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Original Research Article

Assessment of Dementia in Individuals with Dual Sensory Loss: Application of a Tactile Test Battery

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Abstract
Background/Aims: Individuals with dual sensory loss (DSL) are more likely to experience cognitive decline with age than individuals without sensory loss. Other studies have pointed to the challenges in assessing cognitive abilities in individuals with DSL, as most existing instruments rely on use of vision and hearing. The aim of this study was to develop and evaluate a Tactile Test Battery (TTB) for cognitive assessment in individuals with DSL. ***Method:*** Twenty elderly individuals with DSL, 20 with diagnosed dementia, and 20 without dementia or DSL (controls) completed the following tactile tests developed for the present study: Spatial learning, Spatial recall, Tactile form board, Clock reading, and Naming. The participants with dementia and controls also completed the Mini-Mental State Examination (MMSE). ***Results:*** Overall, participants with dementia performed significantly worse on the tactile tests than participants with DSL and control participants. No significant differences on the tactile tests were found between participants with DSL and controls. The TTB and MMSE scores correlated significantly. ***Conclusion:*** The findings from this study of applying tactile tests for cognitive examination in individuals with DSL are promising. They indicate that symptoms of dementia can be differentiated from symptoms related to DSL.

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Introduction

Conventional assessment for dementia includes an evaluation of several key cognitive domains: anterograde memory (learning and recall), perception of spatial relationships, naming, and processing speed [1]. However, commonly applied short mental state assessments, such as the Mini-Mental State Examination (MMSE) [2], as well as more comprehensive neuropsychological test batteries used for diagnosing dementia, primarily rely on the use of vision and/or hearing. Accordingly, individuals who have severe vision or hearing loss – and in particular those who have combined vision and hearing losses (dual sensory loss [DSL] or deafblindness) – cannot easily be assessed [3, 4]. Sometimes, adaptations of tests and/or applications of vision and hearing aids provide satisfying solutions, but it is not always the case. The objective of this study therefore has been to develop and evaluate a number of tactile tests for cognitive assessment in individuals with DSL.

Prevalence studies of DSL estimate a rate close to zero for populations below 65 years of age, increasing to around 30% in populations above 80 years of age [5–9]. The main causes of DSL are age-related, including for vision loss: diabetic retinopathy, cataract, macular degeneration, and glaucoma [10], and for hearing loss: presbyacusis (age-related sensorineural hearing loss) [11]. No generally accepted definition or objective criteria for DSL exist in research or clinical practice [12]. Functional definitions are often applied, in which the degree of impact of vision and hearing loss on the individual's activities of daily living is evaluated [12]. Accordingly, DSL is diagnosed when combined hearing and vision losses cause significant limitations in independent living due to restricted mobility, access to information, communication, and social interaction. Functional definitions of DSL therefore do not imply that the individual is totally deaf and blind; in most cases, residual hearing and/or vision are present [4, 13].

Another health problem afflicting the elderly population in particular is dementia. Dementia includes a number of neurological diseases which cause cognitive, emotional, and motivational symptoms [1]. Alzheimer disease and vascular brain pathology are the major etiological causes of dementia [14]. According to a recent review [15], the prevalence of dementia in the age group 65–69 is between 1 and 2%. However, prevalence rates nearly double with each 5-year increment in age, reaching about 12% at age 80–84 and well above 25% in the age group 90+ [16, 17]. Similarly to age-related sensory loss, dementia is most often progressive.

Comorbidity of DSL and dementia is to be expected. If the risks of DSL and dementia were independent, then a prevalence rate of 27% for DSL [8] and 12% for dementia [17] would yield a prevalence of comorbidity of 3.2% for the 80-year-old group. However, studies have reported an elevated risk of cognitive decline among individuals with DSL. In a cohort study by Lin et al. [18] 6,112 women aged 69 and older participated. Vision and hearing loss was measured, and the participants completed a modified version of the MMSE. Of the sample, 15.7% showed symptoms of cognitive decline. After adjustment for sociodemographic characteristics and chronic conditions, the odds for reduced cognitive function were 2.19 times higher for women with DSL than for women without sensory loss. Overall, 2 hypotheses for a higher prevalence of comorbidity of DSL and dementia have been discussed in the literature [1, 19]. The first is that shared pathological processes (e.g., some age-related neurological disorders) affect hearing and vision as well as cognitive functioning. The second is that dual sensory deprivation afflicts cognitive functions either due to the restricted sensory input or increased levels of stress [4, 19–21].

