J Am Acad Audiol 15:486–497 (2004)

Revisiting Loudness Measures in Children Using a Computer Method of Cross-Modality Matching (CMM)

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Abstract

The test efficiency and reliability of loudness assessment using a computer-controlled method of cross-modality matching (CMM) between line length and loudness was investigated in children 4 to 12 years with normal hearing or mild to severe degrees of sensorineural hearing loss. Adult listeners with normal hearing served as a comparison group. Computer-generated visual and acoustic stimuli were used to derive individual loudness data.

Children and adults with normal hearing presented with similar loudness functions, while children with sensorineural hearing loss had steeper functions than their normal-hearing counterparts. Retest data supported reliability of the CMM method with children within the current study and between previous studies performed with a similar, but manual, method. The computer CMM approach proved more time efficient than the manual one, halving the test time. The CMM loudness task in a computerized version may have potential in a research or clinical setting, in particular for individualizing hearing aid fittings with children.

Key Words: Children, cross-modality matching, loudness, loudness growth, sensorineural hearing loss

Abbreviations: CCMM = childrens' cross-modality matching; CMM = cross-modality matching; LDL = loudness discomfort level

Sumario

Se investigó la eficiencia y la confiabilidad de una prueba de evaluación de la intensidad subjetiva utilizando un método controlado por computadora de ordenamiento por modalidad cruzada (cross-modality matching: CMM) entre la longitud de la línea y la sonoridad, en niños de 4 a 12 años con audición normal o con hipoacusias sensorineurales de grado leve a severo. El grupo de comparación fue constituido por sujetos adultos con audición normal. Se utilizaron estímulos acústicos y visuales generados por computadora para establecer los datos individuales de intensidad subjetiva.

Los niños y adultos con audición normal mostraron funciones de intensidad subjetiva similares, mientras que los niños con alteraciones auditivas sensorineurales obtuvieron funciones con pendiente más pronunciada que sus contrapartes normo-oyentes. Los datos de re-evaluación apoyaron la confiabilidad del método de CMM en niños, con relación al estudio actual y a estudios previos, realizados con un método similar, aunque manual. El enfoque computarizado CMM demostró ser más tiempo-eficiente que el manual, reduciendo

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Portions of this work were presented as a poster entitled "Loudness Measures in Children using a Computer Method of Cross-Modality Matching (CMM)" at ASHA National Conference, Chicago, IL, November 2003.

This study was funded by a Pediatric Research Grant from Phonak, A.G., Staifa, Switzerland.

a la mitad el tiempo de examen. La tarea de reconocimiento de la intensidad subjetiva por CMM, en una versión computarizada, puede tener potencial en un contexto clínico o de investigación, en particular, para individualizar la adaptación de auxiliares auditivos en niños.

Palabras Clave: Niños, ordenamiento por modalidad cruzada, intensidad subjetiva, incremento de la sonoridad, hipoacusia sensorineural

Abreviaturas: CCMM = ordenamiento por modalidad cruzada en niños; CMM = ordenamiento por modalidad cruzada; LDL = nivel de sonoridad no confortable

Loudness measures are considered important for the setting of compression circuitry and other forms of output limiting in the fitting of amplification devices for individuals with sensorineural hearing loss (Valente and Valente, 2002). Prescriptive hearing aid fitting strategies are recommended for infants and young children who are unable to provide reliable subjective information, and such procedures are considered optimal for use in the initial setting of hearing aid response characteristics as well as subsequent adjustments of amplification parameters in early life (Pediatric Working Group, 1996). However, whenever possible, it is desirable to obtain subjective judgments about loudness in order to individualize and "fine-tune" hearing aid settings (Fabry and Schum, 1994; Jenstad et al, 1997).

Procedures for loudness assessment involve making a measurement at one discrete level, such as the loudness discomfort level (LDL), or over a range of stimulus levels yielding a loudness growth curve (function). The categorical scaling method, whereby a listener chooses one item from a restricted range of items to match the perception of loudness, is currently the most common loudness growth assessment measure used in the fitting of hearing aids to adults (Dillon, 2001). Word descriptors or number ratings are used in most of the scaling methods (e.g., Geller and Margolis, 1984; Loudness Growth in ½-Octave Bands [LGOB; Allen et al, 1990]; Contour Test [Cox et al, 1997]).

