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Assessing performance on the Montreal Cognitive Assessment (MoCA) in experienced cochlear implant users: use of alternative scoring guidelines

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\textbf{ABSTRACT}

Although research suggests a relationship between hearing impairment and cognitive decline in older adults, nuances of this relationship remain unclear. This uncertainty could be attributed to verbal administration of standardized cognitive measures to hearing-impaired (HI) individuals. Various strategies for testing HI populations have been suggested. We tested the efficacy of applying alternative scoring methods that systematically removed auditory-based items on the Montreal Cognitive Assessment (MoCA) in 27 cochlear implant patients. We calculated the original MoCA score and three alternative scores. The first alternative removed items from the Attention and Language sections; the second alternative removed the Delayed Recall task, and the third alternative removed the Attention, Language, and Delayed Recall items. QoL was assessed using the Glasgow Benefit Inventory and Nijmegen Cochlear Implant Questionnaire. Results indicate a significant difference in MoCA scores with two alternative scoring methods. The second alternative MoCA score related to self-reported performance on the GBI.

\textbf{Cognition and hearing loss}

Hearing impairment and cognitive decline are of greatest prevalence in older adults (Hoffman, Dobie, Losonczy, Themann, & Flamme, 2017; Roberts & Knopman, 2013). In particular, 15–20\% of individuals over the age of 65 are diagnosed with mild cognitive impairment (MCI), which is classified as a disruption in cognitive abilities that does not interfere with activities of daily living (Gauthier et al., 2006; Roberts & Knopman, 2013). Early identification and treatment of mild cognitive impairment is crucial given that it typically precedes a diagnosis of dementia. Furthermore, dementia can negatively affect quality of life (QoL) by decreasing activities of daily living (e.g., grooming, getting dressed), increasing psychological and behavioral disturbances associated with the disease, and increasing the need for caregiving assistance (Andersen, Wittrup-Jensen, Lolk, Andersen, & Kragh-Sørensen, 2004; Banerjee et al., 2006). One way to help minimize the impact of negative outcomes associated with dementia is to fully understand the
mechanisms (biological, social, and environmental) involved in its development through MCI, and whether these factors can be modified.

One potential risk factor for MCI that has garnered attention in recent years is hearing loss. Along with MCI, age-related hearing loss (ARHL, i.e., presbycusis) is common in adults over the age of 65 (Jayakody, Friedland, Martins, & Sohrabi, 2018). Interestingly, evidence suggests an association between hearing impairment and reductions in cognitive function in older adults (Cacciatore et al., 1999; Gallacher et al., 2012; Lin, Metter, et al., 2011), with these reductions becoming more pronounced as the degree of hearing loss increases (i.e., profoundly deaf individuals experience greater cognitive decline than individuals with mild to moderate hearing loss; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011; Lin et al., 2013). However, the ways that cognition is measured and how hearing loss is defined are variable across the literature, making it difficult to determine if perceived cognitive deficits are a result of true cognitive impairment or a lack of accurate perception of test stimuli. Indeed, some research has shown only moderate effects for the relationship between these constructs (Taljaard, Olathe, Brennan-Jones, Eikelboom, & Bucks, 2016), or no relationship at all when factors such as age, education, and depression are controlled for (Bucks et al., 2016), suggesting that the relationship between hearing loss and cognition is complex. Taljaard et al. (2016) observed only small contributions of treatment with hearing aids (HAs) or cochlear implants (CIs) on cognitive performance, suggesting that treatment alone is not responsible for improvements in cognitive abilities in hearing-impaired (HI) listeners. Nonetheless, patients who undergo cochlear implantation show significant post-implantation improvements in QoL measures (Mosnier et al., 2015) and reductions in depressive symptomatology (Castiglione et al., 2016; Mosnier et al., 2015). As such, a better understanding of the interrelationships of hearing loss, cognition, and QoL, especially in HI populations, is needed.