Dementia as well as (dual) sensory loss requires early and correct assessment as a prerequisite for adequate treatment. However, clinical symptoms of dementia may be difficult to distinguish from symptoms of DSL, and erroneous (false positive as well as false negative)

diagnoses of dementia and of sensory loss are probably quite common [4]. Symptoms such as communication difficulties, social withdrawal and isolation, as well as emotional changes are common in both conditions. For instance, an individual with dementia, who might not remember what he/she was recently told, or who does not recognize his/her visitors, may mistakenly be considered to be auditorily or visually impaired. By contrast, a person with DSL, who has a restricted ability to access information and to participate in social interaction, may erroneously be suspected to be in cognitive decline.

In most cognitive psychological tests, the patient has to follow spoken and written instructions and commands, for example repeat numbers, perceive visual figures, and copy patterns. Experimental studies have shown that performance in cognitive tests is highly sensitive to restrictions in sensory input. Even a relatively small decline in visual acuity artificially induced by goggles that imitate cataracts, or by applying low-contrast stimuli, has been shown to have a negative effect on the accuracy and speed of cognitive test performance in older adults [22–24]. In the auditory modality, negative effects of background noise during stimulus presentation on short-term memory performance have also been demonstrated [25].

Although shortcomings regarding the use of standard tests among individuals with DSL are recognized in the literature (for a review, see Hill-Briggs et al. [26] and Valentijn et al. [19]), few successful attempts to validate existing tests, or to develop new ones, for individuals with sensory loss have been published. Wittich et al. [27] evaluated the sensitivity and specificity of a version of the Montreal Cognitive Assessment (MoCA) [28] in which 5 visual items were omitted. In parallel, Lin et al. [29] published another version of the MoCA for individuals with severe hearing loss. In this version (HI-MoCA), spoken instructions were converted into written instructions while other items were modified. Though alternative assessment procedures thus have been suggested for individuals with uni-modal sensory loss, to our knowledge assessment procedures for elderly persons with DSL have never been published.

Study Aim

No adequate tools for neuropsychological assessment of dementia in individuals with functional DSL exist. One way to circumvent this obstacle might be to develop cognitive tests based on the tactile modality. Accordingly, the aim of this study was to transform a number of traditional visual- and auditory-based tests of dementia into the tactual modality and to evaluate their validity by applying them to 3 groups: (1) individuals with dementia and no vision loss or hearing loss, (2) individuals with DSL and no dementia, and (3) individuals with neither DSL nor dementia (controls).

Methods

Participants

Participants with DSL

Twenty individuals (4 men), who fulfilled the criteria for having DSL based on the functional Nordic Definition of Deafblindness [30] volunteered to participate in the study. The participants were recruited through the Danish national provider of counselling services for individuals with acquired DSL. Participants were between 63 and 92 years of age (mean = 81.5 years; SD = 8.3), and their mean years of completed education was 10.7 (SD = 2.4, range 8–16). Etiologies of hearing loss were presbyacusis (n = 12), noise exposure (n = 5), genetic (other than Usher syndrome) (n = 4), Usher syndrome type 2 (n = 1), infection (n = 1), stroke (n = 1), and unspecified (n = 1). Etiologies of visual loss were reported to be age-related macula degeneration (n = 10), diabetic retinopathy (n = 3), glaucoma (n = 3), cataract (n = 2), stroke (n = 2), retinitis pigmentosa (n = 1), Usher syndrome type 2 (n = 1), genetic (other than

Table 1. Demographic characteristics of the study groups: individuals with dual sensory loss, dementia, and controls

Variable	Dual sensory loss (n = 20)	Dementia (n = 20)	Controls (n = 20)	Dual sensory loss vs. controls, p	Dementia vs. controls, p	Dual sensory loss vs. dementia, p
Age, years	81.5±8.3	79.7±5.5	77.6±6.5	ns	ns	ns
Education, years	10.7±2.4	10.2±2.4	11.0±3.0	ns	ns	ns
Males/females	4/16	7/13	8/12	ns	ns	ns

Data are presented as mean ± SD or *n*. $p > 0.05$ (two tailed) was considered not significant (ns).

Usher syndrome) (n = 1), and unspecified (n = 2). (Note, multiple etiologies of vision and hearing loss were present.) All of the participants had acquired DSL and had, prior to the onset of DSL, developed and used spoken language. None of the participants with DSL were suspected of, or diagnosed with, dementia or reported tactile sensation problems. For characteristics of the participants, see Table 1.

