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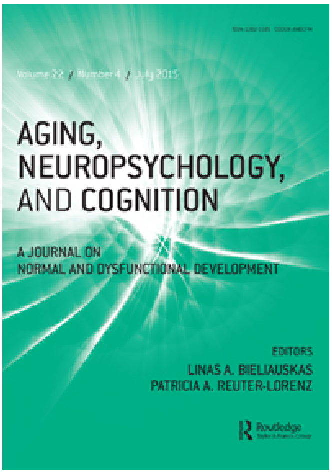

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Many standardized measures of cognition include items that must be seen or heard. Nevertheless, it is not uncommon to overlook the possible effects of sensory impairment (s) on test scores. In the current study, we investigated whether sensory impairments could affect performance on a widely used screening tool, the Montreal Cognitive Assessment (MoCA). Three hundred and one older adults (mean age = 71 years) completed the MoCA and also hearing and vision tests. Half of the participants had normal hearing and vision, 38% impaired hearing, 5% impaired vision, and 7% had dual-sensory impairment. More participants with normal sensory acuity passed the MoCA compared to those with sensory loss, even after modifying scores to adjust for sensory factors. The results suggest that cognitive abilities may be underestimated if sensory problems are not considered and that people with sensory loss are at greater risk of cognitive decline.

Keywords: cognitive screening; Montreal Cognitive Assessment; hearing loss; vision loss; dual-sensory loss

Many standardized measures of cognition include items that must be seen or heard. Nevertheless, it is not uncommon to overlook the possible effects of sensory impairment(s) on cognitive testing. Notably, a common experimental finding is that cognitive performance, in particular memory, can be affected by the quality of the sensory input during testing, even in adults who have little or no clinically significant sensory impairment (McCoy et al., 2005; Rabbitt, 1968, 1991; Schneider, Pichora-Fuller, & Daneman, 2010). Furthermore, the degree to which older adults who do have clinically significant sensory impairments are able to hear and/or see test stimuli will likely influence their cognitive test results.

The prevalence of sensory impairment is high in older adults and increases with age. Hearing loss (HL) affects at least one third of persons over the age of 65 years (e.g., Cruikshanks, Zhan, & Zhong, 2010); uncorrectable vision problems affect about one tenth of persons over the age of 70 years (e.g., Crews & Campbell, 2004); dual-sensory (hearing and vision) loss affects about one tenth to one fifth of those over the age of 80 years (e.g., Schneider et al., 2011; Smith, Bennett, & Wilson, 2008; Swenor, Ramulu,

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Willis, Friedman, & Lin, 2013). It is noteworthy that HL defined by pure-tone thresholds has been found in up to 90% of those who have dementia (Gold, Lightfoot, & Hnath-Chisolm, 1996) and is more prevalent in those with dementia than in age-matched controls (Uhlmann, Larson, Rees, Koepsell, & Duckert, 1989; Uhlmann, Teri, Rees, Mozlowski, & Larson, 1989). In addition, relationships have been found between tests of central auditory processing and cognitive declines: for example, individuals diagnosed with mild cognitive impairment (MCI) had worse performance on the Dichotic Digits Test (Musiek, 1983) compared to those with normal cognition, while individuals diagnosed with Alzheimer's disease (AD) had worse performance than those with MCI (Idrizbegovic et al., 2011). Moreover, reduced performance on tests of cognitive executive functioning has been associated with performance on tests of central auditory processing (Gates et al., 2010). Population studies have revealed links between sensory and cognitive aging (Baltes & Lindenberger, 1997; Lindenberger & Baltes, 1994). Epidemiological studies have suggested that audiometric thresholds (Gurgel et al., 2014; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011) and scores on dichotic speech tests (Gates, Anderson, McCurry, Feeney, & Larson, 2011; Gates, Beiser, Rees, D'Agostino, & Wolf, 2002) may be predictive of the future manifestation of dementia. Dual-sensory impairment is associated with even greater odds for cognitive decline (Laforge, Spector, & Sternberg, 1992; Lin et al., 2004). Thus, given the high prevalence of age-related sensory loss, the strong connection between sensory and cognitive functioning, and the higher risk for dementia associated with sensory loss, it is important to determine how sensory loss influences older adults' performance on measures of cognition and to better understand how the evaluation of sensory impairments could inform the interpretation of cognitive test results and clinicians' recommendations for case management.

Current practice guidelines recommend the use of screening measures such as the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) or the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) in the diagnosis of cognitive impairment (e.g., Feldman et al., 2008). Accordingly, recent work by Davey and Jamieson (2004) found that over 90% of neurologists in one UK sample used cognitive screening tests. The MMSE has long been considered the standard for cognitive assessment in primary care, and it continues to be the most commonly used cognitive screening tool worldwide (Damian et al., 2011). More recently, the MoCA has grown in popularity because of its usefulness for detecting mild degrees of cognitive impairment. Indeed, researchers in Canada, the United States, and England have all shown that the MoCA has higher sensitivity for identifying individuals with MCI and AD than the MMSE (90–100% vs. 17–78%; Luis, Keegan, & Mullan, 2009; Nasreddine et al., 2005; Smith, Gildeh, & Holmes, 2007). Furthermore, the MoCA is more accurate than the MMSE for identifying cognitive impairment in individuals with specialized medical conditions such as diabetes (e.g., Alagiakrishnan, Zhao, Mereu, Senior, & Senthilselvan, 2013), aneurysmal subarachnoid hemorrhage (e.g., Wong et al., 2013), and chronic heart failure (e.g., Cameron, Worrall-Carter, Page, Stewart, & Ski, 2013). The MoCA may also have higher sensitivity than the MMSE for predicting rehabilitation success in an inpatient geriatric population (Sweet et al., 2011). However, its specificity is lower compared to that of the MMSE (36–87% vs. 84–100%: Ismail, Rajji, & Shulman, 2010; Luis et al., 2009; Nasreddine et al., 2005; Smith et al., 2007).

One possible explanation for the lower specificity of the MoCA compared to the MMSE could be that individuals with sensory loss underperform because, apart from the instructions, test stimuli must be heard to earn 10 of the 30 possible points on the MoCA, but only 4 of the 30 possible points on the MMSE. Another difference between the MoCA and the MMSE that is especially relevant for the diagnosis of AD or amnestic MCI, in which memory loss is a primary concern, is that there are five words in the delayed recall item for the MoCA compared to only three for the MMSE. If an individual does not hear these words accurately or easily in the learning trials, then up to one sixth of the points on the MoCA may be compromised by hearing difficulty. As a result, apparent memory deficits may be exacerbated. In addition, test stimuli must be seen to earn 8 of the 30 possible points on the MoCA, but only 4 of 30 possible points on the MMSE. If the stimuli are not seen accurately or entirely, then there is a risk that the patient's degree of cognitive impairment may be overestimated.

Taking vision and hearing abilities into account could possibly improve the specificity of cognitive screening tests. For instance, Weinstein and Amsel (1986) found that, when a cognitive screening test was readministered using sound amplification in a group of institutionalized older adults with HL, one third of them were reclassified as having a lesser degree of dementia than was originally assessed. In another study, significantly better MMSE scores were obtained three months posthearing aid fitting compared to prefitting unaided scores (Acar, Yurekli, Babademez, Karabulut, & Karasen, 2011). Likewise, customizing the visual displays used in cognitive testing has been shown to reduce apparent cognitive declines in patients with AD and to eliminate them in healthy older adults and patients with Parkinson's disease (Toner et al., 2012). Thus, cognitive test results may be improved if care is taken to ensure that older adults have the best possible access to auditory and/or visual test stimuli given their sensory functioning and needs.

Alternatively, by removing or modifying some of the items that rely on sensory processing, it may be possible to derive scores that are uncontaminated by the effects of sensory loss. Such an approach was evaluated by developing a new scoring procedure for the MoCA (MoCA-Blind) with the four visually presented items removed. Although these modifications reduce test sensitivity (from 90% to 44% for patients with MCI and from 100% to 87% for patients with AD), the MoCA-Blind yields better test specificity (98%) than the original MoCA (87%) and increases the number of older adults who pass the cutoff score for normal cognition (Wittich, Phillips, Nasreddine, & Chertkow, 2010). No similar test modification of the MoCA has been undertaken for HL.