### Measuring cognitive function

Two commonly administered tests that assess cognitive function and screen for MCI and dementia are the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975; Mosnier et al., 2015, 2018) and Montreal Cognitive Assessment (MoCA; Castiglione et al., 2016; Claes et al., 2018; Nasreddine et al., 2005). The MMSE and MoCA are particularly favorable in clinical settings because they measure global cognitive function in a relatively short amount of time (i.e., 10–15 minutes; Folstein et al., 1975; Hoops et al., 2009; Lim & Loo, 2018). Although both tests are useful, they each have advantages and disadvantages. The MMSE was designed and is widely used to screen for dementia in the general population (Ismail, Rajji, & Shulman, 2010), with a sensitivity of 17–78% and 100% specificity in identifying individuals with typical cognition (Boustani, Peterson, Hanson, Harris, & Lohr, 2003; Landi et al., 2000; Nasreddine et al., 2005; Smith, Gildeh, & Holmes, 2007). Decades later, MCI emerged as its own diagnostic category distinguishable from normal aging and dementia, necessitating the creation of additional cognitive screening tools such as the MoCA, which displays sensitivity of 90% and 100% in detecting MCI and Alzheimer’s disease (AD), respectively, and specificity of 50–87% (Damian et al., 2011; Nasreddine et al., 2005; Smith et al., 2007). While the MoCA and MMSE have clinical utility as screening tools for MCI and dementia, respectively, an issue arises when screening individuals living with a sensory impairment (e.g., visual or auditory), which has been
shown to negatively influence test performance (Dupuis et al., 2015; Jorgensen, Palmer, Pratt, Erickson, & Moncrieff, 2016).

**Alternative scoring and presentation of the MoCA**

To reduce the effect that sensory impairment may have on MoCA performance, modification of scoring methods or presentation of test items have been suggested as solutions. For example, some research suggests that lowering the cutoff score of the MoCA altogether can reduce the amount of false positives in non-clinical populations (Carson, Leach, & Murphy, 2018; Rossetti, Lacritz, Cullum, & Weiner, 2011). The original MoCA was validated with a cut-off score of 25 (83.33%) or below indicating the presence of MCI (Nasreddine et al., 2005); however, lowering the cut off score to 23 (76.67%) or below to indicate MCI has shown to increase the MoCA’s sensitivity and specificity (Carson et al., 2018; Luis, Keegan, & Mullan, 2009). A critique of lowering the MoCA cutoff score is that it could affect test validity (Dupuis et al., 2015; Nasreddine et al., 2012). To explore this further, Horton et al. (2015) created a short-form MoCA (SF:MoCA) using the most predictive test items that accurately classified MCI, AD, and normal cognitive function. They found no significant differences between the screening capacity of the original MoCA (71.9% classification accuracy) and the SF:MoCA (72.6% classification accuracy) for normal cognitive function, MCI, or AD, suggesting that an adjusted MoCA score is possible without compromising the integrity or accuracy of the original MoCA. However, this scoring alteration may not be sufficient to accurately measure cognitive performance in populations with sensory deficits (i.e., hearing and visual impairments; Lin et al., 2017; Wittich, Phillips, Nasreddine, & Chertkow, 2010).

For HI individuals, one suggestion has been to eliminate audibility as a confound by adapting the MoCA test items. Specifically, Lin et al. (2017) created a modified version of the MoCA for older individuals (i.e., over the age of 60) with severe hearing impairment (HI-MoCA) where all of the instructions and stimuli were presented visually through a PowerPoint presentation. Although this novel modification displayed good test–retest reliability in HI participants, it was not without limitations. Particularly, the original (auditory-visual) MoCA was not administered to the HI participants, making it difficult to quantify a difference in performance (if any) between auditory-visual and visual-only test presentation. Additionally, duration of hearing loss was not defined and it was unclear whether the participants used CIs, HAs, or were unaided listeners, which would have been pertinent for examining between-group differences in performance. Another suggestion to eliminate audibility as a confounder on test performance has been to strategically remove all auditory-based test items (i.e., items that rely largely on auditory abilities to comprehend and complete) from the total score (Dupuis et al., 2015). While Dupuis et al. (2015) showed that unaided, HI individuals (\(M_{\text{better-ear PTA}} = 33.2, SD = 12.7 \text{ decibels [dB]}, M_{\text{impaired-ear PTA}} = 42.9, SD = 13.8 \text{ dB}; \text{PTAs were calculated from octave frequencies 500, 1 k, and 2 k Hz}) demonstrate improvements in MoCA test performance when these alternative scoring methods were applied, it is unclear if differences in MoCA performance exist when alternative scoring methods are applied to profoundly deafened individuals with a CI.
The current study

