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Word Recognition Variability With Cochlear Implants: The Degradation of Phonemic Sensitivity

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Objective: Cochlear implants (CIs) do not automatically restore speech recognition for postlingually deafened adults. Average word recognition remains at 60%, and enormous variability exists. Understanding speech requires knowledge of phonemic codes, the basic sound units of language. Hearing loss may result in degeneration of these long-term mental representations (i.e., ''phonemic sensitivity''), and CI use may not adequately restore those representations. This investigation examined whether phonemic sensitivity is degraded for CI users, and whether this degradation results in poorer word recognition.
Study Design: Thirty adults with CIs and 20 normal-hearing controls underwent testing.
Methods: Participants were assessed for word recognition in quiet, along with tasks of phonemic sensitivity using an audiovisual format to maximize recognition: initial consonant choice (ICC), in which they selected the word with the same starting sound as a target word, final consonant choice (FCC), in which they selected the word with the same ending sound, and backwards words, in which they repeated phonemes comprising words in backwards order.
Results: Phonemic sensitivity was poorer for CI users than for normal-hearing controls for ICC and FCC. For CI users, ICC and FCC predicted 25% and 40% of variance in word recognition, respectively. Longer duration of CI use did not lead to greater restoration in phonemic sensitivity.
Conclusion: Even for adults who presumably had developed refined phonemic representations, hearing loss can degrade those representations, which results in poorer word recognition. Cochlear implants do not adequately restore those representations. Findings suggest the need for rehabilitative efforts to improve CI users' phonemic sensitivity.

Key Words: Cochlear implants—Sensorineural hearing loss—Speech perception.

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Cochlear implants (CIs) have significantly improved the lives of adults who acquire sensorineural hearing loss. Nonetheless, implanted patients are still only able to recognize about 60% of spoken words in quiet during common clinical tests (1–3). Moreover, enormous variability exists, with some patients able to recognize fewer than 10% of words presented to them, and others able to recognize 100% in quiet (1–3).

It is assumed that this variability in word recognition exhibited by CI users is largely related to the degraded nature of the speech signals delivered through their CIs to a diseased auditory system. Current CI speech processors recover the temporal envelope in approximately 20 independent frequency channels, but the effective number of available channels is typically limited to four to seven (4). Thus, the spectral (i.e., frequency-related) structure of the delivered signal is significantly degraded. Because of this degradation, listeners with CIs lack access to much of the spectral detail that is used to perceive speech. If this signal degradation was solely responsible for speech recognition, outcomes would vary based primarily on the extent of spectral degradation faced by individual CI users, and improving spectral resolution should lead to better word recognition for CI users, as well as decreased outcome variability.

But it could be that factors beyond simple auditory sensitivity to the speech signals transmitted through CIs contribute to word recognition performance. It may be that the language experience and knowledge of the listeners contribute to their abilities to recognize spoken words through their implants. If this were true, it would suggest that aural rehabilitation focused on improving this linguistic knowledge could serve as a target of intervention to optimize outcomes.

A beneficial effect of language knowledge on recognition of degraded speech has been found for adults with normal hearing listening to sentences in noise. Highly refined language knowledge enables the listener to predict the language structure that is likely to be present within the degraded signal, and the absence of this

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Supplemental digital content is available in the text.

linguistic knowledge inhibits recognition (5). Several studies have shown that recognition of words in sentences is more accurate when sentences are predictable, both syntactically—the sentences follow grammatical rules of how words are put together—and semantically—there are close relationships of meaning among words (6–8). When it comes to CI users, Most and Adi-Bensaid (9) found that adolescent and adult listeners with implants performed better on speech recognition tasks when speech materials provided greater context. In addition, some CI users were able to use syntactic and semantic context more effectively than others.

