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Relations between self-reported executive functioning and speech perception skills in adult cochlear implant users

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Abstract

Hypothesis—As a result of their hearing loss, adults with cochlear implants (CIs) would self-report poorer executive functioning (EF) skills than normal-hearing (NH) peers, and these EF skills would be associated with performance on speech recognition tasks.

Background—EF refers to a group of high order neurocognitive skills responsible for behavioral and emotional regulation during goal-directed activity, and EF has been found to be poorer in children with CIs than their NH age-matched peers. Moreover, there is increasing evidence that neurocognitive skills, including some EF skills, contribute to the ability to recognize speech through a CI.

Methods—Thirty postlingually deafened adults with CIs and 42 age-matched NH adults were enrolled. Participants and their spouses or significant others (informants) completed well-validated self-reports or informant-reports of EF, the Behavior Rating Inventory of Executive Function – Adult (BRIEF-A). CI users' speech recognition skills were assessed in quiet using several measures of sentence recognition. NH peers were tested for recognition of noise-vocoded versions of the same speech stimuli.

Results—CI users self-reported difficulty on EF tasks of shifting and task monitoring. In CI users, measures of speech recognition correlated with several self-reported EF skills.

Conclusion—The present findings provide further evidence that neurocognitive factors, including specific EF skills, may decline in association with hearing loss, and that some of these EF skills contribute to speech processing under degraded listening conditions.

Keywords

Cochlear implants; Cognition; Executive functioning; Hearing loss

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Introduction

Executive functioning (EF) refers to a group of high order neurocognitive skills responsible for behavioral and emotional regulation during goal-directed activity (1,2). These skills are necessary to identify, process, plan, and complete everyday tasks. Core EF includes abilities such as sustained attention to a task, working memory (WM), inhibition of competing actions or thoughts, and the ability to shift attention appropriately (3). Other higher level neurocognitive skills—including processing of information, planning a course of action, organization of materials, and problem solving—are dependent on these core EF skills (1,3).

During early childhood, EF pathways in the prefrontal cortex begin to develop (4), experience a period of rapid growth during the preschool years, mature in adolescence, and decline in older age (5). Because auditory deprivation has been associated with the disorganization of developing cortical pathways in children (6), it has been proposed that hearing ability is crucial to the development of EF in childhood (7). Studies measuring EF using performance and questionnaire-based assessments in children with hearing loss provide support for this premise: prelingually deafened children with severe-to-profound hearing loss who use cochlear implants (CIs), devices that permit access to sound but provide highly degraded sensory input, have been shown to have significant deficits in EF skills compared with their normal hearing (NH) age-matched peers (2,8). Even after long-term device use, most children with CIs do not demonstrate EF skills comparable to NH children (9).

At the other end of the age spectrum, hearing loss in older adults has been associated with cognitive declines (10). In general, based on studies of adults with mild-to-moderate degrees of hearing loss, there appears to be a small but significant association between degree of hearing loss and severity of cognitive declines, as well as a greater incidence of clinically significant cognitive impairment in adults with impaired hearing (11–13). However, these studies typically examine neurocognitive functions using relatively broad screening measures of general cognition (e.g., the Mini Mental State Examination or the Modified Mini Mental State Examination) or assess only a small number of neurocognitive functions that could be considered tests of EF (e.g., the Digit Symbol Substitution Test of psychomotor speed) (12). Moreover, few studies have specifically examined EF in adults with severe-to-profound postlingual hearing loss who use CIs. Unlike patients with mild-to-moderate hearing loss, postlingually deafened adult CI users represent a population with more severe hearing loss, and who typically experience a relatively long duration of auditory deprivation. Examining this clinical population of postlingually deafened adults with CIs will allow us to examine the extent to which prolonged auditory deprivation is associated with significant declines in EF, and the degree to which demographic and audiologic patient measures are associated with these declines.