Through application of Dupuis et al.’s (2015) alternative MoCA scoring guidelines (i.e., removing auditory-based test items), we examined whether profoundly deafened CI patients (unaided $M_{\text{right ear PTA}} = 99.2$, $SD = 22.8$ dB, unaided $M_{\text{left ear PTA}} = 95.6$, $SD = 17.1$ dB) with more than 6 months of CI experience displayed differences in MoCA scores (i.e., moving from MCI cut-off to the normal cognitive function range). We also assessed QoL in CI users with the Nijmegen Cochlear Implant Questionnaire (NCIQ) and the Glasgow Benefit Inventory (GBI). We hypothesized that CI users would display differences in MoCA scores using alternative scoring guidelines, and that MoCA performance would be associated with patient-reported QoL.

Method

Participants

Twenty-seven experienced CI users (>6 months CI experience; range: 7–79 months, $M = 28.96$ months, $SD = 21.07$), between the ages of 52 and 88 years old ($M = 69.56$, $SD = 11.29$) were recruited from the patient pool at the Center for Hearing and Skull Base Surgery at the Swedish Neuroscience Institute in Seattle, Washington, USA. Participants were considered experienced CI users after 6 months of use based on the findings of Lenarz et al. (2012), who determined that there were no statistically significant improvements or deteriorations in speech testing after 6 months of CI use compared to performance at a 20-year follow-up. Etiology of hearing loss among our CI users varied, with the majority attributed to chronic otitis media (48%) and genetics (30%), followed by Ménière’s disease (11%) and sudden idiopathic hearing loss (11%). Average duration of hearing loss among all CI users was 21.87 years ($SD = 13.95$). Of the 27 participants, 11 were male and 16 were female. Four participants were unilateral CI users, 5 were bilateral CI users, and 18 were bimodal (i.e., a CI with a contralateral HA). In terms of device manufacturer, 2 had Advanced Bionics, 20 had Cochlear Americas, and 5 had Med-El; See Table 1 for additional demographic characteristics of the sample. Participants had average clinical speech perception scores of 89.78% ($SD = 8.41$, ranged from 70% to 100%), as measured by AzBio sentences in quiet and with participants tested in their best-aided hearing configuration (i.e., one CI for unilateral users, CI and HA for bimodal users, two CIs for bilateral users). None of the participants had a diagnosis of dementia, reported symptoms of cognitive decline, or had congenital etiology or pre-lingual hearing loss. All participants were native English speakers, had at least a high school education ($M_{\text{years of education}} = 15.32$, $SD = 1.99$), and demonstrated normal IQ scores (>89; $M = 105.48$, $SD = 7.55$), as measured by the Test of Nonverbal Intelligence – 4th Edition (TONI-4; Brown, Sherbenou, & Johnsen, 2010). All testing was conducted with participants in their best-aided listening condition. All participants who regularly wore glasses or contacts were asked to keep them on for the entire study session. All testing procedures were approved by the Swedish Medical Center Institutional Review Board (#SWD5655-14), and all participants provided informed written consent.
**Montreal Cognitive Assessment (MoCA)**

The MoCA is a 12-item test designed as a quick (i.e., 10 minute) cognitive screening tool for MCI that measures eight different cognitive domains (Nasreddine et al., 2005). Each participant was administered the MoCA by a trained research assistant who also scored the MoCA. Participants were able to engage in speech reading to complete test items if needed; given that up to 40% of speech sounds are visible with lip-reading (Woodward & Barber, 1960), standard presentation of the MoCA is considered here as auditory-visual rather than purely auditory. Testing occurred in a clinic room with access to windows, which provided greater luminosity and better visibility for test stimuli. All participants reported test stimuli to be clear and visible. The original MoCA has been validated with a cut-off score of 25 or below indicating the presence of MCI. In the present study, we applied this cut-off score and also calculated three alternative scores proposed by Dupuis et al. (2015) that systematically remove the auditory-based test items. The first alternate score removed the language repetition, attention to letters, and digit span items; totaling five points for a new total score of 25. The second alternate score removed the delayed recall item, which totals five points and results in a new total score of 25. The last alternate score removed all auditory-based items (i.e., language repetition, attention to letters, digit span, and delayed recall), resulting in a new total score of 20. See **Table 2** for a comparison of test items included in the original and alternative MoCA scoring methods. Cut-off scores for these alternative scoring methods were determined based on the original scoring method, by using the maximum percentage of correct items to still be considered as having MCI (i.e., 83.33% correct or 25 out of 30), rounded to the nearest whole number. Therefore, the cut-off scores for MCI for alternative scoring method one, two, and three were 21, 21, and 17, respectively.

