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Assessing speech perception in children with hearing loss: What conventional clinical tools may miss

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Abstract

Objective—This study tested the hypothesis that word recognition in a complex, two-talker masker is more closely related to real-world speech perception for children with hearing loss than testing performed in quiet or steady-state noise.

Design—Sixteen school-age hearing aid users were tested on aided word recognition in noise and two-talker speech. Unaided estimates of speech perception in quiet were retrospectively obtained from the clinical record. Ten parents completed a questionnaire regarding their children's ease of communication and understanding in background noise.

Results—Unaided performance in quiet was correlated with aided performance in competing noise, but not in two-talker speech. Only results in the two-talker masker were correlated with parental reports of their children's functional hearing abilities.

Conclusions—Speech perception testing in a complex background such as two-talker speech may provide a more accurate predictor of the communication challenges of children with hearing loss than testing in steady noise or quiet.

INTRODUCTION

It is well established that children with hearing loss require a more favorable signal-to-noise ratio (SNR) than children with normal hearing to achieve comparable levels of accuracy on masked speech recognition tasks in steady-state noise or multi-talker babble (e.g., Finitzo-Hieber &Tillman 1978; Gravel et al. 1999; Hicks & Tharpe 2002). There is a growing consensus, however, that the speech perception deficits experienced by children with hearing loss are more pronounced when competing background sounds are complex, such as speech produced by one or two talkers(e.g., Sininger et al. 2010; Leibold et al. 2013).

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We recently examined the influence of hearing loss on children's masked speech perception abilities using an adaptive spondee identification task (Leibold et al. 2013). Listeners were school-age children with hearing loss who were full-time hearing aid users and children with normal hearing. Maskers were speech-shaped noise, expected to interfere with the peripheral encoding of the target speech (i.e., energetic masking), and two-talker speech, expected to interfere with the target spondees at both peripheral and central (i.e., informational masking) stages within the auditory system. Consistent with results from previous work (e.g., Finitzo-Hieber & Tillman 1978; Gravel et al. 1999; Hicks & Tharpe 2002), children with hearing loss required an average SNR increase of 3.5 dB to perform as well as their normal-hearing peers in speech-shaped noise. This performance gap increased to 8.1 dB in two-talker speech. Performance in speech-shaped noise was correlated with children's three- and four-frequency pure-tone average thresholds (PTA). As previously observed for children (e.g., Boothroyd, 1984), greater hearing loss was associated with poorer speech perception. In contrast, there was no correlation between the PTA and speech recognition in the two-talker speech masker. These results highlight important differences in the factors limiting speech perception under different masker conditions, and suggest that testing in quiet or in steady-state maskers may not predict the difficulties experienced by children with hearing loss in natural environments, which often include complex sounds such as competing speech. The aims of the present study were twofold. The first goal was to evaluate the relationship between aided performance for children with hearing loss on our laboratory-based measure of masked spondee identification and performance on two unaided measures of speech perception obtained during a clinical evaluation: (1) the speech reception threshold (SRT); and (2) open-set word recognition using the Phonetically Balanced Kindergarten test (PBK; Haskins 1949). We predicted a strong correlation between these clinical measures in quiet and spondee recognition in speech-shaped noise, but no such association was predicted for spondee recognition in a two-talker masker. The second goal was to evaluate whether performance in the two-talker masker was associated with the extent of perceived communication challenges reported by the children's parents, as assessed by questionnaire. It was hypothesized that parental report of greater functional hearing and communication challenges in children would be associated with poorer word recognition in the two-talker masker. No association was expected for testing in the speech-shaped noise masker or under quiet listening conditions.

METHODS

Overview

Estimates of the SNR required for 70.7% correct spondee identification in competing noise or speech were collected from children with hearing loss as part of a larger study comparing their performance to that of peers with normal hearing (Leibold et al. 2013). Behavioral pure-tone thresholds, SRTs, and PBK scores were retrospectively obtained for these children from their most recent clinical evaluation (within six months of laboratory testing). New subjective data were also collected from the parents of a subset of children using the Children's version of the Abridged Profile of Hearing Aid Performance (Kopun& Stelmachowicz 1998).