To our knowledge, there have been only a few prior attempts to compare the EF of postlingual adult CI users and adults with NH, and these studies have primarily obtained performance measures of WM (14,15). Moberly, Harris, Boyce, and Nittrouer (16) recently compared basic WM skills for auditory stimuli in adult CI users and age-matched NH peers using tasks of digit span and serial recall of monosyllabic words. Accuracy scores and response times were similar between groups for digit span, but accuracy scores on serial recall of words were slightly poorer for CI users than NH controls. In another recent study, neurocognitive functions were assessed using non-auditory tasks in adult CI users and NH peers, using visually presented tasks assessing global intellectual abilities, WM, inhibition-concentration, and controlled fluency (17). Neurocognitive functions were similar between groups for all tasks except WM, on which CI users scored significantly more poorly. These findings provide some support for the premise that adult CI users may have poorer EF than their NH counterparts, particularly on tasks requiring WM.

An issue that limits the clinical relevance of these previous studies of EF in adult CI users is the artificial nature of the laboratory behavioral tasks used to investigate and quantify these skills (9,12,18). These methods typically consist of tasks that participants would not perform in daily life. As a result, laboratory testing is unlikely to reveal participants' abilities pertaining to daily goal-oriented tasks. As an alternative, self-report questionnaires may provide additional methods for quantifying EF skills. Questionnaire data is complementary to laboratory performance-based data and provides information about real-world behavior within the participants' daily environment. Questionnaires are diagnostically valuable, clinically useful for tracking functioning and progress across time, simple to administer, and easy to interpret (19). Additionally, informant-report questionnaires of EF, completed by a family member or close friend, can serve as an additional source of information regarding patients' EF skills in daily life, and can be completed even in a setting in which self-report questionnaires cannot be completed (e.g., cognitive dysfunction, illiteracy). To our knowledge, neither self-report nor informant-report questionnaires of EF have been studied in adult postlingually deafened CI users.

Finally, there is growing evidence that EF skills underlie speech recognition abilities in patients with hearing loss, including postlingual adults with CIs. For example, in the Moberly et al. study, response times during a laboratory measure of inhibition-concentration correlated significantly with scores on a task of sentence recognition in noise for adult CI users (17). Other studies have demonstrated associations of scores on WM tasks with speech recognition in adults with milder degrees of hearing loss (20,21). An additional aim of the current study was to investigate the relations between scores on self-report measures of EF and several assessments of auditory-only and audiovisual speech recognition. Identifying significant associations would suggest that a self-report measure of EF could potentially serve as a clinically useful preoperative outcome predictor, or could help to explain outcome variability in adult CI users, including in those who experience unexpected poor speech recognition outcomes.

In summary, this study investigated four primary questions concerning EF in adult CI users. First, do postlingually deafened CI users self-report deficits in everyday EF skills, compared with their age-matched NH peers? Second, based on previous reports suggesting that cognitive decline appears to occur commensurate with degree of hearing loss and/or age (12,22), to what extent are self-reported everyday EF skills associated with traditional audiological and demographic measures in CI users? Third, to examine CI users' self-awareness of potential deficits in everyday EF, we examined whether CI users' self-reported EF skills were corroborated by informant-reports of patient EF. Lastly, we examined whether self-reported EF skills are associated with the recognition of words in sentences presented under auditory-only and synchronous audiovisual stimulation. To address these questions, we administered self- and informant-report versions of the Behavior Rating Inventory of Executive Function – Adult Version (BRIEF–A), a well-validated questionnaire assessing EF skills in everyday life, along with speech recognition tests that varied in complexity, cognitive demand, and need for audiovisual integration (23). Developing a better understanding of EF in adult CI users should provide insight into the role of auditory input in the maintenance of EF skills in adults or, conversely, the detrimental effects of a lack of auditory input for clinical populations with hearing loss, as well as the relation of EF to speech recognition outcomes in this clinical population of CI users.

Methods

Participants

All CI participants experienced postlingual hearing loss during childhood or adulthood and were implanted after age 18 years, and all had greater than 18 months of CI experience. CI users demonstrated CI-aided thresholds better than 35 dB HL at 0.25, 0.5, 1, and 2 kHz, as measured by clinical audiologists within 12 months prior to enrollment in the current study. Thirty postlingually deafened adults with CIs were enrolled, along with 42 adults with age-normal hearing. These participants were a subset of participants who presented for a larger study examining speech recognition abilities. Demographic and audiological data are presented in Table 1. All CI users had Cochlear (Sydney, Australia) devices, and used an Advanced Combined Encoder speech processing strategy. Thirteen (43.3%) CI participants used a right CI, 8 (26.7%) used a left device, and 9 (30%) used bilateral devices. Twelve (40%) participants wore a contralateral hearing aid. During testing, participants used their devices in everyday mode, including use of any contralateral aids, and kept the same settings throughout testing. Unaided audiometric assessment was performed prior to speech recognition testing to assess residual hearing in each ear.