These loudness procedures, however, may have limitations when used with a pediatric population. Word descriptors may not be meaningful for very young children, or for those with limited language abilities. Studies using word categories of loudness have been shown to result in unreliable LDL measures in children with developmental ages less than 5 to 7 years (Macpherson et al, 1991). In addition, the quantification of stimulus magnitude by numeric rating is difficult for children younger than eight years (Teghtsoonian, 1980; Zwislocki and Goodman, 1980). Even pictorial representations of loudness have not been shown to produce reliable loudness scaling (LGOB) findings in children 7 to 12 years (Ellis and Wynne, 1999).

Psychoacoustic studies have demonstrated that children with normal hearing as young as 4 years are able to provide reliable matches of loudness to visual length (Teghtsoonian, 1980; Collins and Gescheider, 1989), a procedure termed "cross-modality matching" (CMM; Stevens, 1959). In preliminary investigations, Serpanos and Gravel (2000, 2002) supported the reliability of a manually controlled CMM method modified for a pediatric population 4 to 12 years with normal hearing or sensorineural hearing loss. These findings were similar to CMM results obtained from adult listeners with normal or impaired hearing (Hellman and Meiselman, 1988, 1990, 1993; Hellman, 1999).

The purpose of this investigation was to examine the usefulness and performance characteristics of a computer-controlled method of cross-modality matching (CMM). Specifically, we examined the efficiency and reliability of loudness assessment between line length and loudness in children 4 to 12 years with normal hearing or mild to severe degrees of sensorineural impairment and compared these findings from a fully computer-controlled procedure to our previous outcomes using a manually controlled CMM method.

METHOD

Participants

Thirty-six children participated in this investigation. Twenty-two children, 4 to 12 years (mean = 7.4 years; SD = 2.4 years), had normal hearing, and fourteen children, 4 to 12 years (mean = 9.4 years; SD = 2.7 years), presented with mild to severe degrees of sensorineural hearing impairment. Ten adults (mean = 34 years; SD = 12 years) with normal hearing also participated in this study and served as a comparison group for the children with normal hearing. All children and adults had normal or corrected normal vision and no prior experience with loudness growth assessment.

Individuals were recruited from the Clinical Research Center for Communicative Disorders at the Rose F. Kennedy Center, Albert Einstein College of Medicine, Bronx, New York, and were paid for their participation. This study was approved by the Albert Einstein College of Medicine Committee on Clinical Investigations. Signed parental informed consent was obtained prior to a child's participation in this study; in addition, children over age seven years signed child assent forms. All adult participants provided written informed consent.

One unaided test ear was used for each participant. Hearing and middle ear status were verified for each individual with pure-tone and speech audiometry (GSI-16, Grason-Stadler, Inc.) and 226 Hz probe tone tympanometry (GSI-33 Middle Ear Analyzer, Grason-Stadler, Inc.). Measures were obtained in a double-walled sound-treated test room. Normal hearing was defined as pure-tone thresholds less than or equal to 20 dB HL at octave frequencies from 250 to 8000 Hz.

Sensorineural hearing loss was defined as three-frequency (500, 1000, 2000 Hz) pure-tone average (PTA) thresholds greater than 25 dB HL with no air-bone gap exceeding 10 dB at more than one frequency from 250 to 4000 Hz. The hearing losses of the participants were symmetric (<15 dB difference between PTA in each ear). Thresholds of hearing for the test ears based on the three-frequency PTA ranged from mild to severe (range: 27 to 82 dB HL). Case history information revealed that most children had congenital hearing loss; two were reported to be genetic. One participant presented with an acquired hearing loss of unknown etiology. Thirteen of the 14 children with hearing loss were fit with binaural amplification of one to ten years duration. One listener (H6) who presented with the best auditory thresholds (PTA = 27 dB HL) was not aided. Audiometric and background data for each of the children with hearing impairment are displayed in Table 1.

Table 1. Audiometric and Demographic Data for Children with Sensorineural Hearing Impairment

Subject #	Age (yr.)	Test Ear	Gender	Etiology	# Years Aided	Three Frequency PTA (dB HL)	Test Ear Thresholds (dB HL) by Frequency (Hz)					
							250	500	1000	2000	4000	8000
H1	12	R	M	acquired	5	63	50	65	60	65	40	15
H2	9	R	M	congenital	3	77	60	65	80	85	85	80
H3	11	R	F	genetic	8	52	30	40	60	55	50	45
H4	12	L	F	genetic	10	72	45	60	75	80	65	65
H5	11	L	M	congenital	7	37	20	25	35	50	35	15
H6	10	L	M	congenital	N/A	27	25	25	25	30	30	25
H7	12	R	F	congenital	7	57	45	60	60	50	10	10
H8	5	L	F	congenital	4	35	30	25	30	50	40	60
H9	11	L	F	congenital	3	38	20	30	40	45	55	55
H10	7	R	M	congenital	1	68	45	60	75	70	65	50
H11	12	R	M	congenital	5	48	25	40	45	60	55	85
H12	8	R	M	congenital	5	33	25	30	35	35	40	55
H13	8	L	M	congenital	5	52	40	40	50	65	60	65
H14	4	R	M	congenital	1	67	60	65	70	65	50	40
Mean	9.43					51.88	37.14	45.00	52.86	57.50	48.57	47.50
SD	2.68					16.16	13.97	16.64	18.26	15.66	18.23	23.92