Listeners

Participants were sixteen children (9–17 years; mean age = 12 years) with bilateral sensorineural hearing loss, ranging from mild to profound (Table 1). The average age at identification of hearing loss was 2.67 years, and age at first hearing aid fitting was 2.94 years. All children were oral English speakers in mainstream educational classrooms, and were full-time hearing aid users of devices with active nonlinear frequency compression (NLFC) processing. They had a negative history of recurring middle ear issues and other medical, developmental, or learning problems. They were recruited from the University of North Carolina Pediatric Audiology program, where they receive ongoing clinical management. Interested families were consented to participate by laboratory personnel in accordance with the policies of the University of North Carolina Institutional Review Board.

Stimuli and Procedures

Laboratory measure of masked spondee identification—The stimuli and procedures associated with the laboratory measure are described in detail by Leibold et al. (2013). During testing, children wore their personal behind-the-ear (BTE) hearing aids, which were programmed and verified to match DSL v.5 i/o gain and maximum power output (MPO) targets (Bagatto et al. 2005). Prior to laboratory testing, a listening check and simulated real-ear measures were performed at user settings using measured real-ear-to-coupler-difference (RECD) values to confirm gross hearing aid functioning.

The task was a closed-set, four-alternative, forced-choice spondee recognition measure adapted from Hall et al.(2002). Target stimuli were 25 spondees, each associated with an illustration. Words were presented at 65 dB SPL in a competing background of either speech-shaped noise or two-talker speech. Children were seated 1 meter in front of a speaker (0° azimuth, 0° elevation). Masker level was adaptively varied to determine the SNR associated with 70.7% identification. At least two estimates of SNR were obtained for each masker condition, with test order counterbalanced.

Clinical speech perception measures—Two conventional estimates of speech perception in quiet were obtained from each child’s most recent audiologic evaluation: 1) SRT in the better-hearing ear and (2) percent-correct supra-threshold PBK score in the better-hearing ear. Individual estimates for both measures are shown in Table 1. The SRTs were obtained for spondees using monitored live voice; while the use of live-voice presentation may be less consistent than recorded materials (Mendel & Owen 2011), it is occasionally adopted for its efficiency and flexibility(American Speech-Language-Hearing Association, 1988). The PBK scores were based on half lists (25 words)of recorded material played through the audiometer at 40 dB sensation level (SL) with respect to each listener’s SRT for spondees. Both measures were obtained by the child’s audiologist using ER-3A insert earphones.

Parent questionnaire—Parents were mailed a paper copy of the Children’s Abbreviated Profile of Hearing Aid Performance (Kopun & Stelmachowicz 1998), an adaptation of the Abridged Profile of Hearing Aid Performance (APHAP; Cox & Alexander 1995). Eleven questionnaires were returned; one was excluded from analysis due to missing data in one field. Scores reflecting parent's perception of their child's level of communication difficulty in various situations (wearing their hearing aids) were computed for the two subscales pertinent to the current work: (1)Ease of Communication, and (2)Background Noise.

RESULTS

Bivariate correlations (one-tailed) between clinical and laboratory speech measures indicated a negative correlation between PBK scores in the better hearing ear and SNRs at threshold in the speech-shaped noise masker ($r = -0.596$, $p = 0.007$). No significant relationship between spondee identification performance in speech-shaped noise and the clinical SRT was observed ($r = 0.261$, $p = 0.165$), or between spondee identification performance in two-talker speech and either clinical measure (PBK: $r = -0.241$, $p = 0.184$; SRT: $r = 0.084$, p = 0.378). As observed by Leibold et al. (2013), the better-ear four-frequency pure-tone average (PTA4) was positively associated with performance in speech-shaped noise ($r = 0.562$, $p = 0.012$), but not in two-talker speech ($r = 0.200$; $p = 0.250$). Scores on the clinical measures obtained in quiet (SRT and PBK word recognition) were associated with spondee recognition scores obtained in a speech-shaped noise, but not the two-talker background.