Participants with Dementia

Twenty patients (7 men) recruited from the Dementia and Memory Clinic at Glostrup Hospital, Denmark, volunteered. All 20 were diagnosed with dementia based on the ICD-10 criteria after a thorough diagnostic assessment which included a clinical examination, MMSE, laboratory tests, and a CT scan of the brain. Sixteen of the patients were considered to suffer from Alzheimer disease and 4 from mixed Alzheimer's and vascular dementia. None of the participants reported having any functional loss of vision or hearing or tactile sensation problems. Mean age was 79.7 years (SD = 5.5, range 71–88) and mean years of education 10.2 (SD = 2.4, range 8–17). See Table 1 for details.

Controls

Twenty controls (8 men) were recruited among relatives to the participants with DSL and consultants. Mean age of the controls was 77.6 years (SD = 6.5, range 69–96) and mean age of education 11.0 (SD = 3.0, range 8–16). All controls reported having no functional vision or hearing loss, tactile sensation problems, or symptoms of cognitive decline.

No significant differences were present between the 3 groups with regard to age, gender, and years of education ($p > 0.05$) as shown in Table 1.

Procedure

All participants completed the Tactile Test Battery (TTB), and participants with dementia and controls also completed the MMSE (see descriptions below). The participants with DSL were examined by consultants from the national deafblind service, who had been trained in administering the TTB and the MMSE and who had expertise in communication with individuals with DSL by use of different communication modalities. Thus, test instructions were given in tactile sign language, spoken language, by use of written texts or other communicative means. All participants with dementia were examined by the first author and all controls by the deafblind consultants.

All participants were carefully informed about the purpose of the study and gave their consent to voluntarily participating. A prepared record sheet, also including clear instructions and scoring criteria for the test administrator, was used to register performance in the TTB tests.

Fig. 1. All tactile subtests were performed using a box.

Tests

Mini-Mental State Examination

The MMSE [2, 31] is a widely used screening measure of cognitive impairment in suspected dementia. It consists of 30 items and takes 5–10 min to complete. It includes items on orientation, registration, attention and calculation, recall, language, visual construction, and the ability to follow simple commands. Validity and reliability of the MMSE for diagnosing and staging dementia have been found to be good (for review see Tombaugh and McIntyre [32]). The MMSE has a maximum score of 30 and a minimum score of 0. A score equal to or greater than 24 is taken to indicate no cognitive impairment, whereas a score 19–23 indicates mild, 10–18 moderate and below 10 severe cognitive impairment [33].

Tactile Test Battery

In order to cover relevant cognitive domains for dementia assessment (e.g., Hodges [34]), the following tactually based tests were developed. All subtests were performed with the dominant hand in a solid box of 32 × 32 × 22 cm (Fig. 1). One side of the box, which turned towards the examinee, had an opening covered by a curtain, which made visual inspection of the stimulus material impossible for the participant. From the opposite position, the examiner was able to manipulate the test material and to guide the participant's hand. Thus, all participants, whether they had no vision loss, residual vision, or were blind, had to rely exclusively on the use of the tactile modality.

Spatial Memory Test. Lhermitte and Signoret [35] originally described a learning and memory task based on a cardboard frame divided into 9 equal squares (3 × 3). The subject had to learn and remember where to place 9 stimulus cards depicting 9 common objects (e.g., chair, drum, kitten). Each card had its specific location in one of the 9 squares. The test has been shown to be sensitive to severe amnesia [36]. For the present study, the cardboard was substituted by a wooden "type case" with 9 equally sized spaces. Instead of stimulus cards, 9 concrete objects (e.g., a cork, safety pin, coin) were used. After presentation of where to place each object (one by one and in random order) by guiding the subject's hand, the subject was asked to remember the correct location of all objects by replacing them. Erroneous placements were immediately corrected, in that the examiner guided the hand (and object) to the correct position. Three learning trials were completed, giving a maximum learning score of 27. After performing the other tactile tests in the TTB, a delayed recall test was completed by asking the subject to place the 9 objects in their correct positions from memory. The maximum score in the recall test was 9.