Computer-Controlled CMM Program

A custom designed computer (running Windows 98) program (CMMSuite v.0.5.3.29, 2002, major league software, llc) was used to generate and control the presentation of the acoustic and visual stimuli for the CMM task. The computer program recorded responses and calculated the loudness growth function slopes for each task. In a prior manually controlled CMM method (Serpanos and Gravel, 2000), the acoustic (narrow bands of noise generated by a clinical audiometer) and visual stimuli (single line length graphics on separate cards) were presented by the examiner; individual responses were recorded, and loudness slopes were calculated manually.

Stimuli

The acoustic stimuli, ½-octave noise bands centered at 2000 Hz of 2 sec duration, were generated (Tucker-Davis Technologies [TDT] SigGen), digitally converted (TDT-DD1), filtered (TDT-FT6), attenuated (TDT-PA4), and transduced (TDT-HB6) for presentation. The visual stimuli were graphics adapted from a previous pediatric version of a childrens' CMM (CCMM) task that used loudness and line length (Serpanos and Gravel, 2000, 2002). Eight separate graphics ("caterpillars" of different sizes) depicted line lengths varying from 0.52 to 65 cm (ratio of 125:1) in accord with previous CMM studies (Hellman and Meiselman, 1988, 1990, 1993; Hellman, 1999). The "caterpillars" consisted of a green cartoon smiley face affixed to a "body," a green straight line of varying length (see Figure 1) and were displayed on a touchscreen monitor (Sampo KM-800Y).

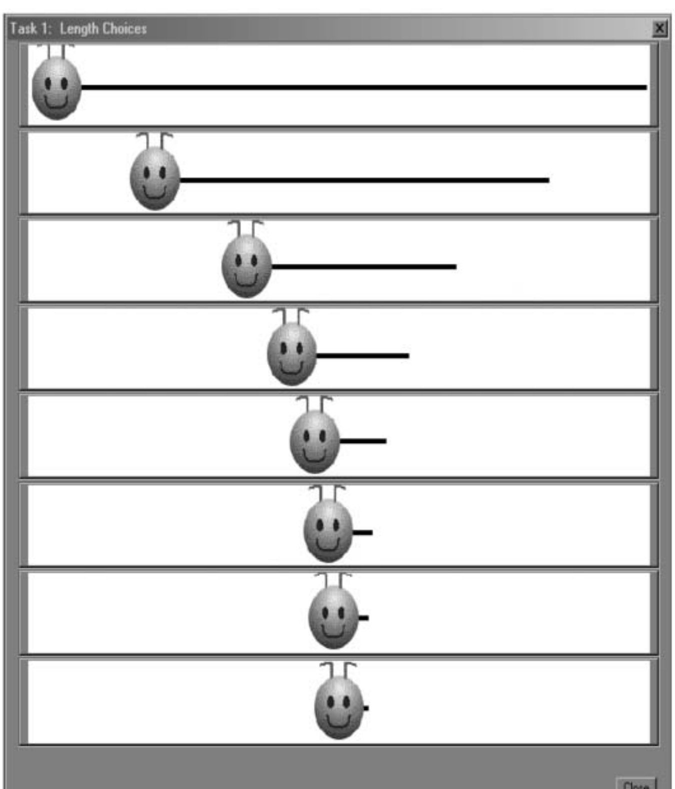

Figure 1. Visual line length options ("caterpillars") presented on touchscreen monitor in CMM Task 1: Line Length to Loudness.

Procedures

Prior to the loudness growth tasks, thresholds of audibility and discomfort levels for the auditory stimulus were obtained from each participant. The stimulus was presented to the individual's test ear through insert earphones (E.A.R.®-3A). The threshold of audibility was measured using an adaptive method of limits (American Speech-Language-Hearing Association, 1978). The search for a threshold of discomfort was established following a protocol that specified the verbal instruction to the individual to indicate the level that was "very, very loud" as he/she listened to an ascending 1 dB increment series of stimulus levels. With young children, the examiner's verbal instruction was also accompanied by a facial expression of discomfort. An identified level of discomfort was to serve as the limit of stimulus level presentation.