The current study was designed to evaluate the effects of hearing and vision loss (VL) on older listeners' performance on the MoCA test. A secondary purpose was to develop and obtain preliminary data on new proportional scoring systems to exclude items likely to rely heavily on auditory abilities. MoCA scores for older adults with normal hearing (NH) thresholds and normal visual (NV) acuity were compared to the scores of their peers with hearing, vision, or dual-sensory loss. The effect on MoCA scores of removing items relying on hearing or vision was also examined for those with and without sensory impairments. Reduced MoCA scores were expected for those with hearing and vision impairments, especially on items that relied on test stimuli being heard or seen. Furthermore, sensory impairments were expected to have an especially deleterious effect on delayed recall performance.

Method

Participants

Participants were 301 healthy, community-living older adults (M_{age} = 71.13 years, *SD* = 7.40) who were recruited for a larger study of the relationship between social and perceptual factors in aging. They were recruited from existing volunteer pools at the

University of Toronto, from the Canadian Hearing Society office in Toronto, and by advertisements placed in local newspapers. The majority of participants had received some university education ($M_{\text{years of education}}$ = 15.67, *SD* = 3.47), were retired (76%), and were female (64%). Participants were asked to rate their general health using the following scale: 1, Poor; 2, Average; 3, Good; 4, Excellent. The majority reported Good or Excellent overall health; 2% of participants answered "Poor," 16.6% "Average", 49.2% "Good", and 32.2% "Excellent," with an average score of 3.1 out of 4 (Good). More detailed participant characteristics are provided in Table 1. Participants were tested in one session lasting between two and three hours, including ample breaks, and they were given a small honorarium. The study was conducted in accordance with human ethics standards and received approval from the research ethics board of the University of Toronto.

Measures and instrumentation

Hearing thresholds

All participants completed a standard audiometric evaluation: pure-tone air-conduction thresholds were measured at standard octave frequencies from 250 to 8,000 Hz in each ear under Telephonics TDH-50P headphones using a Grason-Stadler 61 clinical audiometer in a sound-attenuating booth (American National Standards Institute, 2004a, 2004b). The average pure-tone air-conduction thresholds at 500, 1,000, and 2,000 Hz were calculated for the better ear (PTAB) and the worse ear (PTAW).

WIN

The Words-in-Noise (WIN; Wilson, Abrams, & Pillion, 2003; Wilson & Burks, 2005) test was used to determine the threshold for word recognition in noise. In this test, five words are presented in each of seven signal-to-noise ratio (SNR) conditions; the level of the speech is reduced so that the SNR conditions become progressively more difficult (from 24 to 0 dB SNR in 4 dB decrements). Following the standard procedure for administering the test, to achieve the SNRs, the level of the noise was varied and the level of presentation of the target words was fixed at 80 dB sound pressure level (SPL) for those whose PTAB was no more than 40 dB HL and at 90 dB SPL for those who had a higher PTAB. The WIN threshold is the dB SNR at which 50% of the words are correctly repeated. The test stimuli were presented over TDH-50P headphones from a Sony Compact Disk Player CE375 routed through the audiometer (hearing aids could not be worn during testing due to the use of headphones; presentation levels were titrated to each listener's auditory acuity).

Visual acuity

Data were collected at three sites. Depending on test location, Snellen far visual acuity (binocular) was measured for 297 of the 301 participants (glasses or contact lenses could be worn) using the standard Snellen chart (*n* = 153) or an Optec 6500P machine (*n* = 144: Stereo Optical, Chicago, IL, USA). The equipment required to test near visual acuity was only available at one of the testing locations and, as a result, these data were only obtained for a subset of the participants; near visual acuity (binocular) was measured using the Optec 6500P machine in a subset of 134 participants. Note that far visual acuity is the typical acuity measure used in many research projects and in physicians' offices, while

Table 1. Summary of participant characteristics (means and *SE*s).

	Normal hearing			Hearing loss		
	ALL (n = 165)	NV (n = 147)	VL (n = 16)	ALL (n = 136)	NV (n = 112)	VL (n = 22)
Participant characteristics	Mean (*SE*)	Mean (*SE*)	Mean (*SE*)	Mean (*SE*)	Mean (*SE*)	Mean (*SE*)
Age (years)	69.1 (0.5)	69.0 (0.6)	68.6 (1.3)	73.6 (0.6)	72.9 (0.7)	76.5 (1.4)
Gender (% female)	69	71	50	57	56	64
Retired (%)	74	74	69	80	79	86
Years of education	16.1 (0.3)	16.1 (0.3)	15.9 (0.9)	15.2 (0.3)	15.1 (0.3)	15.2 (0.7)
Health rating score (1–4)	3.1 (0.1)	3.2 (0.1)	2.6 (0.2)	3.1 (0.6)	3.1 (0.1)	2.8 (0.1)
Mean original MoCA score	26.2 (0.2)	26.4 (0.2)	24.6 (0.9)	24.3 (0.2)	24.4 (0.3)	23.9 (0.6)
Percent passing MoCA	66.1	69	44	37.5	40	32
Better ear thresholds (dB HL)						
250 Hz	8.0 (0.5)	7.9 (0.6)	9.4 (1.0)	22.2 (1.2)	21.7 (1.3)	25.5 (3.1)
500 Hz	7.6 (0.6)	7.5 (0.6)	9.1 (1.5)	26.3 (1.2)	25.6 (1.3)	30.2 (3.5)
1,000 Hz	7.5 (0.6)	7.4 (0.6)	8.8 (1.7)	32.4 (1.3)	31.6 (1.4)	36.9 (3.4)
2,000 Hz	11.1 (0.8)	11.3 (0.8)	10.0 (2.5)	39.5 (1.3)	38.5 (1.4)	44.0 (3.3)
4,000 Hz	22.7 (1.3)	22.6 (1.3)	23.1 (4.9)	49.6 (1.5)	48.9 (1.7)	52.6 (3.4)
8,000 Hz	38.0 (1.7)	38.2 (1.7)	37.2 (6.4)	65.2 (1.5)	64.1 (1.8)	70.2 (3.0)
PTAB (better ear, dB HL)*	9.2 (0.5)	9.1 (0.5)	10.0 (1.5)	33.8 (1.1)	33.2 (1.2)	37.0 (2.9)
PTAW (worse ear, dB HL)*	12.8 (0.5)	12.8 (0.5)	13.0 (1.5)	43.6 (1.3)	42.9 (1.3)	46.3 (4.6)
WIN (better ear; dB SNR)	7.9 (0.2)	7.9 (0.2)	8.4 (0.8)	13.5 (0.4)	13.2 (0.5)	15.2 (1.0)
Far acuity (in LogMAR units)	0.85 (0.01)	0.05 (0.01)	0.44 (0.17)	0.15 (0.16)	0.09 (0.01)	0.44 (0.02)

Notes: *Pure-tone thresholds at 500, 1,000, and 2,000 Hz were averaged for the better (PTAB) and worse ears (PTAW). Participants are divided into two groups: normal hearing and hearing loss, which are further divided into normal far vision (NV) and far vision loss (VL). Far vision data were unavailable for four participants.

near visual acuity scores are more relevant for the standard viewing conditions in which the MoCA is administered. As suggested in the literature (e.g., Holladay, 1997; Hussain, Saleh, Sivaprasad, & Hammond, 2006), LogMAR units equivalent to Snellen scores were used in analyses of visual acuity data.

Montreal Cognitive Assessment

The MoCA has 13 items designed to measure cognitive abilities including attention, memory, language, and visuospatial functions. The original English version of the MoCA was used in the current study. The MoCA is scored out of 30, with scores of 26/30 or higher considered to be within the normal range, scores of 25 or below indicating the possibility of cognitive impairment, and scores of 21 or below indicating the possibility of a more significant impairment (Nasreddine et al., 2005).