A particularly relevant aspect of linguistic knowledge that has not been adequately examined in adult CI users for its relationship with speech recognition concerns knowledge of the phonological structure of their primary language. This knowledge relates to the long-term internal mental representations of the fundamental units of that language. Specifically, knowledge of the phonemic structure of the language—the mental representations of the sounds of words (i.e., ''phonemic sensitivity'') —should underlie the ability to recognize spoken words. This is because the lexicon (an individual's store of words) is organized phonemically in mature language users, and recognition of spoken language is largely dependent on recovery of this structure within words for mature listeners (10–12). However, phonemes are not distinctly represented within the acoustic speech signal, and passively collected by the listener; in fact, there is no clear correspondence between the acoustic speech signal and the perceived phoneme. Rather, listeners with normal hearing (NH) must develop phonemic sensitivity during childhood as they gain experience with their native language, a process that entails discovering which components of the signal should be attended to, and how those components should be mentally organized. This phonemic knowledge has been found to predict word recognition in noise for children with normal hearing (13). In the case of adults who lose their hearing after acquiring a first language (i.e., postlingually deafened adults), these patients presumably had well-defined phonemic knowledge before losing their hearing. It seems reasonable to assume that these phonemic structures, once formed, would remain intact, even in the face of diminishing access to the acoustic structure that defines those categories.

It should be noted that a large body of research exists examining phoneme recognition in adult CI users (14–17). Although phoneme recognition certainly relates to the concept of phonemic sensitivity, they are not synonymous. Auditory-only measures of phoneme recognition/identification permit assessment of the ability of the listener to match the incoming auditory speech signal to a phonemic representation in long-term memory; often studies using phoneme recognition are focused on how manipulations of that incoming signal affect phoneme perception (14,15). On the other hand, measures used to assess phonemic sensitivity attempt to tap into the quality of those long-term phonemic representations more explicitly.

A study by Lyxell et al. (18) is one of the few studies to examine phonemic sensitivity by postlingually deafened adults with CIs. Those authors examined the performance of 15 adult CI users on a lexical decision task—requiring determination of whether a string of letters constituted a real word or not—and a rhyme judgment task—requiring participants to judge whether two words rhymed or not. Both these tasks required explicit access to phonological representations. Only the individuals with scores that were equivalent to those of NH participants achieved open-set speech understanding in an auditory-only condition. The CI users as a group showed significant deterioration of their phonemic representations relative to listeners with NH; notably, longer duration of severe hearing impairment before implantation was associated with poorer performance, and implantation did not inevitably lead to improvement in phonemic sensitivity. These results suggested that phonemic knowledge was adversely affected by severe hearing loss, was negatively correlated with longer duration of deafness, and was not automatically restored by cochlear implantation. However, that study did not directly examine for a relationship between phonemic sensitivity and variability in word recognition.

The above findings provide reason to investigate preserved sensitivity to phonemic structure as a contributor to variability in spoken word recognition abilities among adults with CIs. The current study compared phonemic sensitivity for a group of postlingually deafened adults with CIs to those of a group of NH peers, and examined CI users' phonemic sensitivity as a potential predictor of word recognition in quiet. Three hypotheses were tested: 1) adults with CIs would score more poorly than NH peers on tasks that measure explicit sensitivity to phonemic structure; 2) phonemic knowledge would predict variability in word recognition in quiet for individuals with implants; and 3) factors related to CI participants' hearing loss would serve as predictors of phonemic sensitivity. To test the first and second hypotheses, participants underwent testing using three tasks examining phonemic sensitivity (phonemic awareness tasks), along with word recognition in quiet. To test the third hypothesis, data on participants' severity of hearing loss, duration of hearing loss, and duration of CI use were collected for examination as predictors of phonemic sensitivity. If these hypotheses were confirmed, results would suggest that the degradation of phonemic sensitivity plays a role in suboptimal word recognition outcomes for CI users, and that factors related to patients' hearing history relate to this degradation. Moreover, confirmation of the hypotheses would suggest that focusing on improvement of phonemic sensitivity through improved delivery of the acoustic structure that supports phonemic sensitivity, or explicit phonological training, could improve outcomes for implanted patients.