Parent report on the two questionnaire subscales was unrelated to either the clinical measures obtained in quiet or to laboratory measures obtained in speech-shaped noise ($p>0.05$). Contrastingly, there was a significant positive relationship between estimates of the SNR at threshold in the two-talker masker and parental responses on both the Ease of Communication ($r = 0.820$, $p = 0.002$) and Background Noise ($r = 0.573$, $p = 0.042$) subscales (Figure 1).[1] Parents of children requiring a more favorable SNR in the two-talker masker tended to report that their children had greater communication difficulties in their everyday listening situations than parents of children who required a less advantageous SNR.

DISCUSSION

The present results indicate that estimates of speech perception obtained in quiet, or in relatively simple maskers, may not be closely associated with everyday performance for children with hearing loss. While there was a significant correlation between spondee identification performance in speech-shaped noise and clinical PBK scores in quiet, there was no relationship between spondee identification in the two-talker masker and either clinical measure of speech perception. However, spondee identification in two-talker speech was strongly related to parents' perceptions of their children's receptive communication ability, a finding not observed with the conventional noise masker or either clinical measure. We cannot rule out the possibility that testing children with their hearing aids for the clinical measures could improve the predictive power of the clinical speech tests performed in quiet in this group of hearing aid users. However, this possibility is undermined by the finding

[1]Using the method described by Lee and Preacher (2013), a significant difference was observed between the correlation coefficients for the Ease of Communication subscale and the two masker conditions (z=1.77, p = 0.038, one-tailed). Note, however, that the correlation coefficients for the Background Noise subscale were not significantly different for the speech-shaped noise and two-talker maskers (z=0.70, p = 0.241, one-tailed).

that performance on the aided laboratory measure in speech-shaped noise was not correlated with questionnaire data.

Complex sounds such as background speech pervade natural listening environments, but testing under complex listening conditions is not routinely included in the pediatric test battery. This omission may be due to a lack of normative data, and/or the emphasis on establishing estimates of sensitivity for the purposes of prescribing amplification. Although the limited ecological validity of conventional speech perception measures was acknowledged decades ago (e.g., Carhart 1965), research on the development and validation of tools that may better approximate functional, day-to-day receptive communication ability is scant. Results of the present study suggest that evaluating speech understanding in the presence of a small number of competing talkers may more accurately capture children's real-world communication difficulties than traditional tools. Additional research is needed to evaluate the validity and reliability of complex speech perception tests such as the laboratory measure introduced here. Further research is also needed to determine the adequacy of the subjective questionnaire in capturing children's functional communication challenges and the accuracy of parental report of dis/ability.

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References

American Speech-Language-Hearing Association. Determining threshold level for speech [Guidelines]. 1988. Available from www.asha.org/policy

Bagatto M, Moodie S, Scollie S, et al. Clinical protocols for hearing instrument fitting in the Desired Sensation Level method. Trends Amplif. 2005; 9:199–226. [PubMed: 16424946]

Boothroyd A. Auditory perception of speech contrasts by subjects with sensorineural hearing loss. J Speech Hear Res. 1984; 27(1):134–144. [PubMed: 6716999]

Carhart R. Problems in the measurment of speech discrimination. Arch Otolaryng. 1965; 82:253–260. [PubMed: 14327024]

Cox RM, Alexander GC. The abbreviated profile of hearing aid benefit. Ear Hear. 1995; 16:176–186. [PubMed: 7789669]

Finitzo-Hieber T, Tillman TW. Room acoustics effects on monosyllabic word discrimination ability for normal and hearing-impaired children. J Speech Hear Res. 1978; 21:440–458. [PubMed: 713515]

Gravel JS, Fausel N, Liskow C, et al. Children's speech recognition in noise using omnidirectional and dual-microphone hearing aid technology. Ear Hear. 1999; 20:1–11. [PubMed: 10037061]

Hall JW 3rd, Grose JH, Buss E, et al. Spondee recognition in a two-talker masker and a speech-shaped noise masker in adults and children. Ear Hear. 2002; 23:159–165. [PubMed: 11951851]

Haskins, HA. Unpublished Masters Thesis. Northwestern University; Evanston, IL: 1949. A phonetically balanced test of speech discrimination for children.