Novel MoCA scoring procedures to eliminate auditory items. Four MoCA items rely heavily on hearing for the to-be-repeated or to-be-remembered stimuli to be accurately perceived. These items were (1) language repetition, in which the participant listens to and repeats two short sentences (worth 2 points); (2) attention to letters, in which the participant listens to a string of 29 letters and taps his/her hand every time he/she hears the letter "A" (there are 12 "A"s; 1 point earned if <2 errors); (3) digit span, in which the participant first listens to and repeats a string of five digits forwards and then listens to and repeats a string of three digits backwards (2 points); (4) delayed recall, in which the participant recalls five words after a delay of approximately five minutes with intervening test items (5 points). For the five delayed recall words, participants have two learning trials in which they are instructed to immediately repeat the to-be-recalled words. Participants are told that they will have to remember these words both immediately and later on. It is important to note that the responses on the learning trials are not scored and, if items are omitted or repeated incorrectly, no adjustment is made to the delayed recall score.

In order to determine whether the items that rely on auditory function could be disproportionately influencing MoCA scores, three new scoring procedures were implemented with adjustments to the minimum scores needed to pass the test. These new minimum scores were calculated using proportionally adjusted cutoffs (as recommended by Wittich et al., 2010). That is, with the original scoring of the MoCA, the cutoff for a "normal" score is 25/30, or 83% of the total possible points. In the first new scoring procedure, items 1 (language repetition; 2 points), 2 (attention to letters; 1 point), and 3 (digit span; 2 points), which sum to a total of 5 points, were removed, with the maximum MoCA score becoming 25, and the revised cutoff score for a "normal" score becoming 21/25 (20.75/25 = 83%; i.e., need 22/25 to pass). In the second new scoring procedure, only item 4 (delayed recall; 5 points) was removed, with the maximum MoCA score becoming 25 (i.e., same score as with the first new scoring procedure). In the third new scoring procedure, all four auditory items (1, 2, 3, and 4; 10 points) were removed, with the maximum MoCA score becoming 20 and the cutoff score was adjusted to 17/20 (16.6/20 = 83%; i.e., need 18/20 to pass).

MoCA-Blind scoring procedures to eliminate visual items. Four MoCA items rely heavily on vision: (1) trail-making, in which the participant draws a line between numbers and letters, alternating between the two categories (1 point); (2) copying a cube, in which the participant copies a cube below the model cube (1 point); (3) clock drawing, in which the participant draws a clock, including number labels, and sets the hands to 10 minutes past eleven o'clock (3 points); and (4) naming, in which the participant says the words to identify three line drawings of animals printed on the page (3 points). Following Wittich et al. (2010), all four visual items described earlier were removed and a modified proportional visual scoring procedure was used (MoCA-Blind procedure). In this procedure, the MoCA was scored out of 22, with a cutoff score of 18/22 (18.3/22 = 83%; i.e., need 19/22 to pass).

Procedure

Upon arrival in the laboratory, participants first provided their consent. Next they completed a set of 14 questionnaires to assess their self-perceived memory and auditory abilities as well as their views of aging, followed by auditory and visual free recall (VFR) tests (details are described in Chasteen, Dupuis, Pichora-Fuller, Singh, & Smith, 2012). Finally, participants completed audiometric testing, the WIN test, the MoCA, and the assessment of their visual acuity (described earlier). The MoCA was administered in a quiet office space with the examiner seated across from the participant in the usual face-to-face manner. If participants owned hearing aids and/or corrective eyewear, these could be worn during all tests except for audiometry and the WIN test. Hearing aids were not worn during the auditory tests because these tests were administered under headphones and the protocols incorporated adjustments of the sound level according to the person's degree of HL. The entire session took approximately two hours on average, with breaks offered throughout. At the end of the session, participants were debriefed and given a small honorarium.

Results

Hearing and vision

Pure-tone hearing thresholds, WIN thresholds, and visual acuity results on the Snellen test converted to LogMAR units are provided in Table 1. The PTAW was used to categorize participants as having either NH (PTAW $\leq$ 25 dB HL; n = 165) or HL (PTAW $\geq$ 26 dB HL; n = 136). Those who scored equal to or better than 0.3 in LogMAR units on the vision test (equivalent to 20/40 on the Snellen test of far visual acuity) were considered to have NV (n = 259) acuity and those who scored worse were considered to have VL (n = 38). Of the 297 participants for whom Snellen far acuity data were available, 50% were categorized as having NH and NV acuity, 38% were categorized as having HL and normal vision, 5% were categorized as having NH and VL, and 7% were categorized as having dual losses. As described earlier, a subset of 134 participants completed the test of near visual acuity, and all but two of those participants also completed the test of far visual acuity. Of the 132 participants who completed tests of both far and near visual acuity, 92% were normal on both, 1.5% had both far and near VL, 5% had normal far vision but near VL, and 1.5% had far VL but normal near vision. Thus, in 94% of the cases, assignment to the normal vision or VL categories was consistent for both near and far acuity measures. Given that the MoCA relies on near vision, in order to isolate hearing from VL, a conservative approach would be to restrict the sample to only those 122 participants who passed both far and near visual acuity tests. Note that, using only far vision acuity to define normal vision, 7% of the 297 participants were categorized as having dual-sensory impairment, whereas for the sample of 132 who completed both far and near visual acuity tests, if normal vision is defined based on both far and near vision, then only slightly more (7.5%) were categorized with dual-sensory impairment. Furthermore, there were only two participants who had HL in addition to abnormal far and abnormal near vision.

MoCA

In total, 47% of the 301 participants obtained MoCA scores below the usual cutoff for normal cognition. Compared to those who passed the MoCA (n = 160), the participants who failed the MoCA (n = 141) were older (M_{pass} = 69.74 years, SD = 6.68; M_{fail} = 72.7 years, SD = 7.79; $t(299)$ = 3.50, P = .001, d = .43), in poorer self-reported health (M_{pass} = 3.24, SD = .71; M_{fail} = 2.94, SD = .74; $t(298)$ = 3.64, $P < .001$, d = .42), and had higher PTABs (M_{pass} = 21.5 dB HL, SD = 15.67; M_{fail} = 32.58 dB HL, SD = 20.55; $t(299)$ = 5.19, $P < .001$, d = .60) and higher WIN thresholds (M_{pass} = 9.03, SD = 3.77; M_{fail} = 11.98, SD = 5.06; $t(299)$ = 5.68, $P < .001$, d = .66).

A significantly higher proportion of those with NH and vision obtained MoCA scores within the normal range compared to those with hearing or vision impairments. Specifically, 66% of those in the NH group, but only 38% of those in the HL group, had MoCA scores in the normal range (χ^2 = 24.42, df = 1, $P < .001$) while 56% of those in the NV group, but only 37% of those in the VL group, had MoCA scores in the normal range (χ^2 = 4.88, df = 1, P = .036).

For the 122 individuals who had normal near and far visual acuity, 52% passed the MoCA. Seventy-three of these 122 participants (60%) also had NH thresholds. Of those in the NH group, 68% had MoCA scores in the normal range, compared to 37% of those in the HL group (χ^2 = 11.99, df = 1, P = .001). There were two individuals with dual-sensory loss (abnormal near and far visual acuity and abnormal hearing thresholds) and both failed the MoCA when the original scoring was used (scores of 18 and 22).

Original versus new MoCA scoring: auditory

Analysis for all 301 participants

The mean scores determined using the original MoCA scoring procedure are provided in Table 1. Figure 1 shows the mean scores for the original and the three new auditory scoring procedures for the NH and HL groups; scores are expressed as proportions of the total possible score (i.e., 30, 25, 25, and 20, respectively, for the original and three new scoring procedures). When the original scoring procedure was used, participants in the NH group had significantly higher scores (M = 26.18, SD = 2.59) than those in the HL group (M = 24.26, SD = 2.9), $t(299)$ = 6.08, $P < .001$, d = .70. Participants in the NH group also had significantly higher scores than participants in the HL group using the first new scoring procedure, $t(299)$ = 5.57, $P < .001$, d = .64, the second new scoring procedure, $t(299)$ = 4.68, $P < .001$, d = .54, and the third new scoring procedure, $t(299)$ = 3.66, $P < .001$, d = .42.