METHODS

Participants

Thirty postlingually deafened adults who wore CIs were recruited from the Otolaryngology department at The Ohio State University Wexner Medical Center. Participants were between the ages of 52 and 88 years (mean, 66.7; SD, 10.2) and had varying etiologies of hearing loss and ages of implantation. See Supplementary Digital Content (http://links.lww.com/MAO/A368) for additional participant information. During testing, participants wore their devices (including contralateral hearing aids for those who used them) with their usual daily settings and were instructed not to change settings during testing.

Twenty NH participants were tested as the control group, age-matched as closely as possible to the first 20 CI participants (mean age, 63.7 yr; SD, 8.1; range, 52–78). All control participants were evaluated for NH, measured at the time of testing, and defined as four-tone (500, 1000, 2000, and 4000 Hz) pure-tone average (PTA) thresholds of better than 30 dB HL, because lower thresholds might be difficult to obtain for elderly controls. Mean four-tone PTA for the control group was 12.8 dB HL (SD, 7.6; range, 1.3–26.3). Control participants were identified from a pool of patients with nonotologic complaints in the Otolaryngology Department, as well as through ResearchMatch, a national database for research study recruitment.

All participants spoke American English as their first language and had graduated from high school, except for one NH listener who only finished the 11th grade. Data regarding socioeconomic status (SES) was collected, because it is known to be correlated with language abilities, at least in children (19). The SES was computed using a metric that indexes the occupational status and educational level using two eight-point scales between 1 and 8 (19). The two scores were multiplied, which resulted in an SES score between 1 and 64.

All participants underwent a screening test for cognitive dysfunction. The Mini-Mental State Examination is a validated screening assessment for memory, attention, and ability to follow instructions. It was used in this study to rule out evidence of cognitive impairment that might affect test responses (20). The examination materials were presented in a version that was read by the participant (21). Raw scores were converted to T scores per Folstein, Folstein, and Fanjiang, based on age and education level. A T score less than 29 is suggestive of cognitive impairment (20). Two CI users and one NH participant had T scores less than 29, so their data were excluded from analyses.

Word reading ability and expressive vocabulary were measured for all participants as metrics of overall language proficiency, as these measures could serve as potential covariates when performing analyses of predictors of word recognition. Data regarding demographics and audiologic testing are shown in Table 1 for the 28 CI participants whose data were included in subsequent analyses. Mean age, SES, reading, expressive vocabulary, and Mini-Mental State Examination T scores of those participants whose data were included in analyses were not significantly different between the CI and NH groups, and mean scores are shown in Table 2.

General Procedures

All study procedures took place at the Eye and Ear Institute of The Ohio State University Wexner Medical Center. See Supplemental Digital Content (http://links.lww.com/MAO/A368) for details of equipment and software used as well as reliability assessments. Approval was obtained from the Institutional Review Board of The Ohio State University, with informed written consent obtained from all participants. All stimuli were presented in a sound proof booth or acoustically insulated testing room at 68 dB SPL. Participants were tested during a single 2-hour session.

Task-specific Procedures

Word Recognition

The CID-22 (Central Institute for the Deaf) word lists were used for the word recognition task (22), presented in an auditory-only fashion by loudspeaker at 0-degree azimuth. Percent correct whole word recognition scores were computed.

Phonemic Awareness

Three tasks were used to assess phonemic awareness: Initial Consonant Choice (ICC), Final Consonant Choice (FCC), and Backwards Words (BW). Importantly, these tasks were administered using an audiovisual format, in which the participant saw a talker's face on a computer monitor and heard the talker over the speaker. This was done to maximize participants' ability to recognize the stimuli. By maximizing stimulus recognition, scores on these phonemic awareness tasks would provide a more explicit assessment of participants' phonemic sensitivity (i.e., their long-term phonemic representations) than simply auditory phoneme recognition. Each task included 48 items, and these tasks have been used extensively in this laboratory and are known to have internal consistency (23–25).

These specific tasks were selected to vary in the phonemic structure they examined as well as in the level of metalinguistic processing required to complete the tasks. Metalinguistic processing refers to the ability to manipulate the linguistic structure itself, and it is known that this ability develops as a result of language experience (26). Having variability in tasks that assessed both sensitivity to phonemic structure as well as metalinguistic processing diminished the possibility of missing a difference in abilities between NH and CI groups, if a difference should exist.

