The Montreal Cognitive Assessment After Omission of Hearing-Dependent Subtests: Psychometrics and Clinical Recommendations

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OBJECTIVES: Hearing loss (HL) is the third most common chronic health condition in older adults, yet it is often undiagnosed and/or untreated. Given the association between HL and cognitive impairment, it is expected that many people undergoing cognitive screening may have HL. The Montreal Cognitive Assessment (MoCA) is a brief screening test that assesses a wide range of cognitive functions sensitive to Alzheimer's disease (AD) and mild cognitive impairment (MCI). Although MoCA items were carefully designed to be sensitive to deficits in MCI, they were not designed to take sensory declines into account. In the current investigation, we examined the MoCA's psychometric properties following omission of subtests primarily dependent on hearing status (memory, digit span, attention to letters, and sentence repetition).

DESIGN: Cross-sectional analytic design (retrospective analysis).

SETTING: We used the original MoCA validation study data.[4]

PARTICIPANTS: Groups consisted of healthy controls (N = 90), subjects with MCI (N = 94), and subjects with mild AD (N = 93).

MEASUREMENTS: We assessed sensitivity and specificity using absolute and proportional cutoff score adjustments. We developed receiver operating characteristics curves to determine the best cutoff values for both MCI and AD patients using different combinations of auditory subtest omissions.

RESULTS: Compared with the original MoCA (MCI sensitivity = 90%; specificity = 87%), MCI sensitivity was substantially reduced (absolute scoring = 43%; proportional scoring = 56%) when all auditory subtests were omitted, with the biggest contribution to the reduction coming from the delayed recall subtest. Excluding three subtests and maintaining the delayed recall had no effect on MCI sensitivity but reduced specificity (sensitivity = 94%, specificity: 71% using proportional scoring). AD sensitivity, in contrast, was not strongly influenced by our manipulation and remained relatively high through all three subtest omission combinations.

CONCLUSION: The current study highlights the contribution of hearing-dependent subtests on the sensitivity and specificity of the MoCA. Clinical recommendations related to these findings are discussed. **J Am Geriatr Soc 67:1689–1694, 2019.**

Key words: hearing loss; Montreal Cognitive Assessment (MoCA); cognitive screening; psychometrics; delayed recall

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Hearing loss (HL) is the third most common chronic health condition in older adults[1] (OAs). Deficits in peripheral hearing are prevalent in almost one-third of adults 65 years of age and in more than half of those 75 years of age.[2,3] HL is often undiagnosed and/or untreated. Importantly, the results of cognitive screening for OAs with unidentified HL may not accurately reflect their functioning. The Montreal Cognitive Assessment (MoCA[4]) test is a widely used brief cognitive screening tool that has high sensitivity for detecting mild cognitive impairment (MCI) and Alzheimer's disease (AD) in OAs. Here we demonstrate the potential effect of hearing-dependent subtests on the MoCA's sensitivity and specificity as a screening tool.

HL is independently associated with the development of dementia in OAs.[5–7] Furthermore, when the quality of auditory test stimuli is reduced, performance on cognitive tests

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Table 1. Montreal Cognitive Assessment Subtests and Corresponding Cognitive Domains, Sensory-Motor Domains Activated, and Test Points

MoCA subtest	Cognitive domain	Sensory/Motor domain	Points awarded Original (/30)	Points awarded H1 (/20)	Points awarded H2 (/25)	Points awarded H3 (/25)
Trail making	Visuospatial attention, task switching	Visual perception/Manual production	1	1	1	1
Copy cube	Visuoperceptual abilities	Visual perception/Manual production	1	1	1	1
Clock drawing	Semantic memory, visuospatial abilities, executive functioning	Recollection from semantic memory/Manual production	3	3	3	3
Animal naming	Confrontation naming, semantic memory	Visual perception/Oral production	3	3	3	3
Delayed recall	Episodic verbal learning and memory	Auditory perception/Oral production	5	0	0	5
Digit span	Attention, short-term memory, working memory	Auditory perception/Oral production	2	0	2	0
Attention to letters	Sustained attention	Auditory perception/Oral production	1	0	1	0
Serial subtraction	Attention, working memory, mental arithmetic	Not sensory dependent/Oral production	3	3	3	3
Sentence repetition	Attention, working memory, language (morphosyntax)	Auditory perception/Oral production	2	0	2	0
Fluency	Word generation, executive function	Not sensory dependent/Oral production	1	1	1	1
Similarities	Abstract reasoning	Not sensory dependent/Oral production	2	2	2	2
Orientation	Orientation to time and place	Not sensory dependent/Oral production	6	6	6	6