CI users were matched as a group on chronological age with NH controls. NH control participants were recruited from patients with non-communication complaints in the Department of Otolaryngology, along with use of a national research recruitment database, ResearchMatch. Participants in the NH control sample were evaluated for age-NH immediately prior to speech recognition testing, with NH defined as four-tone (0.5, 1, 2, and 4 kHz) pure-tone average (PTA) of better than 25 dB HL in the better ear. This criterion was relaxed to a PTA of 30 dB HL for individuals over 60 years old, but only 4 had a PTA worse than 25 dB HL.

American English was the first language for all CI and NH participants. All had graduated from high school, except for one CI user who earned his General Education Diploma (GED). Our measure of socioeconomic status (SES) was quantified using a metric defined by Nittrouer and Burton (24), indexing occupational and educational levels, with two scales between 1 and 8, with scores of 8 as the highest level achievable. The two scores were multiplied, resulting in SES scores between 1 and 64.

All participants underwent screenings for cognitive, reading, and vision abilities. The Mini-Mental State Examination (MMSE), a well–validated screening tool for cognition, was used to rule out evidence of cognitive impairment (25). Raw scores of less than 26 are concerning for cognitive impairment; however, all participants had scores ≥ 26. A computerized Raven's Progressive Matrices was used to assess global nonverbal intelligence (26). The Raven's presents geometric designs in a matrix where each design contains a missing piece, and participants must complete the pattern by selecting a response box. An abbreviated version of the Raven's test was conducted over 10 minutes. Raw scores were used as the measure of nonverbal intelligence. The Word Reading subtest of the Wide Range Achievement Test, 4^{th} edition (WRAT), was used to assess basic word-reading ability (27). All participants demonstrated a standard score on the WRAT ≥ 80. A final screening test of near-vision was performed; all participants had corrected near-vision of better than or equal to 20/40.

Procedure

All procedures were approved by the Institutional Review Board of The Ohio State University, and written informed consent was obtained. For CI users, sound detection with device use was confirmed prior to testing. All performance–based tasks were performed in a soundproof booth or a sound-treated testing room. For the MMSE and WRAT screening tasks, as well as the sentence recognition tasks, participant responses were video– and audio–recorded for later scoring.

Questionnaire–Based Measures: Executive Functioning

Participants completed a self-report version of the BRIEF-A. A subset of the CI users (27, 93%) and NH controls (35, 83%) also had an "informant" (most commonly a spouse or significant other) evaluate their EF skills by completing the informant-report version of the BRIEF–A scale. The BRIEF–A scale is applicable to adults 18 years and older and is completed in approximately 10 minutes.

The BRIEF–A is a 75-item questionnaire of behavioral problems during the past month and includes nine domains of EF: Inhibit, Shift, Emotional Control, Working Memory, Plan/Organize, Initiate, Task Monitor, Organization of Materials, and Self-Monitor. Each EF item is rated on a 3-point severity scale (never, sometimes, often). Subscales are aggregated to create two broad indices, Behavioral Regulation and Metacognition, along with a Global Executive Composite score. The Behavioral Regulation Index is a composite of the Inhibit, Shift, Emotional Control, and Self-Monitor subscales, while the Metacognition Index is a composite of the remaining five subscales, Working Memory, Plan/Organize, Initiate, Task Monitor, and Organization of Materials. The Global Executive Composite score is the composite of all nine subscales. Raw scores on the BRIEF–A were converted to *T* scores and compared against our sample of NH age-matched control participants, as well as with a nationally representative sample of 1,136 adults aged 18–90. Higher scores on the BRIEF-A indicate greater problems with everyday EF skills.