Chi-square analyses indicated that the number of participants who passed the MoCA was significantly higher for the NH compared to the HL group for the original scoring procedure, χ^2 = 24.42, df = 1, $P < .001$; the first new procedure, χ^2 = 22.64, df = 1, $P < .001$; the second new procedure, χ^2 = 19.32, df = 1, $P < .001$; and the third new procedure, χ^2 = 15.88, df = 1, $P < .001$. Importantly, the difference between the number of participants in the NH and HL groups whose scores fell below the cutoff for normal was reduced to a similar degree for the second and third scoring procedures. The highest

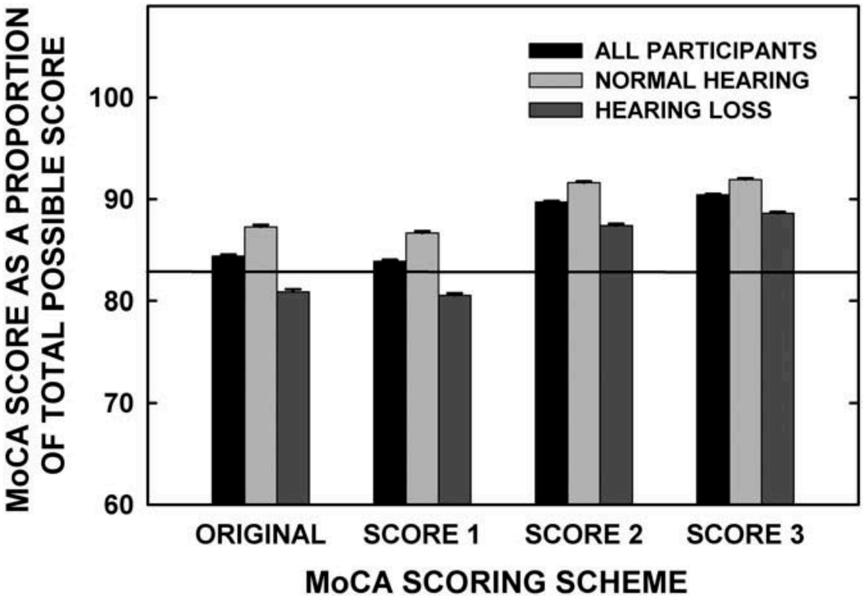

Figure 1. Mean MoCA scores (and *SE*s) calculated using the original and three new proportional scoring procedures, plotted as a proportion of the total possible score for each scoring procedure. Black bars represent the mean scores across all participants (N = 301); dark gray bars represent the scores of the normal hearing group (n = 165); light gray bars represent the scores of the hearing loss group (n = 136). Line at 83% indicating cutoff for passing using proportional scoring.

number of participants in both the NH and HL groups passed the MoCA when scoring procedure two was used (Figure 2(a)). Indeed, a chi-square analysis using the McNemar test indicated that, compared to the original scoring procedure, a significantly higher proportion of individuals passed the MoCA when the second scoring procedure was used (71% compared to 53% originally; χ^2 = 119.28, df = 1, P < .001). The proportion of people who passed the MoCA when the delayed recall item was removed increased by 16% for the NH group and by 21% for the HL group. Nevertheless, even with removal of the delayed recall item, over twice as many participants with HL as participants with NH did not pass the MoCA (41% vs. 18%). Odds ratios were calculated for the original and second scoring procedures. For the original scoring procedure, participants in the HL group were 3.24 times (95% confidence interval (CI), 2.20–5.21) more likely to fail the MoCA than participants in the NH group. Similarly, when the second scoring procedure was used, participants in the HL group were 3.15 times (95% CI, 1.87–5.31) more likely to fail the MoCA than participants in the NH group, suggesting that the second scoring procedure did not eliminate the deleterious effects of HL on MoCA performance.

Analysis for 122 participants with normal near and far visual acuity

The difference in the number of people passing the MoCA, even when the second new scoring procedure was used, may be related to vision impairment combined with HL. Indeed, significant effects of VL were found when either the original or modified scoring procedures were used. The number of participants who passed the MoCA was significantly higher for those with normal far vision (n = 259) compared to those with far VL

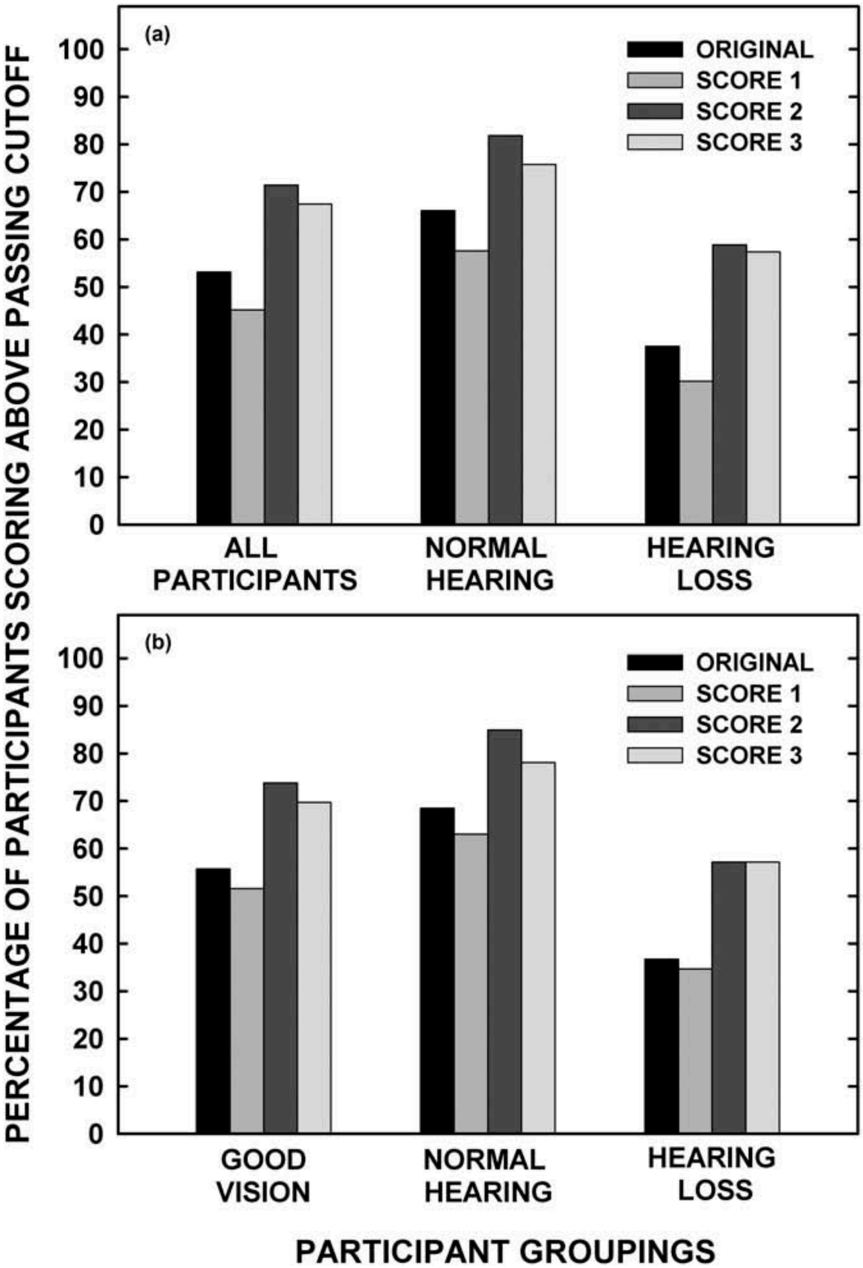

Figure 2. (a) Percentage of all participants ($N = 301$), normal hearing group ($n = 165$), and hearing loss group ($n = 136$) participants who scored above the cutoff passing score for the four MoCA scoring procedures. For the original scoring procedure, the cutoff score for passing was 25/30, for the first and second new scoring procedures it was 21/25, and for the third new scoring procedure it was 17/20. In both (a) and (b), black bars represent the original procedure, dark gray bars represent the first, light gray bars represent the second, and striped bars represent the third scoring procedure. (b) Percentage of all participants with good near and far visual acuity ($N = 122$), normal hearing group ($n = 79$), and hearing loss group ($n = 43$) participants who scored above the cutoff passing score for the four MoCA scoring procedures.

