ORIGINAL RESEARCH

Effect of Hearing Ability and Mild Behavioural Impairment on MoCA and Memory Index Scores

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Abstract

Background

The life-course model of modifiable risk factors for dementia now recognizes managing hearing loss and addressing social isolation.

Objective

To investigate the contribution and inter-relationship of hearing ability and behaviour change on cognitive ability.

Methods

We present the preliminary findings from a prospective longitudinal study of 35 non-demented participants ages 60–93, recruited from community rehabilitation and acute-care programs of Geriatric Medicine, who underwent baseline hearing, behavioural, and cognitive testing.

Results

After controlling for age and hearing impairment, the left ear Dichotic Digit Test (DDT) score accounted uniquely for 20% of the variance in MoCA Memory Index ($p = .016$ with $\beta = .598$). Mild Behavioural Impairment (MBI) was highly prevalent, with 80% of older adults reporting at least one MBI symptom. People with hearing impairment had greater global MBI burden than people with normal hearing, especially in the domains of apathy and impulse dyscontrol; however, greater severity of hearing impairment was not associated with a higher number of neuropsychiatric symptoms (NPS).

Conclusions

Low left DDT contributed to lower memory index and greater MBI burden is associated with hearing impairment. Our findings demonstrate the value of early non-invasive hearing and behavioural assessments as part of dementia risk assessment in older adults.

Key words: hearing impairment, Mild Behavioural Impairment, cognition, MoCA memory index, age

Introduction

The life-course model of modifiable risk factors for dementia was expanded to include managing hearing loss and addressing social isolation.[1] The model predicts that 35% of dementia cases might be preventable.

Hearing loss accounts for 9% of the life-course model owing to its prevalence. Age-related hearing loss is the third most prevalent chronic condition amongst older adults.[2] With increasing degrees of mild, moderate, and severe hearing loss, the risk of developing dementia increases by 2, 3, and 5 times.[3] However, the hearing problems of older adults are more complex than can be predicted by hearing loss alone. Many older adults with or without a hearing loss can hear in quiet conditions, but have difficulty understanding speech in background noise.[4] Knowing more about the impact of speech understanding in complex listening situations, with auditory processing tests like speech-in-noise tests and dichotic listening tests, can help target intervention solutions to better manage hearing loss. Speech-in-noise tests are associated with cognitive measures,[5] whereas low left ear scores on dichotic listening tests (which involve hearing different sound stimuli

in each ear simultaneously) have been shown to be sensitive to MCI and Alzheimer dementia.[6-8] Relative to hearing loss, few longitudinal studies[6,8-10] have examined commonly used auditory processing tests for their predictive value as markers of cognitive decline and incident dementia.

Like hearing loss, changes in personality, behaviour or comportment—as shown by neuropsychiatric symptoms (NPS) that include apathy, impaired motivation, loss of drive, social withdrawal, depression, anxiety, compulsive or obsessive behaviours, and socially unacceptable behaviours—are common[11-14] and more frequently associated with presentation to clinical settings.[15] Later life emergent and sustained changes in neuropsychiatric status characterize the validated neurobehavioural syndrome Mild Behavioural Impairment (MBI).[16] MBI is an at-risk state for incident cognitive decline and dementia, and for some, MBI may be the earliest sign of neurodegenerative disease, manifesting in advance of clear cognitive impairment.[17]

Recognizing that hearing ability may influence behaviour and various types of NPS, this study includes measures of hearing sensitivity, auditory processing, and the Mild Behavioural Impairment-Checklist (MBI-C) as predictors of cognitive change, using the MoCA as our outcome measure. To our knowledge, no studies have explored the relationship between hearing ability and the NPS of the MBI-C explicitly. For our longitudinal study, we hypothesize that changes to hearing ability and behavioural changes will have a synergistic effect, with faster cognitive decline and incident dementia in combination than when either occurs in isolation. For this short report, we present the baseline findings of the first 35 participants.

METHODS

Subjects

Thirty-five non-demented older adults, aged 60–93, were recruited by community rehabilitation and acute-care programs. Inclusion criteria were fluency in English and age > 55 years. Exclusion criterion was dementia at baseline. Cognitive status was determined by cognitive testing and clinical assessment as part of a geriatric medicine consultation. Dementia was diagnosed as per the DSM-5 criteria for Major Neurocognitive Disorder. All participants meeting criteria with consent underwent baseline cognitive, hearing, and behavioural assessment. The study was approved by the Health Research Ethics Board Alberta (HREBA) and is supported by Alberta Health Services and Covenant Health.

Procedure

Baseline cognitive tests were the Montreal Cognitive Assessment (MoCA) version 8.1 with calculation of Memory Index Score (MIS) and visually presented Word Recall subtest of the CERAD.[18,19] Both tests were administered by occupational therapists in one session. In a separate session, baseline hearing and behaviour assessment was given by an audiologist.