In order to ensure an equal input stimulus level on the loudness judgments of children and adults, real ear measurements (RM500, Audioscan, Inc.) were obtained from the test ear of each listener. Using a default program setting (CMMSuite v.0.5.3.29) that generated a continuous 30 sec presentation of the test stimulus (2000 Hz ½-octave noise band at 90 dB SPL), real ear measurements were recorded by inserting the probe microphone tubing 5 mm past the medial end of the foam tip of the insert earphone (Tecca, 1990). The mean real ear sound pressure level of the stimulus was 93.3 dB SPL (SD = 2.4; range = 87.4–96.8 dB; n = 36) for the children with normal hearing and hearing loss, and 94.0 dB SPL (SD = 1.6; range = 91–96.1 dB; n = 10) for the adults. A two-sample t-test assuming unequal variances revealed no significant difference ($t = -1.24$, $p = 0.23$) between the individual ear canal sound pressure levels of the children and adults. Therefore, the loudness functions for these groups of children and adults were measured at essentially equivalent stimulus input levels.

A separate loudness growth function was measured for each individual over a range of stimulus levels using the CMM method, which includes two tasks. In Task 1 (see below), line length is matched to loudness. Task 2 (see below) is the reverse of the first, where loudness is matched to line length. The resulting loudness growth functions derived from each task were geometrically averaged to provide a single loudness growth function for each individual. This procedure was modeled after the psychophysical loudness method proposed by Stevens (1975) whereby the two loudness tasks are used to counterbalance a response bias (regression effect) that may occur if either task is used in isolation.

The procedures, including audiometry and tympanometry, were typically completed within a single one and one-half to two hour session. The CMM tasks were completed within ten minutes on average, excluding breaks, which were offered to the children as needed. Following a minimum of a half-hour break after the CMM task was completed, the CMM tasks were repeated in order to assess short-term test-retest reliability.

CMM Task 1: Line Length to Loudness

For this task, the listener was required to match a line length graphic (one "caterpillar") to the perceived loudness of a specific stimulus level. Eight individual acoustic stimulus levels were randomly selected and generated by the computer. Eight visual stimuli were presented in ascending length order on the computer touchscreen monitor (Figure 1). The listener was instructed verbally (see Appendix A) and by demonstration to touch the graphic on the touchscreen monitor that was as "big" or "small" as the loudness of the sound. The stimulus remained on continuously, typically for a few seconds, until the selection was made.

The stimulus levels presented to the listeners with normal hearing ranged from 20 to 90 dB SPL and varied in 10 dB increments. The eight stimulus levels presented to the children with hearing loss were individually determined based on the dynamic range (dB SPL threshold of discomfort minus the dB SPL threshold of audibility) of the listener. The listener's dynamic range was divided by eight to yield a fixed dB step size that was incrementally added to each subsequent stimulus level beginning with the individual's threshold (in dB SPL).

At least two separate stimulus trials were presented in a randomized order but could be presented as many times as needed until a graphic was reliably matched to the same stimulus level. The line length match by stimulus level was recorded and stored by the computer, which controlled the stopping criterion (each graphic matched to the same stimulus level twice).

CMM Task 2: Loudness to Line Length

For this task, the listener was required to adjust the stimulus to a loudness level that matched the size of the graphic. The computer controlled the randomization of the eight "caterpillars," presented one at a time on the touchscreen monitor. The listener was instructed verbally (see Appendix B) and by demonstration to adjust the level of the auditory stimulus using the up/down arrow keys on the computer keyboard until the loudness was as "big" or "small" as the graphic length. The graphic was displayed until the listener made a selection, typically for a few seconds.

The attenuator step size was set to 1 dB with a range of stimulus level adjustment between -4 and 96 dB SPL; this range of numeric values was not visible to the listener. Two separate trials were presented; each trial included the eight graphics. The computer averaged and stored the perceived loudness for each line length.

RESULTS

Loudness Growth Functions

All children with normal hearing were able to complete the tasks. Three children with hearing impairment did not complete the tasks in their entirety and were therefore not included in the data analysis. One child (H12), age 9 years, completed the first CMM task; however, he showed a poor understanding of the second task in that he repeatedly adjusted the attenuator to the lowest setting (-4 dB SPL) regardless of the presented line length. The two other participants (H13, 8 years; H14, 4 years) did not demonstrate a reliable understanding of either task during informal assessment and possibly did not understand the instructions due to limited verbal and receptive language skills imposed by their hearing impairment.