(n = 38) when the original scoring procedure was used, $\chi^2 = 4.88$, $df = 1$, $P = .027$, and when the second auditory scoring procedure was used, $\chi^2 = 4.11$, $df = 1$, $P = .43$. Those with vision impairment might have been disadvantaged because the items that relied on participants being able to see the stimuli were retained when the new auditory scoring procedures were used.

To rule out the possible effect of VL on MoCA scores, a set of analyses was conducted using the original and three new auditory scoring procedures only for the subset of participants (N = 122) for whom normal near and far visual acuity (NV) had been confirmed. The 122 participants with normal near and far visual acuity were divided into NH (NH–NV; n = 73) and HL (HL–NV; n = 49) groups. Using the original scoring procedure, participants in the NH–NV group had higher scores than participants in the HL–NV group ($M_{NH–NV} = 26.36$, $SD = 2.54$, $M_{HL–NV} = 24.51$, $SD = 2.97$; $t(120) = 3.68$, $P < .001$, $d = .67$). This group difference, presumably due to hearing impairment uncontaminated by VL, held when the first ($M_{NH–NV} = 21.86$, $SD = 2.27$, $M_{HL–NV} = 20.37$, $SD = 2.56$; $t(120) = 3.38$, $P < .001$, $d = .62$), second ($M_{NH–NV} = 23.0$, $SD = 1.62$, $M_{HL–NV} = 21.94$, $SD = 1.94$; $t(120) = 3.28$, $P < .001$, $d = .60$), and third new scoring procedures ($M_{NH–NV} = 18.51$, $SD = 1.29$, $M_{HL–NV} = 17.80$, $SD = 1.54$; $t(120) = 2.75$, $P < .001$, $d = .50$) were used.

Chi-square analyses indicated that the number of participants who passed the MoCA was significantly higher for the NH–NV compared to the HL–NV individuals for the original scoring procedure, $\chi^2 = 11.99$, $df = 1$, $P = .001$; the first new procedure, $\chi^2 = 9.42$, $df = 2$, $P = .002$; the second new procedure, $\chi^2 = 11.70$, $df = 1$, $P = .01$; and the third new procedure, $\chi^2 = 6.08$, $df = 1$, $P = .014$. As was found in the analysis earlier, and as shown in Figure 2(b), the difference between the number of participants in the NH–NV and HL–NV groups whose scores fell below the cutoff for normal was reduced to a similar degree for the second and third scoring procedures, and the highest number of participants passed the MoCA when the second scoring procedure was used. Again, a chi-square analysis using the McNemar test indicated that, compared to the original scoring procedure, a significantly higher proportion of individuals passed the MoCA when the second scoring procedure was used (71% compared to 53% originally; $\chi^2 = 48.67$, $df = 1$, $P < .001$). For participants in the NH–NV group, 69% passed the MoCA using the original scoring procedure, while the pass rate increased to 85% when the second scoring procedure was used. For participants in the HL–NV group, 37% passed the MoCA using the original scoring procedure, while the pass rate increased to 57% when the second scoring procedure was used. Thus, the improvement in pass rates when the delayed recall item was removed was larger for participants with HL. However, as was the case when vision was not controlled, even after removing the delayed recall item, over twice as many participants in the HL–NV group as participants in the NH–NV group failed the MoCA (43% vs. 15%). Including only individuals with normal near and far vision yielded a similar pattern of results in terms of the effect of the scoring procedures on the differences between the groups (NH–NV vs. HL–NV) in the number of individuals who pass the MoCA. For participants in the HL group, the number who passed the MoCA using the second scoring procedure (58%) was identical regardless of whether or not only individuals with normal near and far vision were included. There was a slight increase in the number of participants in the NH group who passed when only those individuals with normal near and far vision were included (84%) compared to when all 165 individuals in the NH group were included (81%).

Original versus new MoCA scoring: visual

Wittich et al. (2010) evaluated the effect of visual impairment on MoCA scores by removing four visually presented items and rescoring the test. However, they did not know the visual acuity of their participants. In the current study, Snellen far acuity scores were obtained for 297 of the participants. As a result, the consequences of rescoring the MoCA could be evaluated for groups of participants with and without far vision impairment. For the current analysis, those with Snellen far acuity of 20/40 (LogMar 0.3) and better were placed in the normal vision group (NV; n = 259) and those with worse acuity were placed in the VL group (VL; n = 38).

Mean scores were higher for participants in the NV group compared to participants in the VL group when the MoCA was scored using the original procedure (M_{NV} = 25.51, SD = 2.78, M_{VL} = 24.16, SD = 3.25; $t(295)$ = 2.74, P = .007, d = .45). Note that this difference in mean score was no longer significant when the MoCA-Blind scoring procedure was used (M_{NV} = 18.84, SD = 2.32, M_{VL} = 18.05, SD = 2.59); however, there was a trend towards continued differences between the two groups ($t(295)$ = 1.92, P = .056, d = .32). In terms of the number of individuals who were deemed to have passed, using the MoCA-Blind scoring, 60% of participants in the NV group and 42% of participants in the VL group passed the MoCA cutoff, compared to 56% and 37%, respectively, who passed when the original scoring procedure was used. Chi-square analyses indicated that the number of participants who passed the MoCA was significantly higher for participants in the NV group compared to those in the VL group for the original scoring procedure, χ^2 = 4.88, df = 1, P = .027, and for the MoCA-Blind scoring procedure, χ^2 = 4.47, df = 1, P = .035.

Proportional scoring versus absolute subtraction scoring adjustments

In the proportional scoring approach described earlier, new passing cutoffs were set to be 83% correct, which corresponds to the original pass point for the MoCA (26/30). An additional series of analyses were calculated using an absolute subtraction approach to create cutoff scores for the new auditory scoring procedures. That is, rather than calculate new cutoff points that corresponded to a score of 83%, new scores were created by simply subtracting the number of points that could have been earned for the removed item(s). For scoring procedures one and two, where the maximum number of possible points was 25, participants would need more than 20/25 to pass, while in scoring procedure three, where the maximum number of possible points was 20, participants would need more than 15/20 to pass. Appendix 1 shows the percentage of individuals who passed the MoCA using the absolute subtraction approach to calculate cutoffs for the new auditory scoring procedures. Compared to when the original scoring method was used (53%), more participants pass the MoCA when the second new scoring procedure was used, using either the proportional (71.4%) or the absolute subtraction (82.7%) scoring adjustments. The proportional scoring method is a more conservative approach and it is the one recommended by Wittich et al. (2010). Results using this alternative scoring approach are provided to illustrate the potential advantages of using proportional scoring, namely, improved test sensitivity, described by Wittich et al. (2010).

Analysis of the MoCA delayed recall items

Of the three new scoring procedures used to eliminate items that relied heavily on hearing, the second procedure differed the most from the original scoring method in terms of the number of participants who passed the MoCA. Recall that only the delayed recall item was removed in the second scoring procedure. Further analyses explored whether the effect of HL on this item was due to problems at initial encoding of the words or at retrieval after a delay.

There are five words in the MoCA delayed recall item. Participants have two learning trials with these five words; the set of five words is read to participants twice, and after each set, they are asked to repeat as many words as they can aloud. We examined how accurately the lists were repeated during the learning trials. If a word was not repeated correctly on the learning trials, then it stands to reason that later recall of the words would be compromised. Conversely, if a word was correctly repeated on the learning trials but was not accurately recalled later then retrieval problems would be implicated. Sensory difficulty would primarily hamper encoding during the learning trials, whereas errors in delayed recall following accurate repetition on the learning trials suggest difficulty at retrieval that may not be attributable to sensory problems. Unfortunately, substitutions during the learning trials (e.g., repeating "fate" instead of "face") were not recorded; therefore, it was not possible to analyze the participants' incorrect repetitions.

First, we examined the frequency with which individuals in the NH and HL groups correctly repeated the words on either one or on both learning trials. Overall, each of the words was repeated correctly at least once on over 97% of the learning trials. Figure 3(a) shows the percentage of times that each word was accurately repeated on both learning trials.