Practice with feedback was provided before testing for each task. During testing, the task was discontinued when a participant responded incorrectly to six consecutive items. All remaining trials during that test were scored as incorrect. If the participant was unable to repeat a target word correctly after three attempts, that item was skipped and was excluded from analyses (counted as neither correct nor incorrect). The percentages of correct answers were used as the measures of phonemic awareness during analyses.

Initial Consonant Choice (ICC)

In the ICC task, participants were presented audiovisually with a target word, which they were required to repeat correctly. They were then given three word choices, and they had to select which of the three words started with the same sound.

Final Consonant Choice (FCC)

This task was identical to the ICC task, except that after repeating the target word, participants were asked to select which of three word choices ended with the same sound as the target.

Backwards Words (BW)

In this task, participants were presented with a target word and had to repeat it correctly. Then they needed to reverse the

TABLE 1. *Cochlear implant participant demographics*

Participant	Sex	Age (yr)	Implantation Age (yr)	SES	Side of Implant	Hearing Aid	Etiology of Hearing Loss	Residual Better-Ear PTA (dB HL)
1	F	62	54	24	B	N	Genetic	105
2	F	64	62	35	R	Y	Genetic, progressive as adult	75
3	M	64	61	18	L	N	Noise, Ménière’s	80
4	F	64	58	15	R	Y	Genetic, progressive as adult	105
5	F	52	47	12	L	Y	Progressive as adult, sudden	105
6	M	67	65	24	R	N	Genetic, progressive as adult	84
7	M	56	52	30	B	N	Rubella, progressive	105
8	F	54	48	16	R	Y	Genetic, progressive	105
9	M	77	67	49	L	N	Genetic, progressive	93
10	M	77	76	48	R	Y	Progressive as adult, noise, sudden	71
11	M	88	83	30	R	Y	Progressive as adult	88
12	F	66	56	12	B	N	Otosclerosis, progressive as adult	105
13	M	52	50	30	B	N	Progressive as adult	105
14	F	61	59	35	R	N	Progressive as adult	105
15	F	75	63	9	R	N	Genetic, progressive as adult	95
16	F	73	67	36	L	N	Genetic, autoimmune	105
17	M	76	74	25	L	N	Ear infections	105
18	M	80	58	30	L	Y	Ménière’s	69
19	F	80	78	12	R	Y	Progressive as adult	65
20	F	79	73	30	R	N	Progressive as adult	86
21	F	58	53	35	B	N	Progressive as adult	105
22	M	57	56	30	R	Y	Autoimmune, sudden	76
23	M	53	50	12	B	N	Noise, progressive as adult	98
24	F	59	58	16	R	N	Sudden hearing loss	80
25	M	80	79	36	R	Y	Progressive as adult	66
26	F	66	62	16	L	Y	Progressive as child and adult	84
27	M	68	67	9	L	Y	Progressive as adult	73
28	M	59	54	35	L	Y	Ménière’s, noise	81

PTA indicates unaided four-tone pure-tone average at 0.5, 1, 2, and 4 kHz; SES, socioeconomic status.

order of phonemes in the word to derive a new word. All of the words and backwards-words were real English words. This task involved more phonological processing than the first two tasks, so it required greater metalinguistic awareness.

Word Reading Ability

The Wide Range Achievement Test 4 is a standardized measure of reading skills (27). The participant was asked to read the words presented on a single page. Participants were scored for words correctly read aloud. Standard scores were computed.