can be compromised.[8] Therefore, assessing cognitive functioning in OAs with HL presents the challenge of dissociating scores that are low due to perceptual issues from those that are solely due to cognitive deficits. This dilemma can have significant consequences when cognition is screened in healthcare settings that do not always have ideal testing conditions. Noise in the test environment can affect MoCA scores even for those with normal hearing.[9] Thus errors due to poor perception could affect an individual's score, potentially affecting diagnostic decisions reached based on that score.

Healthcare professionals cannot assume that older adults know they have HL or how to accommodate for it. In Canada, more than 70% of 60- to 75-year-old adults with HL are unaware of it.[10] Even for those who are aware of their difficulties, the rate of hearing aid use is low[11] (23%). Thus, most OAs with HL undergoing cognitive screening may be tested without adequately taking HL into account.

Due to its brevity and the wide range of cognitive domains it covers (Table 1), the MoCA is ideal for use in settings where a clinician needs to assess a patient's cognition quickly. Wittich and colleagues[12] assessed how the psychometric properties of the MoCA could theoretically be affected in visually impaired individuals by omitting visually dependent subtests of the original MoCA validation sample. Because MCI often involves decline in executive functions, the omission of visual items, which often depend on executive functions, resulted in reduced test sensitivity.[12] In contrast, episodic memory, assessed using the delayed recall subtest, requires the perception, encoding, and recollection of spoken word stimuli and thus depends on hearing. Dupuis and colleagues[13] assessed performance on the MoCA in cognitively healthy individuals with and without HL. They observed that omitting the delayed recall subtest contributed greatly to reducing the gap in scores between HL and normal hearing individuals. Nevertheless, they observed lower scores for the HL group, even when hearing-dependent subtests were omitted from scoring, suggesting the observed deficits are not merely sensory artifacts. It is possible that deficits in a given sensory modality may influence an individual's score and give the impression of deficits in cognitive domains that are tested in that modality.

Previous studies focused on the influence of sensory impairment on cognition in healthy OAs. We examined the potential contribution of hearing-dependent subtests to the sensitivity and specificity of the MoCA in a sample of OAs with MCI, AD, and controls for whom cognitive status was independently verified without using the MoCA. We used the original MoCA validation study data[4] to recalculate MoCA scores with the omission of subtests that depend on hearing the test stimuli. We developed receiver operating characteristics (ROC) curves to determine the best cutoff values for each procedure to categorize patients as having MCI or AD.

METHODS

Participants

The sample from the original MoCA validation study[4] (54% female) consisted of healthy controls (N = 90; mean age = 72.8 y), individuals with MCI (N = 94; mean age = 75.2 y), and those with mild AD (N = 93; mean age = 76.7 y). MCI diagnosis was determined using previously established criteria.[14,15] The diagnosis of probable AD was made using criteria from the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*[16] and the National Institute of Neurological and Communicative Disorders and Stroke/Alzheimer's Disease and Related Disorders Association.[17] Participants were not screened for hearing or vision loss at the time of testing.

Procedure

Table 1 lists all 12 MoCA subtests and describes the primary modalities needed to perceive the stimuli and respond to the task. All require adequate perception of task instructions. However, the four subtests that depend on adequate perception of auditory stimuli are as follows: (1) Delayed recall: Participants repeat five words spoken by the tester in two learning trials and are later tasked to recall the words; (2) Digit span: The tester reads a series of single-digit numbers, and participants are asked to repeat them in the same order (forward) and in reverse order (backward); (3) Attention to letters: the tester reads a list of letters and participants are asked to tap when they hear the letter "A"; (4) Sentence repetition: The tester reads a pair of morphosyntactically complex sentences, and participants are asked to repeat them verbatim.