**The Glasgow Benefit Inventory (GBI)**

The GBI is an 18-item scale that measures benefit following otorhinolaryngological procedures, including cochlear implantation (Robinson, Gatehouse, & Browning, 1996). The total GBI score is composed of three subscales (general health [12 questions], social support [3 questions], and physical health [3 questions]). Scores for each of these subscales can range from −100 to +100, with higher scores indicating greater benefit.
of otorhinolaryngological procedures, which was specific to CIs in the present study. In the current study, the GBI demonstrated a high degree of internal reliability across all subscales (Cronbach’s α ≥ 0.867). One participant did not complete the GBI.

**The Nijmegen Cochlear Implant Questionnaire (NCIQ)**

The NCIQ is a 60-item scale that measures three health-related QoL (HRQoL) domains in CI users. The three domains are Physical, Psychological, and Social (Hinderink, Krabbe, & Van Den Broek, 2000). Within the Physical domain, there are three subdomains: Basic Sound Perception, Advanced Sound Perception, and Speech Production. The Psychological domain measures Self-esteem, and within the Social Domain, there are two subdomains: Activity Limitation and Social Interaction. Higher scores indicate better HRQoL. Two participants did not complete the NCIQ.

**Statistical analyses**

Statistical analyses were conducted in SPSS 25.0 (IBM Corp, 2017). Normality was assessed for all data using the Shapiro–Wilk test. Data from the original MoCA scores, second and third alternative MoCA scores, GBI social support subscale, and GBI physical health subscale were not normally distributed; thus, these variables were analyzed using nonparametric tests (i.e., Spearman’s Rho and Friedman test). A Friedman test, a non-parametric alternative to a one-way repeated-measures ANOVA (Field, 2009; Kim, 2014), was employed to assess differences in CI patients’ original versus alternative MoCA scores. Wilcoxon Signed-Rank Tests, a non-parametric alternative to dependent sample t-tests, were employed to further explore these differences. For all other variables, parametric tests (i.e., Pearson correlations and biserial correlations) were performed. The second and third alternative MoCA scores and the GBI general health subscale were significantly related to age, while the original MoCA score and second alternative MoCA score were significantly related to IQ (as measured by the TONI-4). All correlations with these scores were subjected to partial correlations controlling for age and IQ, respectively. MoCA percentage scores were used in the analyses, as raw scores for the alternative MoCA scoring methods were inherently lower due to the removal of the
Results

Comparison of original MoCA scoring versus alternative scoring

In support of our first hypothesis, the Friedman test indicated statistically significant differences among scores ($\chi^2(3) = 75.73, p < .001$; see Table 3 for the means of each scoring method). To adjust for multiple (six) pairwise comparisons, a Bonferroni correction was applied to the alpha level (corrected alpha = 0.008). The pairwise comparison results revealed that the original MoCA score ($Mdn_{\text{percent}} = 90\%$) significantly differed from the second ($Mdn_{\text{percent}} = 96\%, p < .001, r = -.575$; See Table 3) and third alternative scores ($Mdn_{\text{percent}} = 95\%, p < .001, r = -.609$). Significant differences were also found between the first alternative MoCA score ($Mdn_{\text{percent}} = 88\%$), and both the second ($Mdn_{\text{percent}} = 96\%, p < .001, r = -.487$) and third alternative scores ($Mdn_{\text{percent}} = 95\%, p < .001, r = -.580$). Passing rate for each scoring method is provided in Table 3.