We also determined how many participants were able to repeat each of the five words correctly on both of the learning trials (i.e., 5/5 correct repetitions on both trials). In the HL group, 60% of the participants were able to repeat all of the items correctly on both learning trials, compared to 85% of the participants in the NH group; there was a significant difference between the two groups in the frequency of correct repetitions ($\chi^2 = 25.83$, $df = 1$, $P < .001$). Note that, when the words were examined individually, all of the words except "church" were repeated correctly significantly more often by the NH group than by the HL group.

We then examined recall performance analyzing only the words that had been accurately repeated on both learning trials. As shown in Figure 3(b), participants in the NH group significantly outperformed participants in the HL group for "face" ($t(270) = 4.19$, $P < .001$, $d = .52$), "velvet" ($t(282) = 3.20$, $P = .002$, $d = .39$), "church" ($t(281) = 2.94$, $P = .002$, $d = .35$), and "daisy" ($t(268) = 2.65$, $P = .009$, $d = .33$); however, as illustrated in Figure 4, there was no difference in overall scores between the NH and HL groups for the last word "red" ($P = .36$). Similarly, chi-square analyses revealed that there was a significantly higher percentage of words recalled by the NH group compared to HL group for each the first four words, but no difference for the last word "red." Thus, the recency effect was equivalent for both NH and HL groups, but the primacy effect was stronger for the NH group than for the HL group. The difference between groups in the primacy effect, even for words that were correctly repeated twice during the learning trials, suggests that there could be problems in retrieval of the items from memory that may not be entirely attributable to problems during encoding.

Analysis of modality-specific effects

If the differences between the NH and HL groups on the delayed recall item are attributable to the modality-specific effects of HL on encoding, then recall for items presented visually should not be reduced in the HL group. As described earlier, in addition

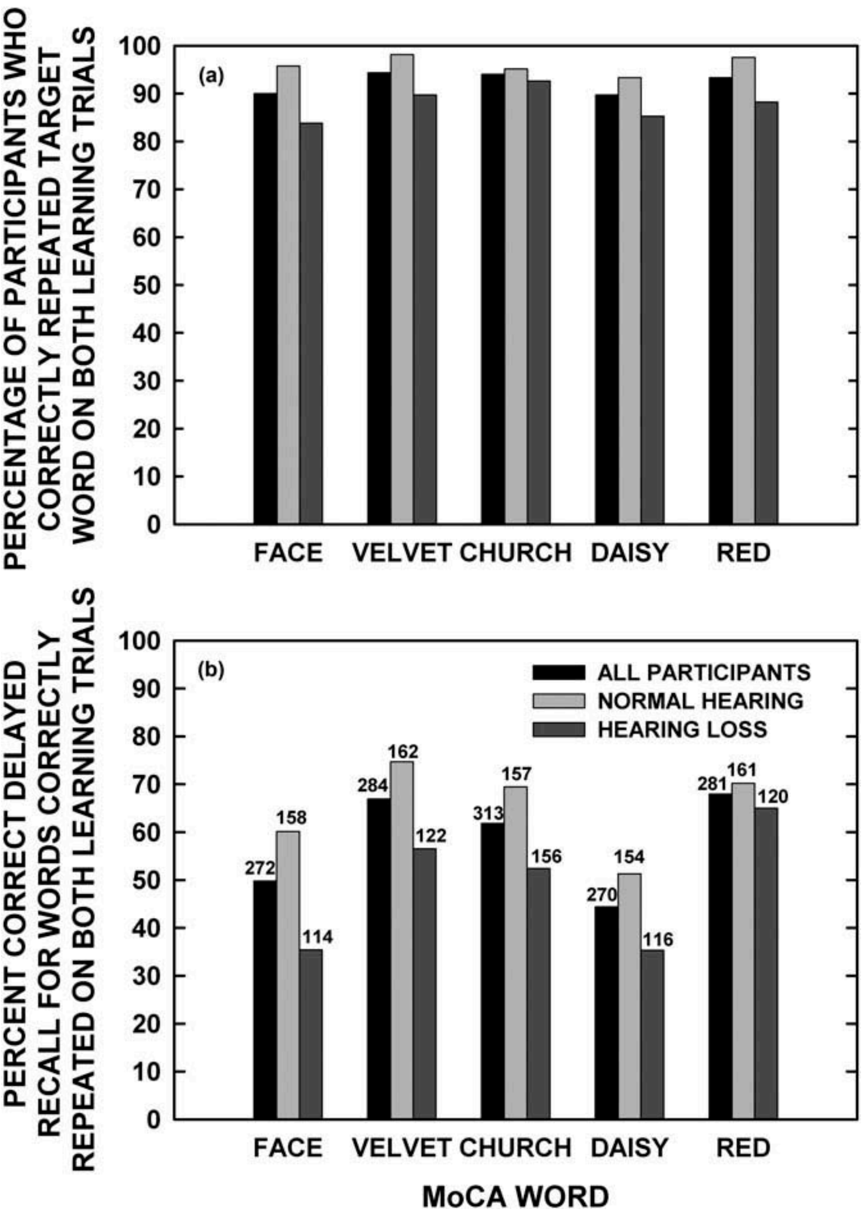

Figure 3. (a) Percentage of participants who correctly repeated each target word on both learning trials. Black bars represent all participants (N = 301); dark gray bars represent the normal hearing group (n = 165); light gray bars represent the hearing loss group (n = 136). (b) Percent correct delayed recall for the MoCA words that were correctly repeated on both learning trials. Note that the number of individuals whose data are represented in each column varies depending on how many participants correctly repeated the word on both learning trials and is indicated on the graph above the corresponding bars. Black bars represent the total group of participants; dark gray bars represent the normal hearing group; light gray bars represent the hearing loss group.

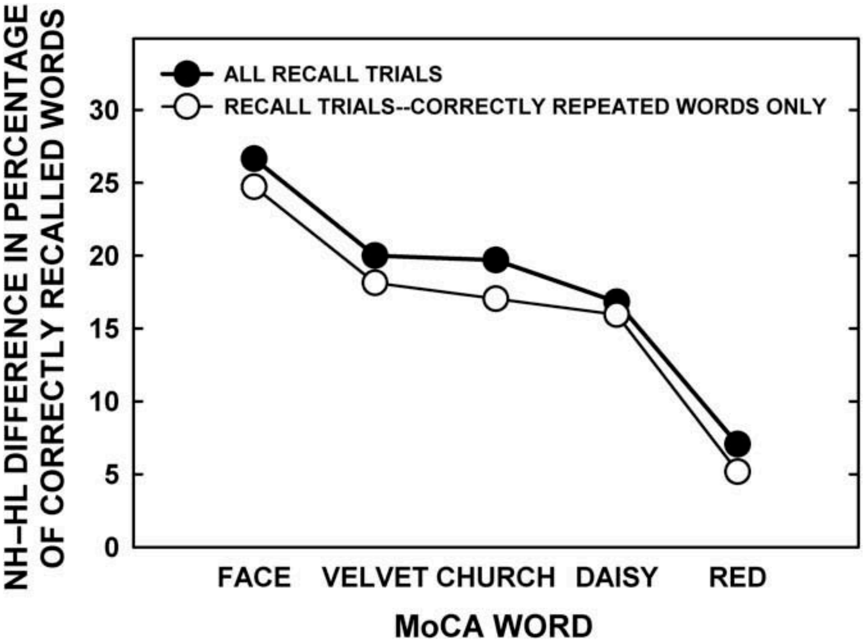

Figure 4. Serial position curve representing the percentage of correctly recalled words, plotted as the mean difference between the results for the normal hearing (NH) and hearing loss (HL) groups for each MoCA word. Closed circles represent NH–HL difference scores for all recall trials; open circles represent NH–HL difference scores only for recall trials where the word had been correctly repeated twice during learning.