We examined the psychometric properties of the MoCA using three combinations of auditory subtest omissions based on the procedures followed by Dupuis and colleagues.[13] The purpose of these procedures was to examine whether certain hearing-dependent subtests disproportionately influence the sensitivity and specificity of the MoCA. The three procedures were as follows: (1) MoCA-H1: All four auditory subtests were removed (10 points removed; total score /20); (2) MoCA-H2: Only the delayed recall subtest was removed (5 points removed; total score /25); and (3) MoCA-H3: Digit span, attention to letters, and sentence repetition subtests were removed (5 points removed; total score /25).

The original MoCA recommended a cutoff score of 26 of 30 or above to indicate normal functioning that corresponds to a proportional score of .866 (26/30). For all three subtest combinations, we established both absolute and proportional cutoff scores (following Wittich and colleagues[12]). For example, in MoCA-H1, 10 points were removed from the MoCA maximum score, such that the absolute cutoff changed to 16 (26-10); the proportional cutoff was changed to 17 ($.866 \times [30 - 10]$). Additionally, we recalculated sensitivity, specificity, overall accuracy, and developed ROC curves for all groups, along with area under the curve (AUC) measurements to establish ideal cutoff scores.

RESULTS

Absolute and proportional cutoff values for the three procedures are provided in Table 2. Overall, the three procedures showed a decrease in overall classification accuracy relative to the original MoCA scoring. Removing all four hearing-dependent subtests from the MoCA (MoCA-H1) resulted in a large decrease in MCI sensitivity that was more pronounced for the absolute cutoff score than the proportional score; sensitivity to AD remained high. MoCA-H2 omitted only the delayed recall subtest. Like MoCA-H1, this omission resulted in a decrease in the test's sensitivity to MCI that was again more pronounced when using the absolute cutoff score; sensitivity to AD remained relatively high. MoCA-H3 omitted digit span, attention to letters, and sentence repetition. Using a proportional cutoff score resulted in a small increase in the test's sensitivity to MCI over the full MoCA at the cost of specificity (Table 2). Note that the overall test accuracy for MoCA-H3 remained lower than the original MoCA.

ROCs allowed us to determine sensitivity/specificity trade-offs at different cutoff values. For AD, the ROC curve rapidly plateaus (Figure 1), showing both high sensitivity and specificity. For MCI, the ROCs show less steep curves. This is particularly evident for MoCA-H1 and MoCA-H2 (Figure 1, panels C and E; AUC = .743 and .758, respectively) that both included the omission of the delayed recall subtest. MoCA-H3 (Figure 1, panel G), which did not omit delayed recall, had better sensitivity and specificity values at most cutoffs (AUC = .824), but MoCA-H3 still had lower accuracy than the full MoCA (Figure 1, panel A; AUC = .885). No significant differences were observed when data were stratified by sex.

Table 2. Psychometric Properties of Original Montreal Cognitive Assessment and Our Three Modified Procedures (H1, H2, and H3) with Absolute and Proportional Scoring[a]

			MoCA-H1		MoCA-H2		MoCA-H3	
		Original MoCA	Absolute	Proportional	Absolute	Proportional	Absolute	Proportional
Cutoff		26	16	17	21	22	21	22
MCI	Sensitivity (%)	90	43	56	53	63	87	94
	Accuracy (%)	86	70	74	73	76	84	83
AD	Sensitivity (%)	100	87	92	89	96	100	100
	Accuracy (%)	93	92	92	91	92	91	86
Specificity (%)		87	97	92	93	89	81	71

Abbreviations: AD, Alzheimer's disease; MCI, mild cognitive impairment; MoCA, Montreal Cognitive Assessment.

Note: MoCA-H1, Delayed recall, digit span, attention to letters, and sentence repetition subtests omitted from the total score; MoCA-H2, Delayed recall subtest omitted; MoCA-H3, Digit span, attention to letters, and sentence repetition subtests omitted.

[a]Cutoff indicates the scores below which a participant would be deemed cognitively abnormal.