Analysis of delayed recall items

Given that the largest change in MoCA test scores occurred with the omission of the delayed recall task, further analysis was conducted to determine whether CI participants experienced problems with the initial encoding of words or with the retrieval of words after the delay period. On the first and second word-learning trials, CI participants correctly repeated words at frequencies 87.4% and 99.3%, respectively. To control for errors due to incorrect word recognition, we assessed delayed recall performance by analyzing only words that had been accurately repeated during both learning trials; CI participants correctly recalled 57.8% of words after the delay period. The overall average accuracy of delayed word recall regardless of learning trial performance was 58.5%.

Table 3. Descriptive statistics and comparison of original versus alternative Montreal Cognitive Assessment scores.

<table>
<thead>
<tr>
<th></th>
<th>Descriptive Statistics</th>
<th>Pairwise Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw Scores M(SD)</td>
<td>Percentage Scores M(SD)</td>
</tr>
<tr>
<td>Original Score</td>
<td>26.37 (1.98)</td>
<td>87.6% (6.38)</td>
</tr>
<tr>
<td>Alternative Score</td>
<td>21.81 (2.02)</td>
<td>87.3% (8.08)</td>
</tr>
<tr>
<td>Alternative Score 1</td>
<td>23.41 (1.25)</td>
<td>93.6% (4.99)</td>
</tr>
<tr>
<td>Alternative Score 2</td>
<td>18.88 (1.15)</td>
<td>94.4% (5.77)</td>
</tr>
</tbody>
</table>

N = 27; Note: *** = p < 0.001.
**Relationships between the MoCA scoring methods and quality of life measures**

Our second hypothesis that MoCA scores and the self-reported QoL would be related was partially supported (See Table 4 for average QoL scores). Specifically, no relationships were observed between MoCA performance on the original or alternate scoring methods and the GBI or NCIQ subdomains (all \( r < .346, p > .115 \)). In order to assess whether there were relationships among the QoL measures and CI users’ passing status on the MoCA, dichotomous variables were created to reflect passing (1) or failing (0) the MoCA and biserial correlations were conducted. We opted to use biserial correlations for two reasons: (1) biserial correlations allow for the assessment of relationships when one of the two variables is dichotomous on a continuum (i.e. MoCA test scores; Field, 2009), and (2) although biserial correlations are equivalent to independent sample t-tests, the current data would not have been powered to detect group differences as the number of participants in the failing group ranged from 3 to 11. Adjustments to alpha were made for multiple comparisons using a Bonferroni correction (adjusted alpha = .005). Passing status using the second MoCA scoring method was significantly related to all of the components of the GBI (all \( r_b \leq -.977, all p \leq .002 \), except the general health subscale (See Table 5). No additional relationships were found between passing status on the MoCA and the NCIQ subdomains (all \( r_b \geq -.215, all p \geq .015 \)).

**Discussion**

We demonstrated significant differences in MoCA test scores in profoundly deafened CI patients when using alternative forms of scoring that eliminate the auditory-based test items. We found a relationship between passing status on the second MoCA scoring method and the GBI subscales, but no additional relationships to the other QoL measures administered.

**Alternative scoring methods for the MoCA**

Our findings are consistent with those reported by Dupuis et al. (2015), suggesting that MoCA performance improves in deafened CI participants when auditory-based items are

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**Table 4. Descriptive statistics for the quality of life measures.**

<table>
<thead>
<tr>
<th>QoL Measure</th>
<th>Subdomain</th>
<th>N</th>
<th>M(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBI</td>
<td>Physical Health</td>
<td>26</td>
<td>15.39 (21.56)</td>
</tr>
<tr>
<td></td>
<td>Social Support</td>
<td>26</td>
<td>28.20 (31.54)</td>
</tr>
<tr>
<td></td>
<td>General Health</td>
<td>26</td>
<td>50.32 (29.93)</td>
</tr>
<tr>
<td></td>
<td>Total Score</td>
<td>26</td>
<td>38.89 (24.24)</td>
</tr>
<tr>
<td>NCIQ</td>
<td>Basic Sound Perception</td>
<td>25</td>
<td>59.08 (15.50)</td>
</tr>
<tr>
<td></td>
<td>Advanced Sound Perception</td>
<td>25</td>
<td>54.40 (13.81)</td>
</tr>
<tr>
<td></td>
<td>Speech Production</td>
<td>25</td>
<td>78.85 (10.86)</td>
</tr>
<tr>
<td></td>
<td>Psychological/Self-esteem</td>
<td>25</td>
<td>60.30 (12.56)</td>
</tr>
<tr>
<td></td>
<td>Activity Limitation</td>
<td>25</td>
<td>69.90 (16.08)</td>
</tr>
<tr>
<td></td>
<td>Social Interaction</td>
<td>25</td>
<td>67.29 (14.12)</td>
</tr>
</tbody>
</table>