to the MoCA, participants also completed two tests of free recall, one with visual and the other with auditory presentation of the test words. In each test, 15 words were presented at a rate of one word every two seconds as either text (Microsoft PowerPoint) or speech (delivered from the audiometer under headphones at the same sound level as the WIN words were presented). In each test, after the presentation of the word list was completed, participants were given three minutes to write down as many words as they could remember, in any order, on a piece of paper. Different words were used in the two modalities. The number of words correctly recalled in each test was then correlated with the score on the five-word delayed recall item on the MoCA. As expected, for both groups, there were significant correlations between the scores on the MoCA delayed recall item and the auditory free recall (AFR: $r = .34$, $P < .001$) test. MoCA delayed recall performance also correlated significantly with performance on the VFR ($r = .40$, $P < .001$) task. The scores on the AFR and VFR tests were also significantly correlated with each other ($r = .50$, $P < .001$). A follow-up repeated-measures analysis of variance with free recall modality (AFR, VRF) as the within-subjects factor and hearing group (NH, HL) as the between-subjects factor was conducted to examine potential group differences in performance on the AFR and VFR tests. There were main effects of hearing group, $F(1, 282) = 33.30$, $P < .001$, $np^2 = .11$ and modality, $F(1, 282) = 15.75$, $P < .001$, $np^2 = .05$, but there was no significant interaction between the two factors ($P = .60$). Post hoc comparisons for the main effects indicated that participants in the HL group ($M = 4.91/15$, $SD = 1.61$) had lower recall accuracy scores overall when compared to participants in the NH group ($M = 6.07/15$ $SD = 1.77$) and that all participants had higher recall for the AFR items (M = 5.73/15 SD = 1.97) compared to the VFR items (M = 5.25/15 SD = 2.0). Thus, it may be that the poorer recall performance of the HL group compared to the NH group is not confined to presentation of auditory test stimuli and cannot easily be attributed solely to the modality-specific effects of HL on the encoding of test stimuli. Although people with HL may have difficulty hearing instructions during testing, the same instructions were presented orally by the experimenter for both the AFR and VFR tasks; thus, it is unlikely that difficulty hearing the instructions would account for the pattern of results that were observed.

Discussion

In the current study, the independent and potentially interactive contribution of sensory and cognitive factors to performance on the MoCA was investigated. Participants with sensory loss were more likely than participants with NH and normal vision to score below the cutoff for normal cognitive function when the original MoCA scoring procedure was used. Indeed, using the original scoring procedure, 47% of the older adults in this sample of 301 participants were categorized as having possible cognitive impairment, with 66% of those in the NH group, but only 38% of those in the HL group, scoring above the original cutoff for passing. Note that the percentage of individuals scoring below the cutoff is higher than the reported MCI prevalence rate of 14–18% for people over the age of 70 years (Petersen et al., 2009). Of course, a failing score on the MoCA is not necessarily indicative of MCI; it is likely that if many of those individuals in the current study who failed the MoCA were to complete extensive neuropsychological testing, they would not meet criteria for MCI (e.g., Hawkins et al., 2014). It is likely that the 34% failure rate of individuals with NH would be significantly lower had more stringent criteria been used to determine whether they met criteria for MCI.

The current findings suggest that HL affects performance on the MoCA. Furthermore, the effect of HL on MoCA scores can be compounded by the effect of vision impairment. Neglecting to take sensory impairments into account when conducting cognitive screening may, at least in some cases, lead to cognitive impairment being overestimated and over-referral for comprehensive evaluations.

Effects of modified scoring

Auditory-related modifications

The discrepancy in the percentage of participants with and without HL who passed the MoCA was reduced, but not eliminated, when items relying on hearing were omitted from scoring. Delayed recall appeared to make the largest contribution to the differences in MoCA scores between the NH and HL groups. With the second modified scoring procedure, in which the delayed recall item was eliminated, 71% of the participants passed the MoCA. Indeed, both the NH and HL groups were more likely to pass the MoCA when the second compared to the original scoring procedure was used. Of note, when the sample was restricted to only those participants who had normal near and far visual acuity, the number of participants who passed the MoCA cutoff using the second modified scoring procedure increased to 74% and the difference between groups was reduced to 28% more passing in the NH group than in the HL group (compared to a 32% difference in the number passing when the original MoCA scoring procedure was used). Nevertheless, even when the modified scoring procedure was used, participants with sensory loss continued to perform worse than those with NH-NV, and a smaller percentage of individuals with sensory loss than individuals with NH-NV passed the MoCA.

The delayed recall item (with a total possible score of 5 points) was key to the differences in the percentage of participants in the NH and HL groups who passed the MoCA. An analysis of participants' learning of the five words in the delayed recall item of the MoCA was conducted to examine the possible effects of HL during encoding. If participants do not accurately hear or encode the words during the learning trials, they could potentially lose up to one sixth of the total number of points on the MoCA. Participants with HL did not correctly repeat the delayed recall words as often as participants with NH. Specifically, 96% of the participants in the NH group correctly repeated at least one of the five test words on both learning trials and 85% correctly repeated all five words on both learning trials. Fewer (88%) of the participants in the HL group correctly repeated at least one of the five words on both learning trials and only 60% were able to correctly repeat all five words on both learning trials. An odds ratio analysis revealed that those who were unable to correctly repeat all five words on both learning trials were 0.4 times more likely to fail the MoCA (95% CI, 0.22–0.64) than those who did successfully repeat all test words on the learning trials. Of those who repeated words incorrectly during the learning phase (79 of 301 participants), 30% were in the NH group whereas more than twice as many (70%) were in the HL group. Taken together, these results suggest that initial encoding was compromised by HL in almost half of participants in the HL group, with potential downstream effects on MoCA pass rates.

Note that there is currently no provision to adjust scoring on the MoCA depending on whether the five delayed recall words are correctly repeated during the two learning trials. For example, modifications to MoCA scoring could be made such that, if a participant responds "faith" rather than "face" during the learning trials and recalls the word "faith" after a delay, their score could be adjusted to give credit for accurately recalling the misperceived item. Alternately, if a word is misperceived during the learning trials (e.g., "lazy" rather than "daisy"), then the delayed recall section could be scored out of four rather than five, and the total possible score on the MoCA could be adjusted accordingly.

Apart from recall errors due to the misperception of words during the learning phase, early work by Rabbitt (1968) demonstrated that words heard in quiet which were repeated accurately were nevertheless not remembered as well when there was competing noise on some of the trials in a list compared to when the entire word list was presented in quiet. This finding suggests that even small levels of sensory degradation on or nearby the items to be recalled could potentially affect memory performance. The effortfulness hypothesis suggests that poor auditory processing at encoding may compromise later recall by reducing the resources available for optimal processing of heard information (Wingfield, Tun, & McCoy, 2005). Indeed, Tun, McCoy, and Wingfield (2009) have demonstrated that there are strong negative costs of age-related HL on a secondary visual tracking task when the primary task is listening to and repeating words. It can be presumed that individuals with HL are not receiving the signal with the same strength as their NH counterparts. Therefore, even repeating the words correctly on the learning trials of the MoCA does not necessarily guarantee that the items are encoded as well as they would be under more favorable listening conditions (e.g., Murphy, Craik, Li, & Schneider, 2000). Indeed, work by Baldwin and Ash (2011) suggests that decreasing the presentation level of a listening span test affects recall in both younger and older adults, but that there is a more detrimental effect on older adults compared to younger adults, even in a sample of older individuals with normal audiometric thresholds. In the current study, the two groups (NH and HL) recalled words in the recency portion of the list equally well, but they differed significantly in recalling items in the primacy portion of the list, suggesting that memory for the items in the early portion of the list is not encoded as well and/or decays faster for those in the HL group compared to those in the NH group.

It is interesting to note that there were group differences not only for measures presumed to implicate auditory processing (i.e., MoCA delayed recall item and AFR task) but also on the VFR task, with those in the HL group recalling fewer visually presented words than those in the NH group. Group differences in recall on the VFR test suggest that there is a modality-general deficit in delayed recall for individuals with HL above and beyond reductions in performance that are attributable to misperceptions or poorer encoding during the learning phase. It may be that the additional effort which individuals who are hard of hearing must continuously expend when listening in everyday environments has downstream effects on neural structure and/or function, which in turn leads to these modality-general issues in their cognitive abilities. Indeed, Peelle, Troiani, Grossman, and Wingfield (2011) have found connections between hearing acuity and both neural responses and gray matter volume in older listeners, while longitudinal data demonstrate that over a span of 6 years, older individuals with hearing impairment at baseline had accelerated rates of atrophy in whole brain and temporal lobe gray matter volumes when compared to those with NH at baseline (Lin et al., 2014).