Tactile Form Board Test. Halstead [37] included a tactual performance test in his comprehensive neuropsychological test battery. Studies have shown that performance decreases with high age as well as in populations with neurological disorders [38]. For the present study, a board with 8 wooden blocks (circle, square, triangle, etc.), each fitting into corresponding cutout holes, was constructed. Two trials were given, both being performed with the dominant hand. Total time (in seconds) for completion of the 2 trials constituted the score.

Clock Reading Test. Reading a visually presented clock face involves visuospatial perception involving the determination of the relative length of the 2 pointers as well as their angle and their relationship to outer space (up, down, left, right). Additionally, the percept has to be translated into a semantic concept (time). Visual clock reading impairment is observed in patients with Alzheimer disease, mixed Alzheimer/vascular dementia and in Lewy Body dementia [39]. In the present study, the participants, after having been demonstrated the circular form and the top of the clock face (D = 25 cm), had to examine the position of the 2 pointers by touch and verbally report the correct time. Correct readings of 12 different settings (a deviation of up to 5 min for the long pointer and 1 h for the short pointer were accepted) resulted in a maximum score of 24.

Naming Tests. Naming ability, activation of the correct verbal substantive in response to a perceived object or body part, is often compromised in individuals with dementia [34], and naming tasks are included in most screening tests for dementia (e.g., the MMSE and The Boston Naming Test [40]). Three different naming conditions were tested in this study.

Object naming: Following the completion of the Spatial Memory Test (see description above), the participant had to name by touch each of the 9 objects.

Shape naming: The 8 shapes from the Form board test (see description above) had to be named by the use of touch.

Finger naming [41]: The participant (with fingers spread and palm down) had to name which finger was briefly touched by the examiner. All 10 fingers were touched in a predefined order and correct naming of all fingers gave a maximum score of 10. A total score (maximum 27) of the 3 tactile naming tests was calculated (object naming maximum score 9, shapes naming 8, and finger naming 10).

Statistical Procedure

Mean level differences were compared for the TTB and MMSE scores between the 3 groups by use of Mann-Whitney U statistics. Further, Spearman's rho correlation coefficients were calculated between TTB summary Z-scores (derived from the mean and SD of the

Table 2. Mean test scores for the MMSE and the 5 tests in the Tactile Test Battery of the 3 groups: participants with dual sensory loss, dementia, and controls

Test	Dual sensory loss (n = 20)	Dementia (n = 20)	Controls (n = 20)	Dual sensory loss vs. controls, p	Dementia vs. controls, p	Dual sensory loss vs. dementia, p
Tactile Test Battery						
Spatial learning	11.5±5.6	3.9±2.0	13.2±5.0	ns	<0.001	<0.001
Spatial recall	4.9±2.3	1.3±1.0	5.7±2.1	ns	<0.001	<0.001
Tactile form board (total time), s	449±168	513±116	397±200	ns	0.001	ns
Clock reading test	20.7±3.4	13.2±7.1	20.3±3.4	ns	0.002	0.001
Naming tests	25.0±1.4	21.7±4.4	25.2±1.5	ns	0.001	0.001
MMSE	–	18.1±3.59 (9–24)	29.0±1.96 (24–30)	–	<0.001	–

Data are presented as mean ± SD (range). $p > 0.05$ (two tailed) was considered not significant (ns).

controls) and MMSE raw scores for the participants with dementia and controls. Also, specificity and sensitivity of the TTB compared to the MMSE were calculated in order to suggest an optimal cut-off of the TTB.

Results

All participants across the 3 groups were able to understand, and comply with, the instructions for the TTB. The entire test session for the TTB lasted for about 30 min.

Mini-Mental State Examination

On the MMSE, participants with dementia obtained a mean score of 18.1 (range 9–24), which was significantly below the controls (mean = 29.0, range 24–30) (t = 11.54, df = 38, $p < 0.001$) (Table 2).

Tactile Tests Battery

Spatial Learning

The controls obtained a mean score of 13.2 correct placements in the Spatial Learning Test. The participants with DSL obtained a mean score of 11.5, which was not significantly different from the controls. In contrast, the participants with dementia performed at a significantly lower level (mean = 3.9) than the controls (U = 7.00, $p < 0.001$) as well as the participants with DSL (U = 30.00, $p < 0.001$), respectively.

Spatial Recall

For the controls, a mean of 5.7 correct placements of the 9 objects was recorded on the delayed recall test. The participants with DSL obtained a mean score of 4.9, which was not significantly different from the controls. The participants with dementia had a significantly lower mean score (mean = 1.3) than the controls (U = 11.00, $p < 0.001$) as well as the participants with DSL (U = 31.50, $p < 0.001$).