QoL = quality of life; GBI = Glasgow Benefit Inventory; NCIQ = Nijmegen Cochlear Implant Questionnaire.
removed and alternate scoring criteria are applied. Furthermore, it appears that the removal of the delayed recall task showcased the greatest improvement in passing rate in the current sample (i.e., from 63.0% to 88.9%), as opposed to the removal of other or all auditory-based items (i.e., alternative scores one and three). Rossetti et al. (2011) found the delayed recall task to be the second most commonly missed test item on the MoCA in a population-based sample (the first being the cube drawing task). Although the delayed recall task may be inherently difficult, Rossetti et al. (2011) suggested that the MoCA test items may function differently for participants depending on comorbidity. HI individuals utilize more cognitive resources (e.g., working memory capacity) when trying to understand speech (Pichora-Fuller et al., 2016). This increased cognitive effort is likely the brain’s attempt to apply existing linguistic knowledge and context to the incoming, degraded auditory signals, a process known as phonemic restoration (Başkent, 2012; Wingfield, McCoy, Peelle, Tun, & Cox, 2006). Similarly, the incoming auditory signals from CIs are still fragmented, degraded, or incomplete, and thus require cognitive effort to interpret (Başkent, 2012; Pals, Sarampalis, & Başkent, 2013). Thus, it could be that the delayed recall task, a cognitively demanding task that involves working memory and rehearsal of words during the initial learning trials and then retrieval of the words (Camos & Portrat, 2015), is competing with limited cognitive resources in CI users simply from them trying to comprehend the incoming auditory signals (i.e., test instructions and the list of words).

Additionally, CI participants may also encode incorrect words based on the incoming-degraded auditory signals, which can be problematic when interpreting their performance on the delayed recall task of the MoCA, given that points are only awarded for words that are correctly recalled without the use of category or multiple-choice cues.