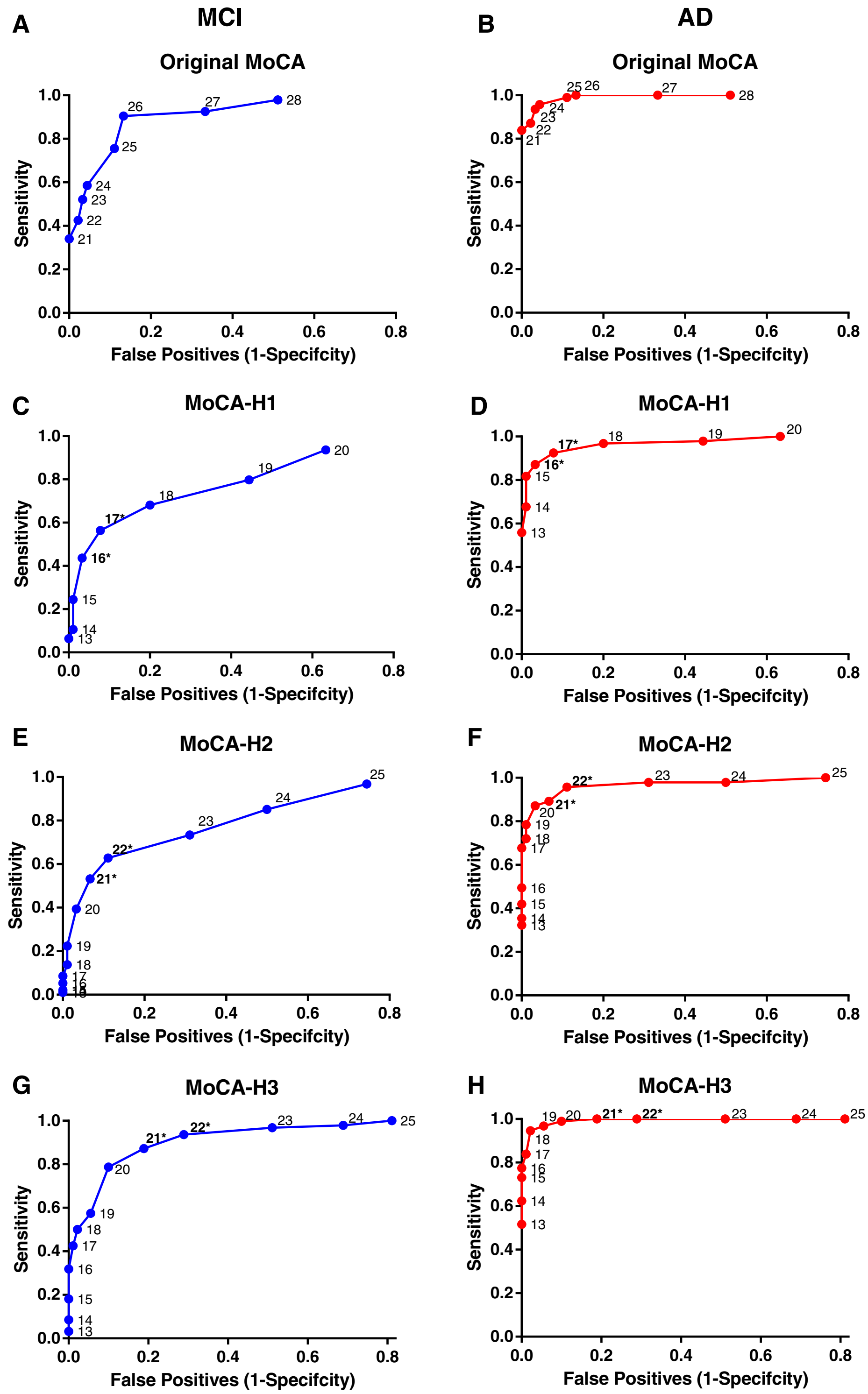

Figure 1. Receiver operating characteristics (ROC) and curves showing the sensitivity and specificity for different cutoff scores on the original Montreal Cognitive Assessment (MoCA) and our three modified procedures (H1, H2, and H3). Values are presented for both mild cognitive impairment (MCI; left panels) and Alzheimer's disease (AD; right panels). Numbers on the curves represent different possible cutoff scores. The absolute (*) and proportional (**) cutoff scores we used to determine sensitivity and specificity comparisons in the present article are indicated by asterisks.