Performanced–Based Measures: Speech Recognition

Three prerecorded sentence lists were used to examine the recognition of words in sentences: 1) The City University of New York (CUNY) consists of 3 sets of 12 topic–

related sentences presented in an audiovisual (AV), auditory-only (A), or visual-only (V) format, with order of presentation (AV, A, V) counterbalanced across participants (28). 2) IEEE consists of 28 relatively complex sentences with a moderate degree of sentential context (29). 3) The Perceptually Robust English Sentence Test Open-set (PRESTO), consists of 30 high–variability sentences and incorporates variation in talkers, dialects, and number of words in a sentence (30). CI users were tested in quiet, while NH listeners were tested using 8-channel noise-vocoding to provide spectral degradation similar to the speech processing performed by a CI. Vocoding was conducted using vocoder software in MATLAB, using a Greenwood function with speech-modulated noise. Percent correct words for each sentence type served as our measure of interest.

Results

CI and NH samples did not differ on age ($t(70) = -0.66$, $p = .51$), Raven's nonverbal IQ scores ($t(70) = -1.58$, $p = .12$), WRAT reading and MMSE cognitive screening tests ($t(70) = -1.48$, $p = .14$; $t(70) = -1.94$, $p = .06$, respectively), or gender ($p = .06$ by Fisher's Exact Test; Table 1). CI participants, however, had significantly lower SES than their NH peers ($t(68) = -3.35$, $p < .01$).

Self– and informant–reported EF scores for CI users and NH controls are shown in Table 2. BRIEF-A scores were not significantly different when comparing bilateral CI users, bimodal CI users (CI plus contralateral hearing aid), and unilateral CI-only users. Compared against the BRIEF–A national norms, CI users self–reported significantly greater problems in shifting and task monitoring ($t(29) = 2.39$, $p = .02$, $t(29) = 2.63$, $p = .01$, respectively), while NH peers self–reported significantly greater problems with working memory ($t(41) = 2.78$, $p < .01$). However, CI users and NH peers self–reported comparable EF on all the subscales and indices of the BRIEF–A. When we compared self vs. informant BRIEF–A scores, results revealed that CI users self–reported significantly greater problems in 5 subscales (shifting, emotional control, working memory, and task monitoring) and 2 indices (Behavioral Recognition and Global Executive Composite), as compared with informant reports. In the NH sample, results revealed convergence between the self and informant reported EF skills.

EF Associations with Demographic and Hearing History Variables

Correlations of BRIEF-A scores with traditional demographic and hearing history variables for CI users are shown in Table 3. In terms of demographic variables, younger chronological age was associated with better self-reported BRIEF–A emotional control, self monitoring, organization of materials, and Behavioral Recognition Index. Higher nonverbal IQ was associated with better self-reported BRIEF–A emotional control, self monitoring, and organization of materials. Higher SES was associated with better emotional control, self monitoring, Behavioral Recognition Index, and Global Executive Composite scores. In terms of hearing history variables, better PTAs were associated with better organization of materials in CI users. Shorter duration of deafness was associated with better self–reported emotional control and Behavioral Recognition Index. Additionally, longer duration of CI use was associated with better self–reported shifting and initiation.

EF Associations with Speech Recognition Skills

Correlations of BRIEF-A scores with speech recognition are shown in Table 4. To summarize, in CI users, better performance in the CUNY AV and CUNY A sentence recognition tasks was associated with better self–reported BRIEF-A scores of emotional control, self monitoring, planning/organizing, Behavioral Recognition Index, and Global Executive Composite scores. Performance in CUNY V was only associated with self monitoring in the CI users. In contrast, performance in the CUNY A and CUNY AV sentence recognition task were not associated with any of the BRIEF–A subscales or indices in the NH sample, but better performance in CUNY V was associated with better self–reported shifting, initiation, planning/organizing, organization of materials, Metacognition Index, and Global Executive Composite scores on the BRIEF–A.

Turning to the IEEE and PRESTO sentences, better performance on the IEEE sentence recognition task was associated with better self–reported emotional control, self monitoring, and Behavioral Recognition Index scores in CI users. In NH controls, better performance on IEEE sentences was associated with better task monitoring. However, performance on PRESTO sentences was not associated with self–reported EF in CI users or NH controls. Similar analyses were performed among all speech recognition scores and informant-report BRIEF-A scores, but no significant correlations were found.