The loudness tasks (Task 1: Line Length to Loudness; Task 2: Loudness to Line Length) provided two separate loudness growth functions (length matched to loudness) for each listener. A single loudness growth function was then derived for each listener by calculating the geometric mean of the two stimulus levels (obtained from both loudness tasks) matched to each graphic line length. Linear regression analysis (length [y] by loudness in dB HL [x]) was performed on each individual intensity function in order to obtain power function exponents (slope values).

Normal Hearing

Thresholds for the auditory stimulus ranged from 10 to 20 dB SPL (mean = 15.5 dB; SD = 3.5 dB; n = 22) for the children with normal hearing (Table 2). The children with normal hearing were able to tolerate the highest presented stimulus level (90 dB SPL). As can be seen in Table 2, the individual loudness growth function slope values for the children with normal hearing ranged from 0.52 to 0.93 with a mean group loudness slope value of 0.76 (SD = 0.12). Individual correlations (r) ranged from 0.93 to 1.00. The adult (n = 10) loudness slopes ranged from 0.60 to 0.84, with group mean slope value of 0.70 (SD = 0.06). The individual correlations of the loudness functions for the adults ranged

Table 2. Individual Measured Loudness Slopes: Children with Normal Hearing

		2000 Hz		
Subject #	Age	Threshold (dB SPL)	Loudness Slope	r
N1	11	15	0.79	0.98
N2	10	10	0.71	0.99
N3	6	15	0.62	0.98
N4	5	20	0.52	0.99
N5	9	20	0.92	0.99
N6	6	20	0.84	0.99
N7	10	20	0.93	0.99
N8	6	15	0.92	0.99
N9	8	15	0.72	0.99
N10	5	20	0.89	1.00
N11	8	20	0.70	0.99
N12	5	15	0.71	0.99
N13	6	15	0.84	0.99
N14	10	15	0.61	0.99
N15	10	15	0.81	0.99
N16	8	10	0.75	0.99
N17	7	10	0.79	0.99
N18	5	10	0.86	0.99
N19	4	15	0.61	0.99
N20	4	15	0.64	0.93
N21	12	15	0.71	1.00
N22	4	15	0.85	0.97
Mean	7.38	15.48	0.76	0.99
SD	2.44	3.50	0.12	0.02

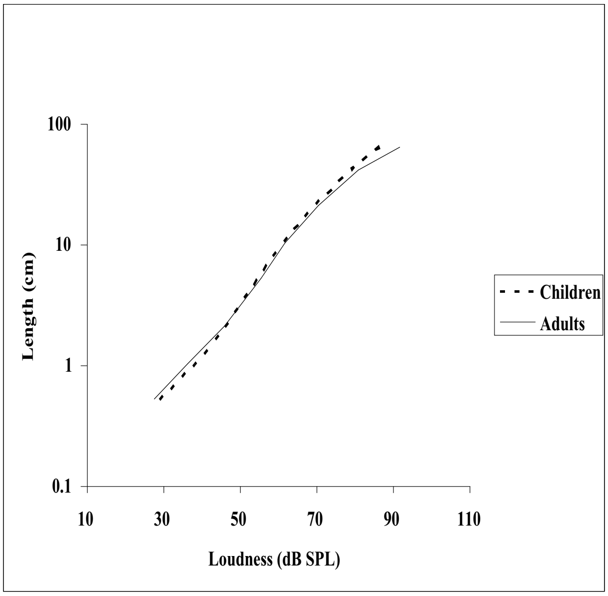

Figure 2. Mean loudness functions of children (dashed lines) and adults (solid black line) with normal hearing.

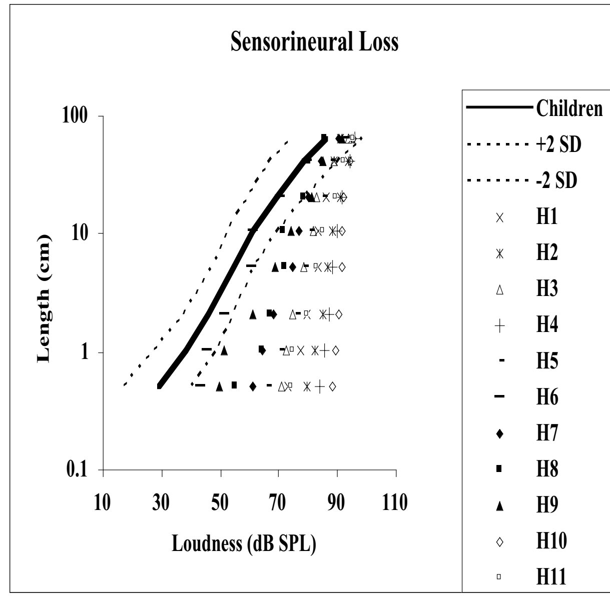

Figure 3. Individual loudness functions of children with hearing impairment against the mean loudness function of children with normal hearing (solid black line) with ± 2 SDs (dashed lines).

from 0.96 to 1.0. The high correlations of the loudness functions found for the children and adults suggest that these data are well described by linear analysis.