Hearing Testing

Standard tone and speech audiometry assessed hearing sensitivity. The hearing thresholds were used to calculate a 4-frequency pure tone average (4FPTA), including the mean of thresholds at 0.5, 1, 2, and 4 kHz for the right and left ears. The ear with the lowest 4FPTA was defined as the "Better Ear" and was used in all analyses, as well as to group the participants.

Auditory processing tests included commercial versions of the Quick Speech-in-Noise (QSIN) test,[20] Words-in-Noise (WIN) test,[21] and Dichotic Digits Test (DDT).[22] All tests were presented at the participant's most comfortable level (~70 dB HL for most listeners). The QSIN test measured binaural speech understanding of sentence material, whereas the WIN test measured single word understanding for each ear. The double-digit Dichotic Digits Test (DDT) measures binaural integration. Using a free report protocol, the listener reported what was heard in both ears and percent correct scores for each ear were calculated.

Behavioural Testing

Behaviour was assessed using the Mild Behavioural Impairment-Checklist (MBI-C). The MBI-C is a 34-item questionnaire that addresses later life emergence of sustained neuropsychiatric symptoms in five domains over a reference period of six months[23,24] Total and domain scores were tabulated for NPS presence and severity ratings.

Analyses

To describe the sample characteristics and baseline measurements, descriptive statistics with appropriate non-parametric tests, including the Mann-Whitney U and χ^2, were used with partial eta^2 (η^2) as a measure of effect size for the group comparisons (shown in Table 1). Cross-tabulation analyses were used to investigate if the distribution of NPS in any and each domain of the MBI-C differed for people with normal hearing vs. those with any degree of hearing impairment (see Figure 1). Results were considered statistically significant with a p value less than .05. We used least squares regression with backward elimination to test the ability of hearing and behaviour measures to predict MoCA-MIS and MoCA, after accounting for the effects of age and PTA4 (Table 2). Age and PTA4 were held as a block in each model and not considered for removal. Given our small sample size, two additional variables were chosen to add to each model, guided by the correlations among predictors and our hypothesized relationships between predictors and outcomes. We then used backward elimination to remove variables that did not contribute to the model. For the MoCA-MIS, left DDT (LDDT) and the total severity rating of Domain 4–social inappropriateness were initially entered in the model. LDDT was chosen based on theory, and social inappropriateness had the highest correlation

TABLE 1.
Sample characteristics and baseline measures of hearing, behavior and cognition

	Total Sample (n=35)	*Normal Hearing (n=7)*	*Hearing Impaired (n=28)*	*Test*	*p value*	*Effect Size*
Age						
Median (IQR)	78 (72,87)	78 (72,81)	80 (72,88)	MWU=77	.386	
Min-Max	60-93	69-82	60-93			
Gender						
Female - n (%)	17 (49)	3 (43)	14 (50)	χ^2 =0.1	.735	
Male - n (%)	18 (51)	4 (57)	14 (50)			
Years Education						
Median (IQR)	12 (14,16)	14 (13,16)	13 (12,16)	MWU=76	.354	
Hearing Sensitivity – Median (IQR)						
Better Ear PTA4[a]	36 (26,44)	19 (15,21)	41 (32,47)	MWU=0	<.001	η^2=.482
Word Discrimination Ability in Quiet – Median (IQR)						
Right	96 (92,100)	100 (96,100)	100 (96,100)	MWU=54	.077	
Left	92 (84,100)	96 (84,100)	88 (84,100)	MWU=44	.021	η^2=.157
Auditory Speech Processing Tests[b] – Median (IQR)						
QSIN	6 (4,10)	4 (1,7)	8 (5,11)	MWU=53	.063	
RWIN	17 (12,20)	21 (19,25)	15 (11,20)	MWU=35	.013	η^2=.191
LWIN	16 (13,21)	22 (21,26)	13 (10,19)	MWU=13	<.001	η^2=.368
RDDT	95 (85,100)	95 (57,100)	87 (16,97)	MWU=56	.678	
LDDT	85 (70,95)	95 (85,97)	70 (10,90)	MWU=22	.015	η^2=.227
MBI-C[c]						
Total Severity – Median (IQR)	4 (1-8)	1 (0,4)	6 (1-10)	MWU=54	.065	
Total Severity – n (%)						
< 7.5 cut-off	26 (74)	7 (100)	19 (69)	χ^2 =3.0	.082	
> 7.5 cut-off	9 (26)	0 (0)	9 (32)			
Cognitive Measures[d] – Median (IQR)						
MoCA	22(20-26)	23(18-28)	21(20-26)	MWU=84	.562	
MoCA Memory Index	8(6-12)	11(9-14)	7(5-11)	MWU=62	.142	
CERAD Recall Score	5(3-6)	5(2,6)	5(3,6)	MWU=87	.672	