Discussion

This study examined the EF skills of postlingual adult CI users, along with their NH age-matched peers. Four questions were asked: First, do CI users self-report deficits in everyday EF skills, compared with their NH peers? Second, to what extent were self–reported EF skills related to traditional audiological and demographic measures in CI users? Third, how do CI users' self–reported EF skills compare with informant reports of patient EF? And finally, how do self-report EF scores relate to speech recognition measures?

Regarding the first question, CI users and their NH peers were found to self-report comparable everyday EF skills. However, when compared against the normative sample of adults, CI users self–reported significantly higher scores (greater problems) on the BRIEF–A shifting and task monitoring subscales. This is consistent with findings of worse EF in pediatric CI users, although EF deficits in that population are more global across EF domains (7). It is unclear specifically why the shifting and task monitoring subscales were the only ones to reveal deficits by self-report in adult CI users, and additional research will be needed to explore these findings in more detail. However, the general finding of poorer EF on some subscales in CI users using self-report questionnaires suggests that these deficits in EF are relevant to the everyday goal-directed behaviors in this patient population. Moreover, this finding suggests that highly refined auditory input is not only important in the development of EF skills during childhood, but also may be important in the maintenance of some particular EF skills – namely, shifting and task monitoring – during adulthood. In contrast, NH peers in this study self–reported significantly higher scores (greater problems) on the BRIEF–A working memory subscale when compared with national norms. It is unclear why this finding occurred, but it suggests potential sampling differences between our NH control sample and the national normative sample.

The second question addressed in this study pertained to the relationship between self-report scores of EF and traditional audiological and demographic patient factors. In general, younger age, higher nonverbal IQ, higher SES, and better PTAs were associated with better self–reported EF skills in CI users, at least in some domains. We found data to support our hypothesis that longer durations of auditory deprivation and shorter duration of CI use were associated with poorer self–reported EF skills in CI users, but again only across a few domains. A limitation that should be considered is that our assessment of duration of hearing loss was acquired from patient self–report and was thus relatively insensitive. Moreover, we could not determine the degree of hearing impairment experienced by patients over their period of auditory deprivation, except that they all experienced bilateral severe-to-profound hearing loss by the time of implantation.

The third question asked in this study was whether self-report measures of everyday EF would be similar to informant-report measures of functioning. In general, self-report and informant-report scores were highly correlated for NH controls, but CI users self-reported poorer EF compared with the reports from their informants. Disparate findings between groups for informant- vs self-reports of EF have previously been found in children with hearing loss, and it has been suggested that this indicates that individuals with hearing loss may be burdened both with poorer language skills (or EF) and poorer awareness of those deficits. In this sample of adults with CIs, the opposite may be true: our adult CI users rated themselves more poorly on EF skills than informants. Regardless of the cause, this finding should be taken into consideration if informant-report BRIEF–A assessments were to be used clinically in this population.

The final question asked pertained to associations between self–reported EF skills and speech recognition skills. In general, several EF skills related significantly to scores of speech recognition for CI users in the auditory-only (CUNY and IEEE) and audiovisual (CUNY) condition. It is particularly noteworthy that self-report measures of everyday EF related to audiovisual sentence recognition, because this is the most typical communication scenario in which CI users find themselves during face-to-face interactions (31). Moreover, the strongest correlations between EF and speech recognition also tended to be for stimuli presented under audiovisual speech stimulation, which may suggest that audiovisual speech integration is more cognitively demanding and/or requires a higher degree of cognitive processing.