A two-sample t-test assuming unequal variances revealed no significant difference ($t = 2.00$, $p = .054$) between the individual loudness slopes of the normally hearing children and adults. Figure 2 shows the mean loudness functions for the children (dashed lines) and adults (solid black line). Linear regression analysis revealed a significant relationship ($r = .99$, $p < .001$) between the mean loudness functions of children (y) and adults (x).

Table 3. Individual Measured Loudness Slopes for Children with Sensorineural Hearing Impairment

		2000 Hz	
Subject #	Threshold (dB SPL)	Loudness Slope	r
H1	65	2.53	0.99
H2	80	2.81	0.99
H3	65	1.86	0.97
H4	85	3.66	0.99
H5	65	1.67	0.99
H6	35	0.85	0.96
H7	50	1.50	0.99
H8	50	1.54	0.88
H9	45	0.98	1.00
H10	80	5.95	0.97
H11	70	1.95	0.99
Mean	62.73	2.30	0.98
SD	16.03	1.46	0.03

Hearing Impairment

The children with hearing loss presented with stimulus thresholds from 35 to 85 dB SPL (mean = 63 dB; SD = 16 dB; n = 11). The LDLs for the children with hearing loss ranged from 91 to 96+ dB SPL. The individual loudness slopes for the children with hearing impairment ranged from 0.85 to 5.95, with slope values increasing as a function of hearing threshold (see Table 3). Individual loudness function correlations ranged from 0.96 to 1.0, supporting the linear fit of the data. Figure 3 shows the individual loudness functions of the children with hearing impairment against the mean loudness function (±2 SD) of the children with normal hearing.

As expected from viewing the individual data, a two-sample t-test assuming unequal variances revealed a significant difference ($t = 3.23$, $p = .009$) between the individual loudness slopes of the group of children with hearing impairment and those of their peers with normal hearing.

Test-Retest Reliability

The tasks were repeated for each participant within the same day to assess the short-term test-retest reliability of the computer-controlled CMM method. Linear regression analysis was conducted on the single loudness growth function (geometrically averaged from the loudness data derived from Task 1 and Task 2; see description in previous section) obtained from the first (x) and the second (retest) (y) sessions completed in this study. A significant correlation was found between the first test and the retest of the children with normal hearing ($r = .97$, $p < .001$, $n = 22$) and those with hearing impairment ($r = .96$, $p < .001$, $n = 11$). In addition, individual test-retest loudness differences were within 10 dB for all children at the lowest (range: 0.5 to 9.1 dB, normal hearing; 0.46 to 6.3 dB, sensorineural impairment) and highest (range: 0 to 6.0 dB, normal hearing; 0 to 7.6 dB, sensorineural impairment) points of the loudness scale. Figure 4 displays the mean test-retest loudness functions for the children with normal hearing (a) and sensorineural loss (b). Previous loudness growth reliability studies in children with normal or impaired hearing that were performed using a manual CMM method also revealed a significant test-retest correlation and loudness differences within 10 dB (Serpanos and Gravel, 2000, 2002).

a.

b.