Hicks CB, Tharpe AM. Listening effort and fatigue in school-age children with and without hearing loss. Journal of Speech, Language & Hearing Research. 2002; 45:573–584.

Kopun JG, Stelmachowicz PG. Perceived communication difficulties of children with hearing loss. Am J Audiol. 1998; 7:30.

Lee, IA.; Preacher, KJ. Calculation for the test of the difference between two dependent correlations with one variable in common [Computer software]. 2013 Sep. Available from http://quantpsy.org

Leibold LJ, Hillock-Dunn A, Duncan N, et al. Influence of hearing loss on children's identification of spondee words in a speech-shaped noise or a two-talker masker. Ear Hear. 2013; 34:575–584. [PubMed: 23492919]

Mendel LL, Owen SR. A study of recorded versus live voice word recognition. Int J Audiol. 2011; 50:688–693. [PubMed: 21812631]

Sininger YS, Grimes A, Christensen E. Auditory development in early amplified children: factors influencing auditory-based communication outcomes in children with hearing loss. Ear Hear. 2010; 31:166–185. [PubMed: 20081537]

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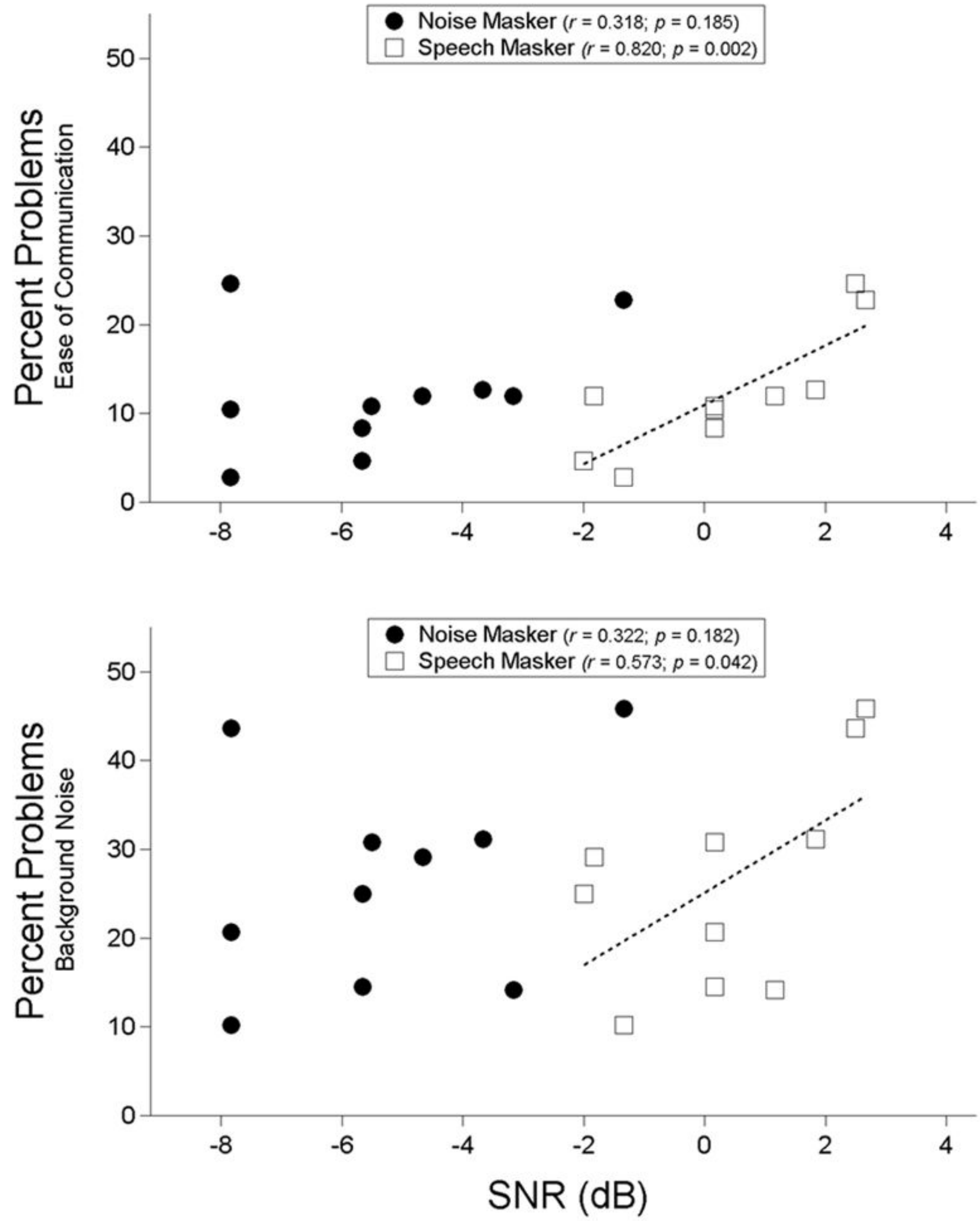