<table>
<thead>
<tr>
<th>GBI</th>
<th>Original Score</th>
<th>Alternative Score 1</th>
<th>Alternative Score 2</th>
<th>Alternative Score 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Health</td>
<td>$r_b = -.414$</td>
<td>$r_b = -.318$</td>
<td>$r_b = -.977$</td>
<td>$r_b = -.254$</td>
</tr>
<tr>
<td></td>
<td>$p = .008$</td>
<td>$p = .049$</td>
<td>$p = .001^{**}$</td>
<td>$p = .037$</td>
</tr>
<tr>
<td>Social Support</td>
<td>$r_b = -.353$</td>
<td>$r_b = -.129$</td>
<td>$r_b = -.866$</td>
<td>$r_b = -.569$</td>
</tr>
<tr>
<td></td>
<td>$p = .051$</td>
<td>$p = .149$</td>
<td>$p = .002^*$</td>
<td>$p = .033$</td>
</tr>
<tr>
<td>General Health</td>
<td>$r_b = -.061$</td>
<td>$r_b = -.318$</td>
<td>$r_b = -.710$</td>
<td>$r_b = -.334$</td>
</tr>
<tr>
<td></td>
<td>$p = .203$</td>
<td>$p = .135$</td>
<td>$p = .008$</td>
<td>$p = .065$</td>
</tr>
<tr>
<td>Total Score</td>
<td>$r_b = -.201$</td>
<td>$r_b = -.057$</td>
<td>$r_b = -.956$</td>
<td>$r_b = -.524$</td>
</tr>
<tr>
<td></td>
<td>$p = .145$</td>
<td>$p = .123$</td>
<td>$p = .002^*$</td>
<td>$p = .065$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NCIQ</th>
<th>Original Score</th>
<th>Alternative Score 1</th>
<th>Alternative Score 2</th>
<th>Alternative Score 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Sound Perception</td>
<td>$r_b = -.131$</td>
<td>$r_b = .020$</td>
<td>$r_b = .235$</td>
<td>$r_b = .311$</td>
</tr>
<tr>
<td>Advanced Sound Perception</td>
<td>$r_b = -.047$</td>
<td>$r_b = -.215$</td>
<td>$r_b = -.074$</td>
<td>$r_b = .062$</td>
</tr>
<tr>
<td></td>
<td>$p = .214$</td>
<td>$p = .087$</td>
<td>$p = .208$</td>
<td>$p = .220$</td>
</tr>
<tr>
<td>Speech Production</td>
<td>$r_b = -.074$</td>
<td>$r_b = -.075$</td>
<td>$r_b = .195$</td>
<td>$r_b = .471$</td>
</tr>
<tr>
<td></td>
<td>$p = .195$</td>
<td>$p = .232$</td>
<td>$p = .112$</td>
<td>$p = .017$</td>
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<tr>
<td>Psychological/Self-esteem</td>
<td>$r_b = -.010$</td>
<td>$r_b = .077$</td>
<td>$r_b = .289$</td>
<td>$r_b = -.084$</td>
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<tr>
<td>Activity Limitation</td>
<td>$r_b = .195$</td>
<td>$r_b = .205$</td>
<td>$r_b = .340$</td>
<td>$r_b = .152$</td>
</tr>
<tr>
<td></td>
<td>$p = .112$</td>
<td>$p = .132$</td>
<td>$p = .199$</td>
<td>$p = .242$</td>
</tr>
<tr>
<td>Social Interaction</td>
<td>$r_b = .471$</td>
<td>$r_b = .454$</td>
<td>$r_b = .873$</td>
<td>$r_b = .527$</td>
</tr>
<tr>
<td></td>
<td>$p = .017$</td>
<td>$p = .015$</td>
<td>$p = .034$</td>
<td>$p = .057$</td>
</tr>
</tbody>
</table>

GBI = Glasgow Benefit Inventory; NCIQ = Nijmegen Cochlear Implant Questionnaire.
Note: Bonferroni correction = adjusted alpha of .005; * = $p < .005$; ** = $p < .001$. 
This scoring approach has received some criticism (Dupuis et al., 2015) in that participants that repeat and encode similar-sounding words (e.g., “bat” instead of “hat” or “bed” instead of “red”) during the learning trial and then successfully recall the incorrectly encoded word do not receive credit for their response. In our sample, we found that words were correctly encoded after both learning trials; however, they were only correctly recalled after the delay period approximately 60% of the time. This suggests that the observed difficulties with the delayed recall task in our CI sample are either a result of poorer memory or a compromised retrieval process for the words, rather than incorrect perception of the words during the learning trials. As such, it may be that a modified scoring system whereby partial credit is awarded for cued recall of words or for successful recall of incorrectly encoded words is needed when assessing delayed recall in a CI population.

By removing the delayed recall task from the MoCA, we are likely controlling for the limitations in cognitive effort needed to comprehend speech while simultaneously processing and retrieving information in HI participants, explaining the difference in CI users that passed the MoCA when this item was removed. The other auditory-based items (i.e., language repetition, attention to letters, and digit span items) do not require processing and retrieval of test stimuli to the extent that the delayed recall task does, which would explain why the removal of these items alone did not result in a significantly larger change in the proportion of passing participants. However, it should be noted that the delayed recall task has been found to be the most predictive component of the MoCA (Horton et al., 2015) and MMSE (Galasko et al., 1990) when distinguishing between participants with and without MCI or dementia. Thus, removing this item altogether could result in false negatives that reduce test sensitivity for detecting MCI.