Expressive Vocabulary

The Expressive One-Word Picture Vocabulary Test, 4th edition was used (28). This is a standardized test of expressive vocabulary. The participant viewed items on a test easel, and for each item, the tester asked, ‘‘What is this?’’ or ‘‘What is he/she

TABLE 2. *Means and standard deviations (SDs) of demographics, as well as language and cognitive test scores, for normal-hearing (NH) and cochlear implant (CI) groups*

	Groups					
	NH (n = 19)		CI (n = 28)			
Demographics	Mean	(SD)	Mean	(SD)	*t*	*p*
Age (yr)	63.7	(8.1)	66.7	(10.2)	1.07	0.29
SES (score)	32.8	(18.7)	25.3	(11.3)	1.71	0.09
Test scores						
Reading (standard score)	104.1	(11.8)	99.6	(10.7)	1.30	0.20
Expressive vocabulary (standard score)	102.9	(19.6)	96.0	(15.3)	1.30	0.20
Cognitive MMSE (T score)	51.1	(8.2)	47.3	(8.5)	1.54	0.13

The *t* value and *p* value columns show results of *t* test, comparing means between NH and CI groups. Degrees of freedom for all *t* tests were 45. MMSE indicates Mini-Mental State Examination; SES, socioeconomic status.

doing?'' depending on the picture. The participant was asked to give a single word response corresponding to what the picture represented, and responses were scored according to the test protocol. Standard scores were computed.

Analyses

Examination of Group Differences for Test Scores

A series of independent-samples *t* tests was performed to identify differences in mean test scores for word recognition and scores for phonemic awareness tasks between the CI and NH groups.

Evaluation of Phonemic Awareness Scores as Predictors of Variance in Word Recognition

A series of separate linear regression analyses was performed to examine phonemic awareness scores as predictors of the dependent measure of word recognition.

Evaluation of Characteristics of Hearing Loss as Predictors of Variance in Phonemic Sensitivity

A multiple stepwise linear regression analysis was performed to examine factors related to participants' hearing loss as predictors of phonemic awareness scores.

RESULTS

Data for 28 participants with CIs and 19 NH controls were included in analyses. Group mean word recognition and phonemic awareness scores for the CI and NH participants are shown in Table 3. Normal distributions were not observed for word recognition and phonemic awareness scores; therefore, arcsine transformations were computed for these variables. Reported analyses were performed on the arcsine transformations, but raw percent correct data are shown in Table 3. For the CI group, one-way analyses of variance (ANOVA) were performed to observe if side of implant (right, left, or bilateral) influenced any scores for word recognition or phonemic awareness scores. No differences were found for any measures based on whether participants used a right, left, or bilateral CIs. Additionally, using independent-samples *t* tests, no differences were found on those same measures between those who wore only CIs versus a CI plus hearing aid. Therefore, data were combined across all CI participants in subsequent analyses. Data from two participants were lost on a phonemic awareness task because of software error as follows: ICC for one NH participant and FCC for one CI participant.

Phonemic Sensitivity for CI and NH Participants

The first question of interest was whether CI users showed poorer phonemic awareness scores than NH listeners during the three tasks: ICC, FCC, and BW. Table 3 shows means and standard deviations for the NH and CI groups for phonemic awareness scores. Inspection of mean scores and independent-samples *t* tests show that these scores for the ICC and FCC tasks were significantly poorer for the group of participants with CIs than those with NH. Thus, CI users showed significantly poorer sensitivity to phonemic structure (ICC and FCC) than the NH listeners. Mean scores on the BW task were lower for the CI group than the NH group, but this difference was not statistically significant. This trend toward poorer performance by the CI users on the BW task is likely explained by poorer phonemic sensitivity, rather than poorer abilities to manipulate phonemic structure.

Predictors of Word Recognition

Before examining whether phonemic sensitivity would predict word recognition for the CI users, it was important to examine demographic and audiologic factors, along with the general language metrics—word reading and expressive vocabulary—as predictors of variance in word recognition. If these factors predicted significant amounts of variance in word recognition, they would need to be accounted for as covariates when examining phonemic awareness scores as predictors. Separate linear regression analyses were performed with word recognition as the dependent measure and the following variables as predictors: age, age at onset of hearing loss, duration of hearing loss (computed as age minus age at onset of hearing loss), age at implantation, duration of CI use, better-ear residual PTA, SES, word reading, and expressive vocabulary. None of these variables predicted significant variability in word recognition.