Tactile Form Board

On average, the controls spent 397 s (sum of 2 trials) to place the 8 blocks in the corresponding cutouts. This compares to 449 s for the participants with DSL (not significant) and 513 for the participants with dementia (significant) (U = 80.50, p = 0.001). The difference between scores for the participants with DSL and dementia was not significant.

Table 3. Specificity and sensitivity of the Tactile Test Battery (TTB) (cut-off –3.0) for participants with dementia and controls

	No dementia (MMSE)	Dementia (MMSE)	Total
No dementia (TTB)	17 (true negative)	3 (false positive)	20
Dementia (TTB)	2 (false negative)	18 (true negative)	20
Total	19	21	40

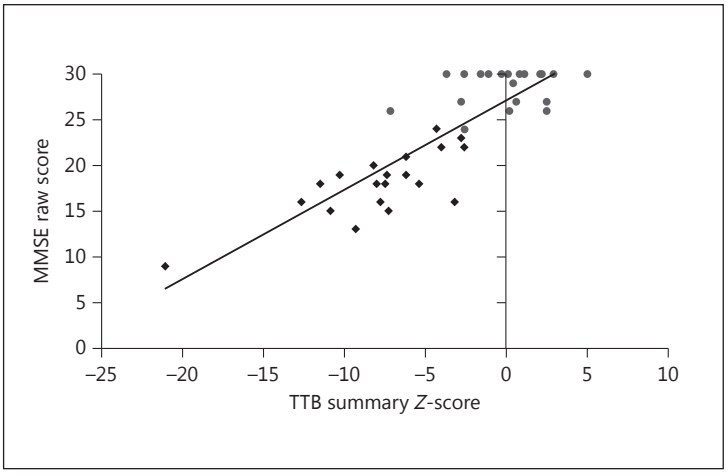

Fig. 2. Correlation of TTB summary *Z*-scores with MMSE scores for participants with dementia (squares) and controls (circles).

Clock Reading

For the controls, a mean score of 20.3 was recorded. This compares to a mean score of 20.7 for participants with DSL (not significant) and 13.2 for the participants with dementia (significant) (U = 84.00, $p = 0.001$). Also, the score of the participants with DSL was significantly better than the participants with dementia (U = 75.00, $p = 0.002$).

Naming

A mean of 25.2 correct names was obtained for the controls. The participants with DSL obtained a mean score of 25.0, which was not significantly different to the controls. A mean score of 21.7 was obtained for the participants with dementia, which was significantly lower compared to controls (U = 78.50, $p = 0.001$) as well as participants with DSL (U = 84.00, $p = 0.001$).

Correlation between MMSE and TTB

As shown in Figure 2, the MMSE raw scores and the TTB summary *Z*-scores correlated significantly (Spearman's rho = 0.83, $p < 0.001$, $n = 40$) for the combined participants with dementia and controls. The correlation between MMSE scores and TTB *Z*-scores was also significant for participants with dementia (Spearman's rho = 0.63, $p < 0.001$, $n = 20$). A sensitivity of 86% and a specificity of 89% were found (Table 3) for the TTB with a cut-off of –3.0 and using a cut-off of 24 on the MMSE as the dementia criterion.

Discussion

The purpose of the present study was to develop and evaluate a number of tactile cognitive tests for dementia screening which could be applied in individuals with DSL. The tactile tests included learning, memory, naming, spatial perception, and processing speed – all cognitive domains that deteriorate in dementia. Four out of 5 measures were able to differentiate successfully between participants with dementia and participants with DSL and controls, respectively. Further, a high correlation between MMSE scores and TTB summary *Z*-scores and an acceptable sensitivity and specificity of the TTB were found. Altogether, the findings from this validity study of the TTB are promising and indicate that cognitive abilities might be assessed by the use of tactile-based tests. However, further studies in different and larger samples are needed, including individuals with both DSL and dementia. This includes studies on different subgroups of individuals with DSL with various degrees and durations of vision and hearing losses. Prospective studies are also needed to further evaluate the validity of the TTB and other kinds of tactile cognitive tests. Furthermore, different kinds of test procedures need to be developed and applied in order to evaluate possible associations between sensory loss and cognitive functions and if reported findings of a higher level of cognitive decline among persons with DSL (e.g., Lin et al. [18] and for a review Fulton et al., [20] and meta-analysis Zheng et al., [42]) might be due to the application of invalid investigational procedures. Finally, one limitation of this study should be noticed. No objective test of vision and hearing loss or tactile sensation of the participants was used, but only self-report and functional evaluation.