Findings from this study support the overall premise that prolonged auditory deprivation is associated with cognitive declines, at least for some EF skills, in agreement with studies of adults with lesser degrees of hearing loss (32). Several theories have been proposed to explain this relationship: 1) The “information-degradation” theory suggests that declines in neurocognitive abilities manifest as a consequence of the shifting of cognitive resources to compensate for impaired auditory input (33,34). 2) The “sensory-deprivation” theory suggests that poor auditory input directly leads to permanent cognitive impairments (12,35). 3) The “common-cause” theory suggests that a common mechanism underlies both auditory deprivation and cognitive declines (36,37). 4) The “social isolation” theory, not mutually exclusive with the other three theories, suggests that hearing loss leads to social withdrawal and subsequent cognitive declines (38,39). Although this study was not designed directly to test these hypotheses, findings provide cautious evidence against the “common-cause” theory, because global deficits were not identified across all domains of EF in CI users; instead, our findings indicate that CI users self-report deficits in only two of the domains examined.

There are a number of limitations to the present study. First, a relatively small sample size was included, which may have prevented identification of small differences in everyday EF skills between CI and NH groups. Second, the adults with hearing loss in this study were experienced CI users, meaning they had received intervention for their hearing loss. Although these patients had some degree of restored auditory input through their devices, raising the concern that the experience of CI use may have affected EF abilities, these patients still experienced a relative deficit in auditory input as a result of the degraded nature of the CI signal. Nonetheless, a future prospective study of self-report EF in adult CI candidates with bilateral severe-to-profound hearing loss, along with postoperative measures of EF after implantation and a period of CI use, would allow the examination of the effects of hearing loss, and the subsequent effects of CI use, on EF abilities.

Conclusions

Adult postlingual CI users demonstrated deficits in attention shifting and task monitoring, relative to NH peers, and self-report EF scores correlated with some measures of speech recognition. Findings provide additional support for the premise that hearing loss is associated with some specific cognitive declines, particularly some everyday goal-directed EF skills. Additional studies will be required to directly assess the effects of cochlear implantation on EF skills in adults with postlingual hearing loss.

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Table 1

Demographic and hearing history of cochlear implant (CI) users and normal-hearing (NH) controls

	CI User		**NH**	
	***N* = 30**		***N* = 42**	
	Mean (*SD*)	**Range**	**Mean (*SD*)**	**Range**
Age at testing	66.47 (8.85)	50.00 – 81.00	67.67 *(6.62)*	50.00 – 81.00
PTA	100.17 *(15.73)*	70.00 – 120.00	16.43 *(7.22)*	6.25 – 30.00
Nonverbal IQ	10.90 *(4.25)*	5.00 – 20.00	12.86 *(5.73)*	5.00 – 26.00
MMSE	28.77 *(1.25)*	26.00 – 30.00	29.26 *(0.91)*	26.00 – 30.00
WRAT	98.30 *(12.41)*	78.00 – 122.00	102.17 *(9.79)*	82.00 – 126.00
SES	24.69 *(13.41)*	6.00 – 56.00	36.15 *(14.55)*	9.00 – 64.00
	Count (% of Sample)			
Hearing device				
CI and HA	12 (40.0)			
Bilateral CIs	9 (30.0)			
Unilateral CI alone	9 (30.0)			
Etiology of hearing loss				
Unknown	13 (44.8)			
Hereditary	14 (44.8)			
Ototoxicity	2 (6.9)			
Menieres disease	1 (3.4)			
Gender				
Female	13 (43.3)		28 (66.67)	
Male	17 (56.7)		14 (33.33)	

Note. Unaided pure-tone average (PTA) in the better ear for the frequencies 250, 500, 1000, and 2000 Hz in dB HL. Nonverbal IQ scores are expressed as raw scores from the Raven's Progressive Matrices. The Mini-Mental State Examination (MMSE) assesses cognitive impairments and dementia. The Wide Range Achievement Test (WRAT) assesses word reading ability.

Table 2

Self and informant-reported executive functioning in cochlear implant (CI) users and normal-hearing (NH) controls