[a]PTA refers to average of pure tone hearing thresholds obtained at 0.5, 1, 2, & 4 kHz.
[b]Auditory speech processing tests include: Quick Speech-in-Noise test (QSIN), right and left versions of Words-in-Noise test (RWIN & LWIN), right and left versions of Dichotic Digits Test (RDDT & LDDT).
[c]MBI-C refers to Mild Behavioural Impairment Checklist.
[d]Cognitive measures include: Montreal Cognitive Assessment (MoCA) and Consortium to Establish a Registry for Alzheimer's Disease (CERAD) neuropsychological battery.
[e]Tests included for comparison between groups: Mann-Whitney U (MWU), χ^2 (Chi Squared).

with the outcome variable. For the MoCA, right WIN (RWIN) and QSIN were initially entered as speech-in-noise tests and have been shown to be correlated with cognitive measures, especially working memory. The RWIN was selected over the left due to its stronger correlation with the outcome. To account for multiple comparisons, statistical significance was set to a *p* value less than .025.

RESULTS

Sample Characteristics and Baseline Measurements

Seven participants had normal hearing (4FPTA < 25 dB HL) and 28 participants had hearing impairment. Of the 28 hearing impaired participants: 13 had mild (4FPTA ≥ 25 and < 40), 10

had moderate (4FPTA ≥ 40 and < 55), and 5 had moderately severe hearing loss (4FPTA ≥ 55 and < 70). Normal hearing vs. hearing impaired groups did not differ in terms of age, gender, years of education or any cognitive test result, but participants with hearing impairment scored lower on the WIN test for right and left ears and had lower left DDT (Table 1).

Relationship Between Hearing Loss and MBI-C

MBI was highly prevalent in our sample, with 80% of participants reporting at least one NPS. Overall, people with hearing impairment had higher numbers of NPS than people with normal hearing, and these findings were significantly higher for Domain 1–apathy ($\chi^2 = 7.62, p = .006$) and Domain 3–impulse dyscontrol ($\chi^2 = 4.41, p = .036$). However, severity of hearing impairment was not associated with a higher number of NPS (Figure 1). Greater MBI burden is associated with hearing impairment; 32% of participants with hearing impairment had MBI-C total severity scores > 7.5 compared to 0% with normal hearing[25](Table 1).

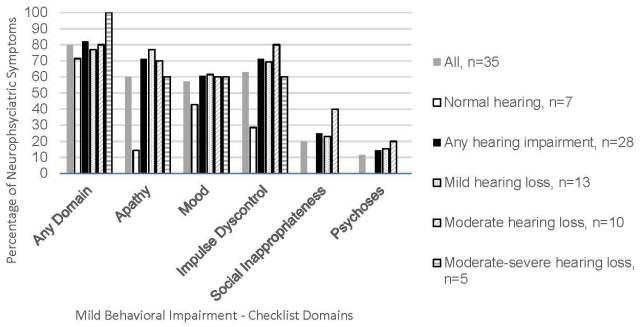

FIGURE 1. Percentage of neuropsychiatric symptoms present on any domain and by each domain of the Mild Behavioural Impairment-Checklist for all participants and by hearing status, showing those with normal hearing, all with any hearing impairment, and further breakdown by degree of hearing impairment

Regression Results

Hierarchical multiple regression models for the MoCA-MIS and MoCA are presented in Table 2. The step 1 results where age and hearing sensitivity were added were not significant for any of the models shown. For the MoCA-MIS, the LDDT emerged as the best predictor carrying the hightest Beta weight. When entered singly, the LDDT accounted uniquely for 20% of MoCA-MIS variance. For the MoCA, the RWIN was the best predictor and accounted for 16% of unique variance.

DISCUSSION

This is the first study to report the association between hearing loss and NPS using the MBI-C. Our three primary findings were:

1. Both hearing loss and NPS were highly prevalent at 80% in our sample, and 32% of those with hearing impairment

TABLE 2.
Hierarchical multiple regression models for the Montreal Cognitive Assessment Memory Index Score (MoCA-MIS) and Montreal Cognitive Assessment (MoCA), showing step 2 results after the effects of age and PTA4[a] have been ruled out