The psychological assessment of individuals with DSL is acknowledged to be a major challenge. Surprisingly, however, little attention has been paid to the possibility of applying tactually based test procedures. The risk of dementia, as well as sensory loss, is highly age related. A considerable increase in the number of elderly citizens is to be anticipated in the years to come in many developed countries [43]. These demographic facts underline the need for further research in assessment, diagnosis, and support in order to provide optimal treatment and health care for individuals suffering from dementia and DSL. This study's findings suggest that that presence of severe hearing and vision losses need not be an obstacle for a detailed and reliable examination of cognitive functions in persons suspected of having dementia.

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Disclosure Statement

All authors declare no conflicts of interest.

References

1 American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5). Arlington, American Psychiatric Association, 2013.
2 Folstein MF, Folstein SE, McHugh PR: "Mini-mental state." A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189–198.
3 Carvill S: Sensory impairments, intellectual disability and psychiatry. J Intellect Disabil Res 2001;45:467–483.
4 Dammeyer J: Deafblindness: a review of the literature. Scand J Public Health 2014;42:554–562.
5 Dammeyer J: Characteristics of a Danish population of acquired deafblindness. Br J Vis Impair 2013;31:189–197.
6 Herada S, Nishiwaki Y, Michikawa T, Nakano M, Iwasawa S, Asakura K, et al: Gender differences in the relationships between vision and hearing impairments and negative well-being. Prev Med 2008;47:433–437.
7 Laforge RG, Spector WD, Sternberg J: The relationship between vision and hearing impairment to one-year mortality and functional decline. J Aging Health 1992;4:126–148.
8 Schneider J, Gopinath B, McMahon C, Teber E, Leeder SR, Wang JJ, Mitchell P: Prevalence and 5-year incidence of dual sensory impairment in an older Australian population. Ann Epidemiol 2012;22:295–301.
9 Smith SL, Bennett L, Wilson RH: Prevalence and characteristics of dual sensory impairment (hearing and vision) in a veteran population. J Rehab Res Dev 2008;45:386–394.
10 Klaver CC, Wolfs RC, Vingerling JR, Hofman A, de Jong P: Age-specific prevalence and causes of blindness and visual impairment in an older population. The Rotterdam Study. Arch Ophthalmol Chic 1998;116:653–658.
11 Van Eyken E, Van Camp G, Van Laer L: The complexity of age-related hearing impairment: contributing environmental and genetic factors. Audiol Neurol 2007;12:345–358.
12 Ask Larsen F, Damen S: Definitions of deafblindness and congenital deafblindness. Res Dev Disabil 2014;35:2568–2576.
13 Wittich W, Watanabe DH, Gagne JP: Sensory and demographic characteristics of deafblindness rehabilitation clients in Montreal, Canada. Ophthalmic Physiol Opt 2012;32:242–251.
14 Goodman RA, Lochner KA, Thambisetty M, Wingo TS, Posner SF, Ling SM: Prevalence of dementia subtypes in United States Medicare fee-for-service beneficiaries 2011–2013. Alzheimers Dement 2017;13:28–37.
15 Alzheimer's Disease International: World Alzheimer Report 2015: The Global Impact of Dementia. https://www.alz.co.uk/research/world-report-2015.
16 Ferri CP, Prince M, Brayne C, Brodaty H, Fratiglioni L, Ganguli M, et al: Global prevalence of dementia: a Delphi consensus study. Lancet 2005;366:2112–2117.
17 Phung TKT, Waltoft BL, Kessing LV, Mortensen PB, Waldemar G: Time trend in diagnosing dementia in secondary care. Dement Geriatr Cogn Disord 2009;29:146–153.
18 Lin MY, Gutierrez PR, Stone KL, Yaffe K, Ensrud KE, Fink HA, et al: Vision impairment and combined vision and hearing impairment predict cognitive and functional decline in older women. J Am Geriatr Soc 2004;52:1996–2002.
19 Valentijn SAM, van Boxtel MPJ, van Hooren SAH, Bosma H, Beckers HJ, Ponds RW, Jolles J: Change in sensory functioning predicts change in cognitive functioning: results from a 6-year follow-up in the Maastricht Aging Study. J Am Geriatr Soc 2005;53:374–380.
20 Fulton SE, Lister JJ, Harrison Bush AL, Edwards JD, Andel R: Mechanisms of the hearing-cognition relationship. Semin Hear 2015;36:140–149.
21 Wongrakpanich S, Petchlorlian A, Rosenzweig A: Sensorineural organs dysfunction and cognitive decline: a review article. Aging Dis 2016;7:763–769.
22 See AY, Anstey KJ, Wood JM: Simulated cataract and low contrast stimuli impair cognitive performance in older adults: implications for neuropsychological assessment and everyday function. Aging Neuropsychol Cogn 2011;18:1–21.
23 Bertone A, Bettinelli L, Faubert J: The impact of blurred vision on cognitive assessment. J Clin Exp Neuropsychol 2007;29:467–476.
24 Bertone A, Wittich W, Watanabe DH, Overbury O, Faubert J: The effect of age-related macular degeneration on non-verbal neuropsychological test performance. Int Congr Ser 2005;1282:26–30.
25 Murphy DR, Craik FIM, Li KZH, Schneider BA: Comparing the effects of aging and background noise on short-term memory performance. Psychol Aging 2000;15:323–334.
26 Hill-Briggs F, Dial JG, Morere DA, Joyce A: Neuropsychological assessment of persons with physical disability, visual impairment or blindness, and hearing impairment or deafness. Arch Clin Neuropsychol 2007;22:389–404.
27 Wittich W, Phillips N, Nasreddine ZS, Chertkow H: Sensitivity and specificity of the montreal cognitive assessment modified for individuals who are visually impaired. J Vis Impair Blind 2010;104:360–368.
28 Nasreddine ZS, Phillips NA, Bedirian V, Charbonneau S, Collin I, Cummings JL, Cherthow H: The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. J Am Geriatr Soc 2005;53:695–699.
29 Lin VY, Chung J, Callahan BL, Smith L, Gritters N, Chen JM, et al: Development of cognitive screening test for the severely hearing impaired: hearing-impaired MoCA. Laryngoscope 2017;127:S4–S11.