DISCUSSION

We assessed the psychometric properties of three procedures for scoring the MoCA omitting different hearing-dependent subtests. Omitting the delayed recall subtest, either by itself (MoCA-H2) or along with other hearing-dependent subtests (MoCA-H1), resulted in a significant loss of sensitivity to MCI. This is expected insofar as memory is the domain most implicated in MCI[15] and is consistent with previous findings.[13] We also observed more modest decreases in specificity when the three other hearing-dependent subtests (digit span, attention to letters, and sentence repetition; MoCA-H3) were omitted. One of the MoCA's advantages as a screening tool is the breadth of cognitive domains it tests. In the interests of brevity, each domain is tested in a single sensory modality (e.g., episodic memory depends on learning auditorily presented items). The current study highlights the contribution of hearing-dependent subtests on both the likelihood of cognitively impaired individuals being identified as such (sensitivity), and the cognitively healthy individuals being correctly identified as healthy (specificity).

These results for hearing largely parallel the findings for vision[12] where the omission of visual subtests resulted in a reduction in sensitivity. We also similarly observed an advantage for using a proportional cutoff score compared with an absolute score. Nevertheless, the reduction in sensitivity, even with proportional scoring, was still meaningful. This demonstrates the potential consequences that HL could have on an individual's apparent cognitive performance.

Limitations and Future Studies

Perceptual problems could result in reduced specificity because people who have HL and normal cognition could be misclassified as having cognitive impairment. Alternatively, clinicians may omit certain subtests to account for a person's sensory status, yet subtest omission can result in a misestimation of an individual's cognitive abilities and, in the case of the highly domain-specific subtests of the MoCA, significant deficits may be missed. Omitting subtests is a crude method to "correct" for the effects of sensory loss on cognitive testing. It does not reflect how people with HL would perform insofar as they may not be likely to score zero on every auditory subtest. The purpose of omitting subtests in this study was to examine the *potential* ramifications of testing individuals with untreated HL or under noisy testing conditions.[9] Importantly, we are not advocating item omission as an appropriate solution. Instead, our procedures allowed us to observe the individual contribution of the hearing-dependent subtests to the MoCA's accuracy.

We have discussed our findings assuming a person has HL as defined by pure-tone audiometric thresholds. However, it is important to note that age-related declines in supra-threshold auditory processing can occur even in persons who would not be considered to have clinically significant threshold elevations. Declines in auditory processing may also affect performance on memory and attention tasks, such as those discussed in this investigation.[18,19]

The participants in this study had diagnoses based on thorough neuropsychological examinations, allowing us to examine the psychometric properties of the MoCA-H. However, similar to OAs seen in other memory clinics,[20] these participants were not assessed for sensory loss. Considering the high prevalence of HL in OAs,[1] it is likely that the original sample included some individuals with hearing difficulties. Future studies should compare MoCA scores with full neuropsychological batteries in individuals with different sensory abilities. Delayed recall tests, in particular, seem to contribute greatly to the variability in auditory-cognitive relationships.[13] Research comparing test administration in different modalities[21] or tests where auditory items have visual substitutions[22] is developing. What is needed are tests that can be administered either in the visual or auditory modality that have similar content validity and have been validated to have similar psychometric properties.

Clinical Recommendations

Sensory loss is prevalent in the population, and yet only a small portion of older adults seen at memory clinics may be asked about HL.[20] OAs who have not had a recent hearing test should be screened and/or referred to an audiologist. Technological advancements now permit relatively affordable and efficient hearing screening.[23] Health professionals administering cognitive screening tests should ensure that persons with hearing aids use them during testing. Because individuals with HL can wait an average of 10 years before beginning hearing aid use,[24] those who have HL but do not have a hearing aid may benefit from using generic amplifying devices (e.g., a pocket talker). When testing individuals with HL, professionals should optimize the presentation of auditory test items by using clear speech spoken at a slow normal rate, reducing noise in the testing environment, and facing the person to enable speech reading.[9,25]

In conclusion, we demonstrated how the MoCA's sensitivity and specificity depend on subtests that rely on hearing test items. Clinicians need to be aware of their patients' sensory functioning and consider how these factors may affect performance on the test and influence clinical interpretations.

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REFERENCES

1. Nasreddine ZS, Phillips N, Bédirian V, et al. The Montreal cognitive assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc. 2005;53:695-699.
2. Cruickshanks KJ, Nondahl DM, Tweed TS, et al. Education, occupation, noise exposure history and the 10-yr cumulative incidence of hearing impairment in older adults. Hear Res. 2010;264(1):3-9.
3. World Health Organization (WHO). Mortality and Burden of Diseases and Prevention of Blindness and Deafness. World Health Organization. http://www.who.int/pbd/deaf- ness/news/GE_65years.pdf. Accessed July 6, 2018.