**Quality of life in CI users**

Our second hypothesis regarding relationships between MoCA performance and self-reported QoL was partially supported. Although none of the self-reported QoL measures were related to the MoCA scores, passing status on the second alternative MoCA score was related to all GBI subscales, except the general health subscale. Current literature assessing cognitive function and self-reported QoL in CI users has primarily focused on comparing pre- and post-implantation changes among these outcomes, with post-implantation improvements seen in both cognition and QoL (Mosnier et al., 2015, 2018). To our knowledge, we are the first to explore whether a relationship between cognitive performance and self-reported QoL is present in experienced CI users. We speculate that the absence of additional relationships between MoCA scores and measures of self-reported QoL are due to the relatively high performance on both constructs seen in our sample of CI users. All of our participants were experienced CI users who have likely undergone post-implantation improvements in their QoL. In fact, our sample displayed typical NCIQ subscale (Hinderink et al., 2000) and GBI total scores (Ho, Monksfield, Egan, Reid, & Proops, 2009).
Necessity of standardized measures for hearing impaired populations

While use of the MoCA has gained more traction as a cognitive screening tool in recent years, it is unclear whether it can be used as a validated measure in HI individuals. Current literature that has included the MoCA as an assessment of cognitive performance in CI users is scarce, with the main focus on pre- to post-CI improvement in cognitive performance (Ambert-Dahan et al., 2017; Castiglione et al., 2016; Claes et al., 2018). These studies are significant in the context of a relationship between hearing loss and cognitive decline, as they suggest that treating hearing loss with a CI is a useful means of intervention. However, it is important to note that pre- to post-CI improvement in cognitive performance does not guarantee being able to meet the threshold required to “pass” the MoCA. Indeed, our results show that more than one third (37.0%) of our experienced CI participants failed to achieve a passing score.

One adaptation could be to lower cutoff scores for achieving a passing threshold. Lowering MoCA cutoff scores may provide higher sensitivity and specificity for MCI (Carson et al., 2018; Rossetti et al., 2011), although it is unclear whether this translates to HI populations. Nonetheless, it provides another avenue by which to measure cognitive performance in HI individuals without omitting tasks that rely on intact auditory processing, and therefore avoiding potential reductions in test validity. Anecdotally, lowering the MoCA cutoff score to 23/30 (as suggested by Carson et al., 2018) would have yielded an even higher passing rate in our CI users (i.e., from 63.0% to 96.3%) compared to performance when auditory test items were removed. Another adaptation is to present MoCA test items using a visual-only modality to avoid audibility as a potential confounding factor on cognitive test performance (Ambert-Dahan et al., 2017; Lin et al., 2017). In support of this adaptation, Hillyer et al. (2018) found that CI users performed better on WM tasks when test items were presented in a visual rather than an auditory-visual modality. These results suggest that visual presentation of the MoCA may be preferential in HI individuals; however, it is still unclear whether there is a quantifiable difference in performance between standard presentation and visual-only presentation of MoCA materials in CI users.

Limitations and future directions

There are two limitations to the present study pertaining to the participant pool. First, there was an absence of neuropsychological testing to confirm the cognitive category of our CI users (i.e., normal cognition versus MCI versus dementia) and therefore no known cases of MCI or dementia were included in our CI sample. Given that performance on the delayed recall task has shown to be predictive of MCI and dementia, future work applying alternate MoCA scoring guidelines to CI users with confirmed cognitive decline could elucidate test sensitivity and specificity for detecting MCI in this population, and determine whether alternative MoCA scoring guidelines are appropriate replacements to traditional MoCA scoring in a CI population. Indeed, recent work by Al-Yawer et al. (2019) has shown that the use of these alternative scoring methods changes test sensitivity and specificity for detecting MCI and AD in normal-hearing individuals. Second, while our sample size is not atypical in the CI literature (e.g., Capretta & Moberly, 2016; Herzog et al., 2003; Olze et
al., 2011), it is relatively small, which may have limited our ability to detect smaller differences. Future research should aim for larger samples.

**Conclusion**

The MoCA was specifically designed to detect MCI in older adults suspected of having cognitive deficits (Nasreddine et al., 2005, 2012), but was not structured to accommodate individuals with sensory impairments even though disturbances in hearing or vision are more prevalent in the elderly. Here we show that strategic removal of auditory-based test items, specifically the delayed recall task, adjusts MoCA scores in CI users such that they more frequently achieve the passing threshold. Manipulation of the MoCA, either via the use of alternative scoring guidelines or lower cutoff scores, should be considered when screening for MCI in HI populations until normative data or standardized testing procedures (i.e., visual-only presentation of cognitive testing items for HI patients) are established.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

**References**