30 Nordisk Lederforum: The Revised Nordic Definition of Deafblindness. Dronninglund, Nordisk Velfærdscenter Uddannelse for Døblindpersonale, 2007. http://www.nordicwelfare.org/PageFiles/992/Nordic%20Definition%20of%20Deafblindness.pdf.
31 Burns A, Lawlor B, Craig S: Assessment Scales in Old Age Psychiatry, ed 2. London, Martin Dunitz, Taylor & Francis Group, 2004.
▶32 Tombaugh TN, McIntyre NJ: The Mini-Mental State Examination: a comprehensive review. J Am Geriatr Soc 1992;40:922–935.
▶33 Mungas D: In-office mental status testing: a practical guide. Geriatrics 1991;46:54–58.
34 Hodges JR: Cognitive Assessment for Clinicians, ed 2. New York, Oxford University Press, 2007.
▶35 Lhermitte F, Signoret JL: Analyse neuropsychologique et différenciation des syndromes amnésiques. Rev Neurol 1972;126:161–178.
36 Walsh KW: Understanding Brain Damage, ed 2. London, Churchill Livingstone, 1991.
37 Halstead WC: Brain and Intelligence. Chicago, University of Chicago Press, 2017.
38 Lezak MD: Neuropsychological Assessment, ed 3. New York, Oxford University Press, 1995.
▶39 Schmidtke K, Olbrich S: The Clock Reading Test: validation of an instrument for the diagnosis of dementia and disorders of visuo-spatial cognition. Int Psychogeriatr 2007;19:307–321.
40 Kaplan EF, Goodglass H, Weintraub S: The Boston Naming Test, ed 2. Philadelphia, Lea & Febiger, 1983.
▶41 Davis AS, Trotter JS, Hertza J, Bell CD, Dean RS: Finger agnosia and cognitive deficits in patients with Alzheimer's disease. Appl Neuropsychol Adult 2012;19:116–120.
▶42 Zheng Y, Fan S, Liao W, Fang W, Xiao S, Liu J: Hearing impairment and risk of Alzheimer's disease: a meta-analysis of prospective cohort studies. Neurol Sci 2017;38:233–239.
▶43 Knickman JR, Snell EK: The 2030 problem: caring for aging baby boomers. Health Res Educ Trust 2002;37:849–884.