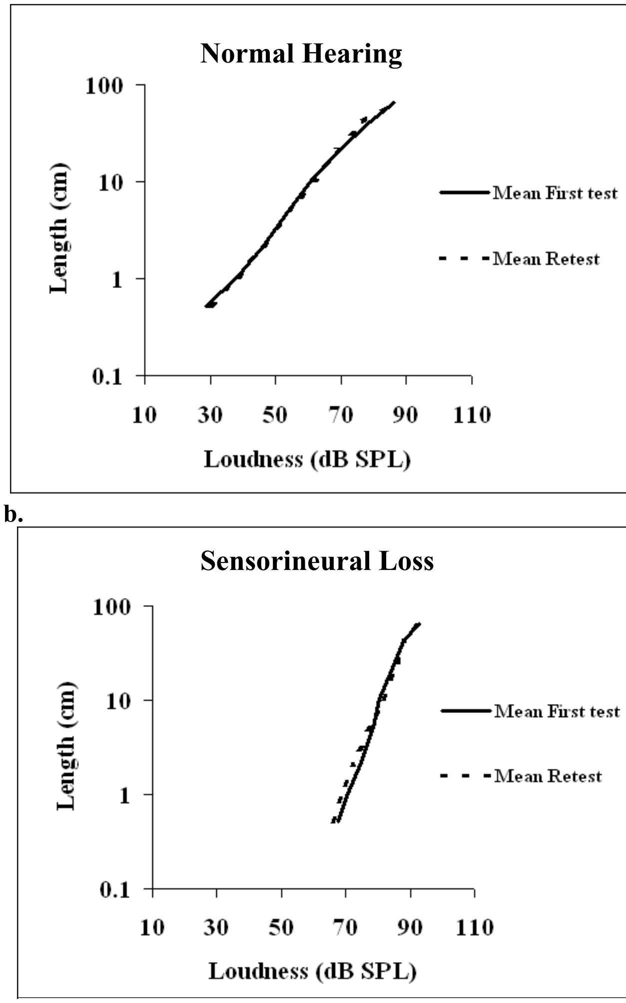

Figure 4. Mean first test (solid black line) and retest (dashed lines) loudness functions of children with normal (a) or impaired hearing (b).

DISCUSSION

This study provided evidence of the usefulness of a computer-controlled method of CMM between line length and loudness in children with normal or impaired hearing. The data revealed that children 4 to12 years and adults with normal hearing present with similar loudness growth functions. Figure 2 shows overlapping mean loudness functions of the children and adult groups, with specific mean slope values of 0.76 and 0.70, respectively. Statistical analysis supported no significant difference between the individual loudness functions of the children and adults with normal hearing. This finding is similar to previous reports using manual methods of CMM between loudness and line length (Teghtsoonian, 1980; Serpanos and Gravel, 2000, 2002).

Children with hearing impairment were found to have steeper loudness growth functions than their normal-hearing counterparts (Figure 3); as expected, statistical analysis revealed that the individual slope values of the children with hearing loss differed significantly from those of the children with normal hearing. The mean loudness growth slope for the group was three times higher than that of the group mean slope value for the children with normal hearing. However, there was greater variability of individual slope values for the children with hearing loss (SD = 1.46) than for those with normal hearing (SD = 0.12). This can be explained by the wide range of the stimulus thresholds (2000 Hz narrow band noise) of children with hearing loss, which varied from mild to severe (see Table

3). Steeper (larger) slope values have been documented with increasing hearing threshold in children (e.g., Serpanos and Gravel, 2000) and adults (e.g., Hellman, 1999).

Differences in the loudness functions based on the degree of loss are evident in Figure 3. While the loudness growth functions of most of the children with hearing loss are displaced from normal, all converge within the range of the normal loudness function at the highest stimulus levels (within 30 dB SL above the individual's threshold for the stimulus), as has been documented in adult listeners with sensorineural hearing loss (Moore, 1989). The individuals (H1 to H5, H10, H11) with the poorest thresholds for the stimulus (65 to 85 dB SPL) also presented with the steepest loudness functions and were the most displaced from the normal function, while those (H6 to H9) with thresholds of mild to moderate degree (35 to 50 dB SPL) were closest. The loudness growth function of one listener (H6) with the best threshold of the group (35 dB SPL) fell essentially within the normal range.

As found in our previous studies, the perception of loudness can vary among children with identical hearing thresholds. Three listeners (H1, H3, H5) present with thresholds for the stimulus of 65 dB SPL, yet their loudness growth functions are different. The slope values for these listeners range from 1.67 to 2.53. Indeed, the variability seen in children with identical hearing loss is similar to the findings of children with normal hearing (e.g., Serpanos and Gravel, 2000). As was seen in this study, slope values for the children with normal hearing and similar stimulus thresholds ranged from 0.52 to 0.93 (Table 2).

The computerized task was found to be reliable for children with normal hearing or sensorineural hearing loss within this study. A significant correlation was found between the individual test-retest loudness functions of both groups. Moreover, test-retest differences of within 10 dB were noted at the lowest and highest points of the individual loudness functions for the groups with normal or impaired hearing, consistent with prior loudness research (Serpanos and Gravel, 2002). As can be seen in Figure 4, the mean test-retest loudness functions are almost identical for the groups of children with normal hearing (a) or sensorineural impairment (b).

