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### Authors

Whitson, Heather E  
Cronin-Golomb, Alice  
Cruickshanks, Karen J  
[et al.](#)

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## American Geriatrics Society and National Institute on Aging Bench-to-Bedside Conference: Sensory Impairment and Cognitive Decline in Older Adults

Heather E. Whitson, MD, MHS<sup>\*,†</sup>, Alice Cronin-Golomb, PhD<sup>‡</sup>, Karen J. Cruickshanks, PhD<sup>§</sup>,  
Grover C. Gilmore, PhD<sup>¶</sup>, Cynthia Owsley, PhD, MSPH<sup>||</sup>, Jonathan E. Peelle, PhD<sup>\*\*</sup>, Gregg  
Recanzone, PhD<sup>††</sup>, Anu Sharma, PhD<sup>‡‡</sup>, Bonnielin Swenor, PhD, MPH<sup>§§</sup>, Kristine Yaffe,  
MD<sup>¶¶</sup>, and Frank R. Lin, MD, PhD<sup>§§</sup>

<sup>\*</sup>School of Medicine, Duke University, Durham, North Carolina; <sup>†</sup>Geriatrics Research, Education,  
and Clinical Center, Durham Veterans Affairs, Durham, North Carolina; <sup>‡</sup>Boston University,  
Boston, Massachusetts; <sup>§</sup>School of Medicine and Public Health, University of Wisconsin,  
Madison, Wisconsin; <sup>¶</sup>Case Western Reserve University, Cleveland, Ohio; <sup>||</sup>University of Alabama  
at Birmingham, Birmingham, Alabama; <sup>\*\*</sup>Washington University in St. Louis, St. Louis, Missouri;  
<sup>††</sup>University of California, Davis, Davis, California; <sup>‡‡</sup>University of Colorado at Boulder, Boulder,  
Colorado; <sup>§§</sup>Johns Hopkins University, Baltimore, Maryland; <sup>¶¶</sup>University of California, San  
Francisco, San Francisco, California.

### Abstract

This article summarizes the presentations and recommendations of the tenth annual American Geriatrics Society and National Institute on Aging Bench-to-Bedside research conference, “Sensory Impairment and Cognitive Decline,” on October 2–3, 2017, in Bethesda, Maryland. The risk of impairment in hearing, vision, and other senses increases with age, and almost 15% of individuals aged 70 and older have dementia. As the number of older adults increases, sensory and cognitive impairments will affect a growing proportion of the population. To limit its scope, this conference focused on sensory impairments affecting vision and hearing. Comorbid vision, hearing, and cognitive impairments in older adults are more common than would be expected by chance alone, suggesting that some common mechanisms might affect these neurological systems.

Address correspondence to Heather E. Whitson, MD, MHS, DUMC 3003, Durham NC 27701. Heather.whitson@duke.edu.

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#### SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

**Supplemental Appendix.** Report summarizing the presentations and recommendations from the AGS/NIA U13 Conference: Sensory Impairment and Cognitive Decline.

This workshop explored the mechanisms and consequences of comorbid vision, hearing, and cognitive impairment in older adults; effects of sensory loss on the aging brain; and bench-to-bedside innovations and research opportunities. Presenters and participants identified many research gaps and questions; the top priorities fell into 3 themes: mechanisms, measurement, and interventions. The workshop delineated specific research questions that provide opportunities to improve outcomes in this growing population. *J Am Geriatr Soc* 66:2052–2058, 2018.

## Keywords

vision; hearing; cognition; dementia; comorbidity

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This article summarizes presentations and recommendations from the tenth annual American Geriatrics Society and National Institute on Aging Bench-to-Bedside research conference, “Sensory Impairment and Cognitive Decline,” on October 2–3, 2017, in Bethesda, Maryland.

The risk of impairment of hearing, vision, and other senses increases with age, and almost 15% of individuals older than 70 years have dementia.<sup>1–3</sup> As the number of older adults increases, sensory and cognitive impairments will affect a growing proportion of the population. To limit its scope, this conference focused on concurrent impairments in cognition, vision, and hearing.

Rates of impairment in near and distance visual acuity increase with age. The most common vision problems in older adults are impaired spatial contrast sensitivity (important for pattern recognition), scotopic dysfunction (slower adaptation to darkness and impaired light sensitivity at night), and slow visual processing.<sup>4</sup>

The link between visual impairment and cognitive decline is complex. For example, impaired vision could affect cognitive function,<sup>5</sup> and improving near vision with eyeglasses can reduce depressive symptoms,<sup>6</sup> which can be manifested as cognitive deficits. Cognition could also affect vision. People locate and fixate on visual targets in semantically appropriate locations that are not visually salient, showing that they use cognitive factors, not only image characteristics, to guide their visual attention. Visual impairment and cognitive decline might also have common causes.

