. Reported agreement with statement 3, "There is evidence to show that average data are adequate for estimating LDLs in children," indicated that the majority of survey respondents (53-55%) neither agreed nor disagreed with this statement regardless of patient age group. This suggests that respondents seemed unable/unwilling to offer an opinion as to whether they should use average of measured LDLs for children. Given that respondents also reported the desire for more research in this area, we speculate that respondents might not have had adequate knowledge of the evidence to answer this question with confidence. Future research should investigate this link.

Limitations and Future Research

Similar to the survey conducted by Moodie and colleagues (2016), respondents frequently selected 'neither agree nor disagree' within the current survey. Reasons for the selection of 'neither agree nor disagree' include a neutral, ambivalent, undecided, or unopinionated stance on survey questions or statements (Kulas & Stachowski, 2009; Nowlis et al., 2002). When survey respondents select a neutral response based on any of the previous reasons, survey data distribution may become distorted (Bradley et al., 2015). Given the large proportion of participants indicating that they 'neither agree nor disagree' in our study and in Moodie et al., future research should consider using a survey that does not provide a 'neutral' option, as data provided might be more informative (Nowlis et al., 2002).

Conclusion

Clinical practice patterns for loudness perception measures vary widely across the audiologists surveyed in this study, with the majority of audiologists reporting use only with older children. The question of clinical relevance and concern with the administration of LDL measures appear as dominating factors impacting their low use with pediatric patients. Considering that several respondents noted their desire for more research in this area, low use of loudness perception measures among pediatric audiologist could be due to a paucity of literature exploring loudness perception in children. A further examination into the relevance of loudness perception measurements used with pediatric patients should be considered. If loudness perception measures are found to improve outcomes for pediatric patients, audiologists in this survey request that the recommended measurement method be easy-to-use, reliable, and vaild. Additionally, increased and wide-spread training regarding the purpose and method of loudness perception measurement is required before audiologists will routinely conduct these measurements with their pediatric patients.

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