TABLE 3. *Means and standard deviations (SDs) of percent correct word recognition and phonemic awareness scores for normal-hearing (NH) and cochlear implant (CI) groups*

	Groups								
	NH			CI					
Test Scores	n	Mean	(SD)	n	Mean	(SD)	df	*t*	*p*
Word recognition (% correct)	19	97.1	(2.5)	28	66.5	(18.7)	45	8.76	<0.001
ICC (% correct)	18	97.9	(2.7)	28	84.9	(19.7)	44	3.98	<0.001
FCC (% correct)	19	86.8	(7.4)	27	64.4	(26.2)	44	3.60	0.001
BW (% correct)	19	66.6	(21.1)	28	58.0	(25.0)	45	1.16	0.253

The *t* value and *p* value columns show results of *t* test, comparing means between NH and CI groups for arcsine transformation values of scores listed.

BW indicates Backwards Words task; FCC, Final Consonant Choice task; ICC, Initial Consonant Choice task.

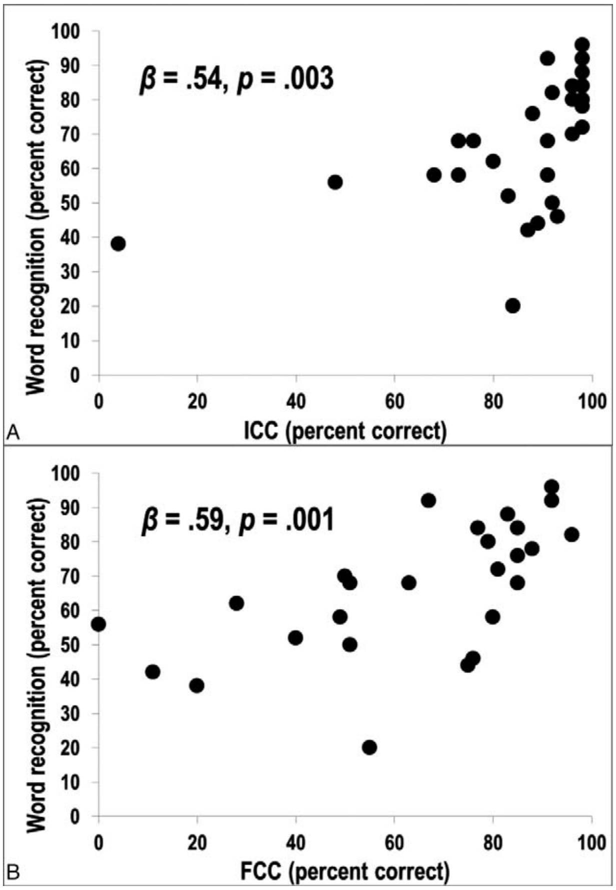

FIG. 1. Scatter plot of word recognition scores for CI users versus scores on (*A*) Initial Consonant Choice (ICC) task and (*B*) Final Consonant Choice (FCC) task.

Phonemic Sensitivity and Word Recognition

The next question of interest, which addressed the second main hypothesis of the study, concerned whether CI users' phonemic awareness scores would predict word recognition. Linear regression analyses were performed separately using ICC, FCC, and BW as predictors, with word recognition as the dependent measure. Both ICC and FCC scores predicted significant variance in word recognition (Fig. 1), whereas scores for BW did not ($\beta = 0.23, p = 0.238$). These results suggest that CI users' sensitivity to phonemic structure plays a role in accurate word recognition, whereas their ability to manipulate phonemes is not as closely related to spoken word recognition.

Predictors of Phonemic Awareness

The next analysis, addressing the third hypothesis, was performed to examine if factors related to the participants' hearing history would serve as significant predictors of phonemic sensitivity. It was thought that a patient's severity and duration of hearing loss might predict phonemic awareness, based on findings from the Lyxell et al. study (18): there it was found that phonemic sensitivity was poorer for patients with severe hearing loss, was worse with longer duration of deafness, and was not automatically restored by cochlear implantation. For the current group of CI users, a multiple stepwise linear regression analysis was performed with FCC score as the dependent measure, because this task provided the strongest predictor of word recognition. Predictor variables were current age, age when hearing loss began, duration of deafness, age at first CI, duration of CI use, and better-ear residual PTA as predictor variables. Only current age was a significant independent predictor of FCC score, $\beta = -0.66$, $p < 0.001$. Thus, phonemic awareness scores showed worse degradation for older individuals with CIs. Moreover, those individuals with longer duration of CI use did not show better phonemic awareness scores, suggesting that extended experience with a CI did not necessarily restore phonemic sensitivity.