Test	*Model*	*R*	*Adjusted R^2*	*Predictor*	*β*	*p value*	*Semi partial r^2*
MoCA-MIS	Addition of LDDT[b] and MBI-C D4[c] severity ratings	0.593	0.234	Age	-0.227	0.226	0.046
				PTA4	-0.080	0.678	0.005
				LDDT	0.377	0.084	0.097
				MBI-C d4	-0.186	0.365	0.025
	Removal of MBI-C D4[c]	0.571	0.239	Age	-0.271	0.136	0.070
				PTA4	-0.042	0.825	0.001
				LDDT	0.471	0.016	0.197
MoCA	Addition of RWIN[d] and QSIN[e]	0.578	0.239	Age	-0.270	0.166	0.048
				PTA4	0.240	0.274	0.030
				RWIN	0.810	0.014	0.162
				QSIN	0.295	0.322	0.024
	Removal of QSIN[e]	0.549	0.23	Age	-0.233	0.166	0.048
				PTA4	0.268	0.274	0.030
				RWIN	0.598	0.022	0.140

[a]PTA refers to pure tone average of hearing thresholds obtained at 0.5, 1, 2, & 4 kHz.
[b]LDDT refers to left ear Dichotic Digits Test.
[c]MBI-C D4 refers to the Mild Behavioural Impairment Checklist–Domain 4, which addresses social inappropriateness.
[d]RWIN refers to right ear Words-in-Noise test.
[e]QSIN refers to the Quick Speech-in-Noise test.

had high MBI-C scores (i.e., > 7.5), as opposed to 0% with normal hearing.
2. Overall, people with hearing impairment had greater global MBI-C burden, and these findings were significantly higher for the apathy and impulse dyscontrol domains.
3. While the influence of both hearing and behaviour measures were considered, two measures of auditory processing—LDDT and RWIN—emerged as the best predictors of baseline MoCA-MIS and MoCA, respectively, after removing the effects of age and hearing sensitivity.

High hearing loss prevalence is expected, given the age range, but the high MBI-C findings are notable. In descending order, the prevalence of the MBI domains for the hearing impairment group was: apathy and impulse dyscontrol (tied in first place), mood, social inappropriateness, and psychoses. These distributions were tested with a model and age was not found to have an influence. A sample item from the apathy domain includes:

"Has the person become less spontaneous and active? Is she/he less likely to initiate or maintain conversation?"

In contrast, the implulse dyscontrol domain reflects agitation. Taken together, we may speculate a causal relationship such that, when listening becomes too effortful, hearing impaired people disengage, socially withdraw, become bored, and are easily irritated. However, the same underlying neurodegenerative process could also account for both MBI and hearing impairment, as both are prevalent in prodromal dementia, and both are associated with more rapid progression from MCI to AD.[3,14] In the broader literature, the interconnections between hearing loss, cognition, and social participation have been examined using structural equation modeling. It's possible that the NPS of the MBI-C, much like social participation, may mediate the association between hearing loss and cognitive decline.

Combinations of hearing and behaviour variables from the MBI-C were examined to determine their ability to predict baseline MoCA-MIS. The MoCA-MIS measures the influence of category and multiple-choice cues on delayed word recall. Low MIS is linked with a greater risk to convert from MCI to dementia.[26] Our model began with the addition of Domain 4–social inappropriateness and LDDT in block 2, but it was the LDDT that emerged as the best predictor, accounting for 20% unique variance. Our LDDT finding is consistent with research showing low left ear scores on dichotic listening tasks linked with MCI and Alzheimer dementia[7,8] and, more recently, a connection with vascular health, lending support to a common etiology linking hearing ability to cognitive and physical functioning.[27]

Low left DDT is consistent with the long-recognized right ear advantage, which reflects left hemisphere dominance for speech processing and the contralateral pathways linking the cochlea to the auditory cortex and association areas.[28] Right ear speech stimuli access the left hemisphere directly, whereas left ear speech stimuli transfers across the corpus callosum from right to left hemisphere. Low left ear dichotic scores implicate the corpus callosum. An intriguing finding from brain imaging studies shows that the shape, and not the traditional measure of size, of the corpus callosum can differentiate between very mild and mild cases of Alzheimer dementia.[29] It's possible that our low left DDT may reflect this neuroanatomical finding in a way that traditional cognitive measures cannot. The right ear advantage may also explain why the right WIN was the better predictor of the MoCA composite score, in agreement with other correlation findings of speech and noise tests after adjustment for age.[30]

As this short report represents preliminary findings, our results are limited by our small sample size, clinical sample bias (i.e., participants seeking clinical care were recruited from community rehabilitation and acute-care programs), and lack of statistical power. By keeping our model predictors to a minimum (i.e., two candidate variables and two known predictors), we attempted to minimize the potential for an idiosyncratic fit. In the future, a larger baseline sample size will enable us to examine more comprehensive regression models, and our longitudinal design will help us understand the role of various MBI domains and hearing abilities on cognitive outcomes over time. For now, our findings underscore the value of non-invasive hearing and behavioural assessment as part of comprehensive dementia risk assessment.

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CONFLICT OF INTEREST DISCLOSURES

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