BRIEF–A	Self–Report				Informant–Report			
	CI User		NH		CI User		NH	
	N = 30		*N* = 42		*N* = 27		*N* = 35	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Inhibit	49.47	6.54	50.81	8.25	46.81	6.83	48.23	8.24
Shift	**53.93***	9.00	50.83	10.74	45.96	6.20	48.94	10.01
Emotional Control	52.40	9.43	48.86	9.63	48.00	8.66	46.34	10.18
Self Monitor	49.33	8.28	48.05	12.42	49.42	8.54	46.60	9.72
Initiate	50.97	8.80	52.79	12.35	51.11	8.86	50.71	12.07
Working Memory	51.33	8.92	**54.55***	10.61	47.85	5.99	51.49	12.07
Plan/Organize	50.87	10.36	51.36	10.86	48.89	8.80	48.49	10.62
Task Monitor	**54.50***	9.39	52.86	11.87	49.48	7.80	48.97	11.74
Organization of Material	50.83	7.91	51.19	12.45	51.15	9.47	50.97	10.74
Behavioral Recognition Index	51.70	7.77	49.48	10.82	47.77	7.20	47.06	10.40
Metacognition	51.77	8.14	52.74	11.73	49.67	7.40	49.74	10.89
Global Executive Composite	51.80	7.20	52.00	12.74	–	–	–	–

Note. BRIEF–A subscale scores are expressed as T scores ($M = 50$, $SD = 10$). Subscale scores in bold represent scores that are significantly (*$p < .05$ based on one-tailed tests) greater than the normative mean.

Table 3

Correlations between self–reported executive functioning and demographic/hearing history variables in cochlear implant (CI) users

BRIEF–A	Age	Nonverbal IQ	SES	PTA	Duration of Deafness	Duration of CI Use
Inhibit	.05	.11	−.26	.16	.23	−.29
Shift	−.01	−.05	−.31	.07	.04	**−.33***
Emotional Control	**.31***	**−.32***	**−.51****	.06	**.40***	−.11
Self Monitor	**.60****	**−.32***	**−.34***	−.12	.17	.01
Initiate	.18	−.12	.07	−.15	.02	**−.32***
Working Memory	.15	−.12	−.22	−.13	.18	−.08
Plan/Organize	.09	−.28	−.24	−.08	.21	−.23
Task Monitor	−.10	.01	−.27	.23	.14	.05
Organization of Material	**.36***	**.37***	−.21	**.48****	−.20	−.02
Behavioral Recognition Index	**.32***	−.22	**−.52****	.07	**.32***	−.23
Metacognition	−.01	−.05	−.23	.08	.10	−.18
Global Executive Composite	.14	−.15	**−.43***	.08	.23	−.23

Note. $N = 30$ CI users.

** $p < .01$;

* $p < .05$ based on one-tailed tests.

Table 4

Correlations between self–reported executive functioning and speech recognition skills in cochlear implant (CI) users and normal-hearing (NH) controls

BRIEF–A	CUNY AV		CUNY A		CUNY V		IEEE		PRESTO	
	CI	NH	CI	NH	CI	NH	CI	NH	CI	NH
Inhibit	−.24	−.05	−.18	.19	.10	−.15	−.24	.15	.03	.26
Shift	−.22	−.04	−.01	.26	−.16	**−.28***	−.02	.25	.06	.17
Emotional Control	**−.53****	−.15	**−.50****	.13	−.13	−.17	**−.43****	.11	−.29	.08
Self Monitor	**−.35***	−.26	**−.33***	.07	**−.32***	−.26	**−.33***	.08	−.16	−.01
Initiate	−.23	−.05	−.14	.22	−.26	**−.38****	−.05	.15	−.07	.20
Working Memory	−.15	−.07	−.04	.17	−.14	−.14	−.01	.16	.11	.25
Plan/Organize	**−.47****	−.14	**−.37***	.21	−.29	**−.33***	−.24	.19	−.27	.14
Task Monitor	−.06	−.11	−.09	.16	−.15	−.22	.04	**−.28***	.09	.11
Organization of Material	−.14	−.24	.07	.25	.19	**−.33***	.14	.18	.16	.10
Behavioral Recognition Index	**−.48****	−.16	**−.38***	.18	−.16	−.25	**−.37***	.17	−.15	.14
Metacognition	−.30	−.15	−.17	.24	−.18	**−.34***	−.05	.21	−.01	.18
Global Executive Composite	**−.46****	−.14	**−.31***	.25	−.19	**−.32***	−.23	.21	−.09	.16

Note. $N = 30$ CI users, $N = 42$ NH peers.

** $p < .01$;

* $p < .05$ based on one-tailed tests.