4. Mick P, Hämäläinen A, Kolisang L, et al. The prevalence of hearing and vision loss in older Canadians: an analysis of data from the Canadian longitudinal study on aging. Can J Aging. In press.
5. Lin FR, Thorpe R, Gordon-Salant S. Hearing loss prevalence and risk factors among older adults in the United States. J Gerontol A Biol Sci Med Sci. 2011a;66A(5):582-590.
6. Lin FR, Metter J, O'Brien R, et al. Hearing loss and incident dementia. Arch Neurol. 2011b;68(2):214-220.
7. Livingston G, Sommerlad A, Orgeta V, et al. Dementia prevention, intervention, and care. Lancet. 2017;6736(17):1-62.
8. Jorgensen LE, Palmer CV, Pratt S, Erickson KI, Moncrieff D. The effect of decreased audibility on MMSE performance: a measure commonly used for diagnosing dementia. J Am Acad Audiol. 2016;27(4):311-323.
9. Dupuis K, Marchuk V, Pichora-Fuller MK. Noise affects performance on the Montreal cognitive assessment. Can J Aging. 2016;35(3):298-307.
10. Statistics Canada. Hearing loss of Canadians, 2012 to 2015. Catalogue No. 82-625-X. Ottawa; 2015. https://www150.statcan.gc.ca/n1/pub/82-625-x/2016001/article/14658-eng.htm. Accessed October 30, 2017.
11. Chien W, Lin FR. Prevalence of hearing aid use among older adults in the United States. Arch Intern Med. 2012;172(3):292-293.
12. Wittich W, Phillips N, Nasreddine Z, et al. Sensitivity and specificity of the Montreal cognitive assessment modified for individuals who are visually impaired. J Visual Impairment Blindness. 2010;104(6):360-369.
13. Dupuis K, Pichora-Fuller MK, Marchuk V, et al. Effects of hearing and vision impairments on the Montreal cognitive assessment. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn. 2015;22(4):413-437.
14. Petersen RC, Smith G, Waring S, et al. Mild cognitive impairment: clinical characterization and outcome. Arch Neurol. 1999;56:303-309.
15. Petersen RC, Doody R, Kurz A, et al. Current concepts in mild cognitive impairment. Arch Neurol. 2001;58:1985-1992.
16. Diagnostic and Statistical Manual of Mental Disorders. 4th ed. Washington, DC: American Psychiatric Association; 1994.
17. McKhann G, Drachman D, Folstein M, Katzman R, Price D, Stadlan EM. Clinical diagnosis of Alzheimer's disease. Report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's disease. Neurology. 1984;34:939-944.
18. Pichora-Fuller MK, Alain C, Schneider B. Older adults at the cocktail party. In: Middlebrooks J, Simon J, Popper A, et al., eds. The Auditory System at the Cocktail Party. Berlin, Germany: Springer; 2017:227-259.
19. Phillips NA. The implications of cognitive aging for listening and the framework for understanding effortful listening (FUEL). Ear Hear. 2016;37:44S-51S.
20. Jorgensen LE, Palmer C, Fischer G. Evaluation of hearing status at the time of dementia diagnosis. Audiol Today. 2014;26(1):38.
21. Wong CG, Rapport LJ, Billings BA, et al. Hearing loss and verbal memory assessment among older adults. Neuropsychology. 2019;33(1):47-59.
22. Lin VYW, Chung J, Callahan BL, et al. Development of cognitive screening test for the severely hearing impaired: hearing-impaired MoCA. Laryngoscope. 2017;127:S4-S11.
23. Thompson GP, Sladen DP, Borst BJH, Still OL. Accuracy of a tablet audiometer for measuring behavioral hearing thresholds in a clinical population. Otolaryngol Head Neck Surg. 2015;153(5):838-842.
24. Davis A, Smith P, Ferguson M, Stephens D, Gianopoulos I. Acceptability, benefits and costs of early screening for hearing disability: a study of potential screening tests and models. Health Technol Assess. 2007;11(42):1-294.
25. Heads Up, Health Professionals: 28 Tips for Treating Older Clients. American Psychological Association, Psychology Benefits Society. https://psychologybenefits.org/2014/11/06/28-tips-for-treating-older-clients. Accessed March 24, 2019.