Vision-related modifications

In addition to the creation of new scores to minimize the effects of HL on MoCA scores, we also used the MoCA-Blind scoring procedure recommended by Wittich et al. (2010) to examine the differential effects of modified scoring of visual items on people with and without VL. Similar to what was found using the new scoring procedures adapted for hearing impairment, eliminating the items relying on vision had a modest reduction on the disparity between the number of participants with normal vision and the number with vision impairment who passed the MoCA (from 19.14% to 18.1%).

Scoring modification caveats

Modifying the scoring of the MoCA is one approach to overcoming the possible confounds between sensory and cognitive impairments that might influence the accuracy of cognitive screening. Indeed, Breitner et al. (1999) report adjusting scores on the Modified Mini-Mental State for sensory deficits by removing incorrect or missing responses and then calculating the percentage correct among the remaining items. However, removing items would likely have a negative effect on test validity. It may be that those items which were eliminated were accurately measuring the presence of cognitive loss, and, by removing these items, important information about the participant's cognitive functioning could be lost. Alternate measures of these skills (e.g., standardized neuropsychological tests) may be used to supplement the removed items. A second alternative approach would be to maintain the original scoring, with the option to use equivalent stimuli presented in alternative or multiple modalities. For example, a multimodal presentation strategy could be used in which the delayed recall words are presented as text in addition to being spoken if the client is hard of hearing, or the words could be signed if the person is Deaf. Indeed, there is an extensive literature on audiovisual speech perception showing that the perception of visual speech complements auditory speech perception such that visual speech perception enhances the accuracy of the speech perception in noise and also increases the speed of auditory speech processing in quiet, implicating cross-modal integration mechanisms in the brain (e.g., van Wassenhove, Grant, & Poeppel, 2005). However, the ability to integrate multisensory information can be reduced in individuals with HL (Musacchia, Arum, Nicol, Garstecki, & Kraus, 2009). In addition, audiovisual stimulus presentation can improve working memory performance for individuals with NH when listening in noise (Pichora-Fuller, 1996) and for individuals with HL when listening in quiet (Brault, Gilbert, Lansing, McCarley, & Kramer, 2010). Older adults may even derive the same level of working memory benefit from audiovisual presentation as their younger counterparts (e.g., Frtusova, Winneke, & Phillips, 2013). Based on these findings, it is imperative that testers ensure that the client is watching them and attending to visual speech cues while the words are spoken in order to improve the likelihood that beneficial speechreading cues can be used to facilitate encoding and recall of the words. For those with HL or with severe dual-sensory loss, tactile cues or the use of objects (e.g., a piece of velvet, a model of a church with a steeple) may even be considered as an option if auditory encoding is not possible. It is important to note that clients with severe dual-sensory loss would most likely still have significant difficulty on testing, even if alternative modalities were used to present test stimuli. Future research would be needed to confirm the equivalence of items presented in alternative modalities and to establish test properties if sensory impairments are accommodated by substituting rather than eliminating items that are difficult for the individual to hear and/or see.

Implications and recommendations for clinical practice

The results from the current study emphasize the importance of considering and/or assessing an individual's auditory and visual functioning when administering and interpreting scores on cognitive screening measures such as the MoCA. This is especially important for physicians whose main strategy for the diagnosis of dementia is often an orally administered evaluation in a test environment in which there may be varying levels of ambient noise. Recent work by Jorgensen, Palmer, and Fischer (2014) indicates that only 13% of patients in a primary care clinic who presented with concerns about memory loss were asked about their hearing status. Not taking an individual's sensory abilities into account may lead to misdiagnosis or overdiagnosis of cognitive loss, at least in some cases, with possibly serious consequences for patients and their family members. Given the rapidly growing population of older individuals being diagnosed with cognitive impairment (14% of Americans aged 71 years and older; Plassman et al., 2007), incorrect diagnoses could have devastating implications not only for patients and their family members but also for the health care system as a whole. From a health economics perspective, the cost of caring for older individuals with cognitive loss is growing rapidly; the total estimated worldwide costs of dementia in 2010 were US$604 billion (Wimo & Prince, 2010). Inaccurate assessments of cognition would likely increase these costs unnecessarily.

Research showing strong connections between HL and incident dementia (e.g., Gates et al., 2011; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011) and VL and dementia (e.g., Pham, Kifley, Mitchell, & Wang, 2006; Uhlmann, Larson, Koepsell, Rees, & Duckert, 1991) further emphasizes the importance of considering sensory health in this potentially vulnerable older population and the need for closer tracking of cognition over time in these cases. It seems that those with sensory loss are at a greater risk of developing cognitive loss and/or may show a faster trajectory of decline than their counterparts with no sensory impairments. For example, Swenor et al. (2013) have suggested that those with concurrent visual and hearing impairments could potentially have a more accelerated rate of cognitive decline than would be seen in individuals with hearing impairment alone. To our knowledge, however, there have been no studies comparing the magnitude of decline on MoCA test scores over time for older adults with NH and/or vision compared to older adults with sensory loss. As recently recommended by O'Malley (2013), research must also be conducted to determine whether integrating assessment and treatment of sensory loss into existing intervention models would serve to improve patient-centered outcomes in an older population.

Follow-up protocols

There are a number of strategies that clinicians may integrate into their practice to avert misdiagnosis or overdiagnosis of cognitive impairment in older adults who have sensory impairment(s). These could include (1) incorporation of hearing and vision screening into protocols for cognitive screening; (2) use of assistive technology during testing (e.g., glasses, hearing aids or other devices such as a Pocketalker (Williams Sound, Eden Prairie, MN)) when indicated; (3) ensuring that test environments meet standards for ambient noise levels and lighting to optimize sensory functioning (e.g., acoustical standards for health care environments could be modeled after existing standards for classrooms, Acoustical Society of America, 2010; as per Cabrera and Lee (2000); hospitals and clinics could establish a "Department of Sound" to minimize the potential negative effects of noise on patient care); (4) development of protocols for patients who fall below cutoff for normal on the MoCA upon initial screening and who also fail sensory screening to be referred for evaluation by appropriate health professionals (e.g., audiologists, optometrists, ophthalmologists) to determine if they could benefit from interventions to improve sensory functioning; (5) increased frequency of follow-up appointments to monitor for change, and (6) use of alternative scoring or alternative presentation modality options to assist in interpretation of results. Finally, given that it is typical for an individual to wait an average of 10 years before accessing care for HL (Davis, Smith, Ferguson, Stephens, & Gianopoulos, 2007), and that many older individuals will not seek help for low vision given their belief that this is simply a part of the normal aging process (e.g., Sussman-Skalka, 2002), an increased awareness of the strong link between sensory loss and cognitive impairment may lead clinicians to encourage their clients to seek treatment for their hearing and/or VL as soon as possible.

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Appendix 1. Percentage of participants who scored above cutoff based on absolute subtraction approach.

		Percentage of participants who passed the cutoff		
Auditory scoring items	Cutoff point	All participants (N = 301)	Normal hearing (n = 165)	Hearing loss (n = 136)
Original scoring procedure	>25/30	53.16	66.06	37.50
Scoring procedure 1	>20/25	60.47	72.73	45.59
Scoring procedure 2	>20/25	82.74	90.91	72.79
Scoring procedure 3	>15/20	93.02	95.76	89.71
		All good vision participants (N = 122)	Good vision and normal hearing (n = 73)	Good vision and hearing loss (n = 49)
Original scoring procedure	>25/30	55.7	68.49	36.73
Scoring procedure 1	>20/25	64.8	76.71	46.94
Scoring procedure 2	>20/25	86.1	94.52	73.47
Scoring procedure 3	>15/20	96.7	97.26	95.92
Visual scoring items		All participants (N = 297)	Normal vision (n = 259)	Vision loss (n = 38)
Original scoring procedure	>25/30	53.5	56.00	36.80
Scoring procedure 1	>17/22	72.1	73.70	60.50