The finding of good test-retest reliability of the CCMM task is important from a clinical perspective. A computerized task removes any potential bias from the individual determination of loudness growth in a pediatric population. Since the task is completely automated, the children can proceed at their own pace. The findings with this group of children suggest that young participants actually provided reliable loudness growth functions in shorter amounts of time than with the manual method. Optimizing the test time (short sessions spent on one task) and increasing the novelty of the task (as with computer interaction) may increase the likelihood of obtaining more subjective judgments of loudness prior to the onset of boredom or fatigue that would limit the test session

Test Efficiency of a Computer-Controlled Method of Loudness Assessment

The computer-controlled CMM method as compared to a manual method was considered more time efficient; test time for one ear was reduced from 20 minutes for a single test frequency with a manual method to 10 minutes with the computerized method. Despite the importance of loudness growth assessment procedures in the hearing aid fitting process, ultimately, as is the case with other clinical measures, it will be the practical efficiency and feasibility of loudness growth assessment that will determine its use in a clinical setting. Certainly further investigation could focus on modification in the test administration of the computer-controlled CMM task in order to shorten test time.

An additional consideration regarding test efficiency is the instruction set used for the CMM task. In this investigation three children with hearing loss could not reliably perform the task, likely due to their limited language abilities. The current investigation made no attempt to alter the instructional set for such listeners (see Appendixes A and B). Individual measures of loudness growth in children should consider age and developmental level and account for the possibility that limited receptive language ability can confound the result or preclude the use of subjective loudness determinations. In a preliminary prior investigation using the current instruction set and a hybrid computer-controlled CMM task (computer-generated acoustic stimuli with manual presentation of visual stimuli) on children 3 to 12 years with normal hearing, Serpanos and Gravel (2002) determined the lowest reliable developmental age of the CMM task to be 4 years. Changes in the instructional set and possibly the overall protocol for the CCMM task (such as limiting it to only one judgment; i.e., length to loudness) should be considered so that the feasibility of completing an individual loudness growth assessment can be adequately addressed in children with a receptive language age younger than 4 years. Such modifications may also shorten the test administration that could make use of the task more practical in a clinical setting.

Finally, the availability of this reliable, computer-controlled CCMM procedure should provide a method for the study of loudness growth in children with congenital hearing loss. At least two important questions need to be addressed in subsequent research. First is the question of whether loudness grows similarly in children and adults with similar degrees of impaired hearing. Second is the question of whether experience to amplified sound alters loudness growth in children with congenital hearing loss. Deriving individual loudness growth functions in children may be more important than in adults, such that manufacturer specified algorithms for limiting output based on thresholds may not be directly applicable to children with congenital hearing loss. These are important clinical issues that are in keeping with our belief that children with congenital hearing loss must be considered unique from adults with acquired loss and that amplification fitting philosophies and protocols developed for adults should not be applied directly to children unless there is evidence to suggest that the practice is valid.

CONCLUSION

These findings are similar to previous loudness studies by Serpanos and Gravel (2000, 2002) and support the efficiency and reliability of loudness growth measurement using a computerized CMM task in children with normal hearing and hearing loss. It has been suggested that the variability of loudness perception among similar auditory thresholds supports the need for individual loudness growth assessment for the purpose of defining hearing aid characteristics (Hellman, 1999). Still, more loudness research is needed with children and in defining how this information is to be used in amplification protocols. The CMM loudness task in a computerized version could serve as a research tool to study loudness and may have potential in the hearing aid fitting process with children.

Acknowledgments. This study was funded by a Pediatric Research Grant from Phonak, A.G., Staifa, Switzerland. We wish to thank Rachel Cutler and Jessica O'Gara for their assistance in data collection. We are especially grateful to Chris Ahlstrom (major league software, llc) for creating the computer software and to Jane Ahlstrom for her help with the many technical aspects of this project. The insightful comments by three anonymous reviewers were helpful and very much appreciated.

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APPENDIX A

Instructions for Task 1: Line Length to Loudness

"You are going to hear some sounds that will be big and small.

My friend Katy the caterpillar likes to copy the sounds.

When the sound is big, Katy makes herself big.

When the sound is small, Katy makes herself small.

Sometimes she will be in the middle.

When you hear the sound, point to one of the pictures and show me what Katy looks like.

You can use any of the pictures.

Let's start."

APPENDIX B

Instructions for Task 2: Loudness to Line Length

"Now I will show you a picture of Katy the caterpillar.

You make the sound big when Katy is big.

Make the sound small when Katy is small.

I'll help you do it. See…

In some pictures Katy is big.

In some pictures, Katy is small.

Sometimes Katy is in the middle.

See how that works?

Now you do it.

Let's start."