It was possible that advancing age alone could predict the decline in phonemic sensitivity observed for older adults with CIs, so a similar analysis was performed for the NH group with FCC score as the dependent measure and current age as the predictor. No significant relationship was found, suggesting that the degradation in phonemic sensitivity for the CI group was related to the hearing loss itself, not simply the aging process.

Although aging alone did not seem to explain the degradation in phonemic sensitivity for the CI users relative to the NH listeners, it was possible that this group of postlingually deafened adults with CIs never developed mature phonemic representations before losing their hearing. If this were the case, it would be difficult to attribute their poorer phonemic awareness explicitly to their experience of hearing loss. Although there was no way to directly assess their previous phonemic sensitivity, a measure that could serve as a reasonable indication of previous phonological development would be the measure of expressive vocabulary, because phonemic sensitivity would have been necessary for these individuals to develop mature vocabularies. Mean scores on the expressive vocabulary task were not significantly different between the CI group and the NH group (see Table 2). This finding suggests that the CI users had developed sufficient phonemic sensitivity before losing their hearing to build relatively normal lexicons. Thus, the degradation in phonemic awareness abilities exhibited by the CI users could reasonably be attributed to their experience of hearing loss.

DISCUSSION

The experiment presented here was conducted to examine the phonemic representations of postlingually deafened adults using CIs and a group of NH peers, and to evaluate if sensitivity to phonemic structure could predict variability for CI users in word recognition performance. Importantly, the tasks used were presented in an audiovisual format to maximize recognition of words and explicitly tap into sensitivity to phonemic representations. The first hypothesis was that CI users would show degradation of phonemic representations, especially on tasks requiring explicit access to phonemic structure. This hypothesis was supported, as ICC and FCC scores were significantly poorer for the CI group as compared with the NH group.

The second hypothesis tested was that phonemic sensitivity for CI users would predict a significant amount of variance in word recognition abilities. This hypothesis was supported for the tasks that required explicit access to phonemic structure, especially the FCC task. However, the ability to process or manipulate phonemes within words, as in the BW task, did not predict variance in word recognition.

The third hypothesis tested was that factors related to the CI participants' hearing loss would predict phonemic sensitivity. It was found that older current age predicted poorer phonemic sensitivity for CI users. Duration of deafness did not predict the extent of degradation of phonemic awareness, in contrast to the findings of Lyxell et al. (18). However, duration of deafness in this study was based on participants' subjective recall of when they first noticed hearing loss, which was likely not a very accurate assessment. Importantly, a longer duration of use of a CI did not predict improvement in phonemic sensitivity for CI users. Thus, a longer duration of listening through a CI does not automatically restore awareness of phonemic structure.

The results of this study suggest that methods to improve phonemic sensitivity may assist in improving speech recognition outcomes for adult patients with CIs. Although several training methods have been used with some success to improve phoneme recognition through repeated stimulus presentation and feedback (29–31), specific training to enhance phonemic representations has only been used in a small number of children with hearing loss (32–34). Although CIs may deliver degraded signals that only poorly support the recovery of phonemic structure, training may facilitate the recovery of phonemic sensitivity by enhancing patients' attention to that structure in their spoken language.

CONCLUSION

Variability in outcomes for patients who undergo cochlear implantation is frustrating for patients and clinicians alike. The results of this study suggest that sensitivity to phonemic structure is significantly degraded for postlingually deafened adults with CIs, and longer duration of CI use does not automatically restore this sensitivity. Moreover, having sensitivity to phonemic structure seems to play an important role in spoken word recognition, at least under quiet conditions. These findings emphasize the possibility of improving clinical outcomes by training programs that restore or enhance sensitivity to the phonemic structure of spoken language.

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