Figure 1.

Scatterplot displaying the relationship between children's performance on laboratory measures and parent report of the percent of perceived problems children experience in two domains: (top) ease of communication, and (bottom) understanding in background noise.

Table 1

Audiometric thresholds are reported for each ear as well as unaided speech perception results for the better ear in quiet from each child's most recent clinical evaluation. Estimates of the SNR required for 70.7% correct spondee recognition are shown for aided testing completed in the laboratory for both masker conditions.

			CLINICAL MEASURES (unaided and ear specific)								LAB MEASURES (aided soundfield)	
			Audiometric Thresholds (dB HL) across Frequency (Hz)									
Listener	Age (yrs)	Ear	250	500	1000	2000	4000	8000	Better-Ear SRT (dB HL)	Better-Ear PBK (%)	Aided SRT Speech-Shaped Noise	Aided SRT Two-Talker Speech
L1	9.70	R	35	35	40	35	10	30				
		L	30	30	35	40	10	0	30	100	−2.83	7.50
L2	10.13	R	10	10	10	55	90	75				
		L	15	10	10	55	80	80	10	64	0.33	3.17
L3	10.44	R	10	15	60	65	60	60				
		L	10	10	50	65	60	60	30	84	−2.83	5.17
L4	11.23	R	35	45	55	50	50	65				
		L	35	40	55	50	50	65	45	84	−0.50	5.17
L5	13.96	R	0	5	5	90	95	75	5	83		
		L	5	10	20	95	95	80			−2.50	5.17
L6	13.31	R	30	45	55	60	50	30	45	100		
		L	35	40	55	60	55	30			−1.17	2.17
L7	9.41	R	35	60	65	55	50	60	55	92		
		L	35	60	65	55	50	65			−0.67	3.00
L8	13.19	R	25	35	65	95	110	nr				
		L	25	40	55	70	65	70	45	88	3.67	7.67

			CLINICAL MEASURES (unaided and ear specific)									LAB MEASURES (aided soundfield)	
			Audiometric Thresholds (dB HL) across Frequency (Hz)										
Listener	Age (yrs)	Ear	250	500	1000	2000	4000	8000	Better-Ear SRT (dB HL)	Better-Ear PBK (%)		Aided SRT Speech-Shaped Noise	Aided SRT Two-Talker Speech
L9	10.28	R	55	60	70	70	65	65					
		L	50	55	65	65	60	65	55	92		−0.67	5.17
L10	15.50	R	30	40	45	75	85	nr	40	60			
		L	30	40	60	90	100	nr				2.33	1.67
L11	10.94	R	65	70	75	75	75	65					
		L	55	65	65	70	70	70	65	88		−2.83	3.67
L12	9.57	R	60	70	85	75	70	65	75	68			
		L	85	85	85	90	80	90				1.33	6.83
L13	10.82	R	50	55	70	80	95	*	60	60			
		L	60	65	80	95	100	*				1.83	6.17
L14	11.18	R	15	25	75	115	110	*					
		L	10	25	60	105	110	nr	35	46		0.83	5.00
L15	17.09	R	15	35	75	115	115	95					
		L	15	20	85	105	105	nr	35	24		2.00	8.00
L16	15.77	R	50	70	90	90	85	nr	60	40			
		L	50	65	95	100	115	nr				1.50	5.83

* data unavailable