Hearing loss is the third most common health disorder in older adults.<sup>7</sup> Peripheral hearing loss in this population is associated with 30% to 40% faster cognitive decline than in those without hearing loss and with a 24% higher risk of cognitive impairment.<sup>8</sup> Hearing impairment is also related to faster decreases in the volume of brain regions that are important for spoken language processing and other cognitive functions.<sup>9</sup>

Cognitive impairment could also contribute to hearing-related difficulties in challenging listening conditions. For example, changes throughout the central auditory pathway make it more difficult for older adults with hearing loss to separate speech from background noise, leading to communication difficulties.<sup>10</sup> This challenge is particularly acute in those with a

decrease in cognitive function. Cognitive auditory training could potentially improve the neural processing needed to understand speech in noisy environments.

## COMORBID SENSORY AND COGNITIVE IMPAIRMENT

### Mechanisms

The co-occurrence of sensory impairments (e.g., vision and hearing) is more common than expected by chance alone, and vision and hearing impairments are associated with greater risk of cognitive impairment.<sup>11</sup> One cross-sectional study in community-dwelling older adults who did not have dementia found that more than 2% of this population reported both vision and hearing impairments and screened positive for cognitive impairment.<sup>12</sup> Hearing and vision rely on cognitive processes, and cognitive testing involves visual or auditory tasks, so these relationships may be multifactorial.

A common pathological process (e.g., vascular disease) might be responsible for sensory and cognitive impairments in older adults (Figure 1). According to some studies, amyloid- $\beta$ , a pathological hallmark of Alzheimer's disease, is present in the ocular lens (where it can cause supranuclear cataracts) and retina, and its presence in the retina could be a biomarker for Alzheimer's disease, which is also associated with changes in retinal ganglion cells and optic neuropathy.<sup>13</sup>

Alternatively, sensory impairments might have a causal role in cognitive impairment. By increasing cognitive load, these impairments might limit the neural resources needed for optimal performance of cognitive tasks. In addition, loss of sensory input could directly alter brain structure and function (e.g., long-term deafferentation or overloaded brain circuitry from resource demands to address poor signal-to-noise ratios). Finally, sensory loss may lead to depression, social isolation, and lack of physical activity, which could cause cognitive impairment.

### Consequences of Comorbid Cognitive and Sensory Impairment

Persons with comorbid sensory and cognitive impairment are at greater risk of depression and death. Whether these are simply additive effects is not clear. Improving vision in persons with cognitive impairment may improve cognition or reduce cognitive decline, but cognitive impairment can reduce the effectiveness of visual rehabilitation.<sup>14</sup> There has been limited research on the functional consequences of combined sensory and cognitive impairments despite the high prevalence of these conditions in older adults. Table 1 summarizes conclusions and key research gaps identified during the "Comorbid Sensory and Cognitive Impairment" session.

## SENSORY LOSS AND THE AGING BRAIN

Age-related changes in the central nervous system (CNS) can drive functional decline directly or indirectly (by weakening the potential for plasticity), and CNS changes (e.g., in hippo-campal volume and artery and vein radius) are related to cognitive impairment.<sup>15</sup>

Noninvasive techniques are invaluable for understanding the neural mechanisms of age-related changes in human sensory perception, but they lack the spatial and temporal resolution needed to fully characterize the sensory processes throughout the CNS or how aging affects these processes. Animal models can help meet this need. Even though the age at which a given species becomes old varies, each species exhibits brain and cognitive changes near the end of the lifespan. Animal models have been used to study the roles of the hippocampus, prefrontal cortex, and perirhinal cortex in cognition and the ability to regulate neuronal responses to sound.

Visual acuity, contrast sensitivity, dark adaptation, and visual processing speed change with aging, even in people who do not have cataracts, glaucoma, or age-related macular degeneration, and these changes have been associated with cognitive impairments.<sup>4</sup> Impaired vision compromises visual cognition, and cognitive deficits can also impair visual perceptual processes. Interventions that enhance visual stimuli (e.g., by increasing contrast) can improve visual search by decreasing reaction time.<sup>16</sup> Other approaches to enhance visual stimuli include medical and surgical ophthalmic interventions (e.g., cataract surgery) and improving the visual environment in the home by, for example, reducing glare and removing visual clutter. Certain methods, including some that use concurrent brain stimulation, can amplify and clarify visual information in adults with cognitive deficits.<sup>17</sup>

Vision is particularly important to adults with hearing impairment, who depend more on visual cues. Vision recruits and repurposes auditory areas of the brain for visual processing in individuals with hearing loss.<sup>18</sup> This reorganization appears to enhance the use of multiple senses in speaking and listening to speech, which is particularly important for people with age-related hearing loss when listening becomes effortful. In difficult listening situations (e.g., noisy environments), older adults also recruit additional brain processes to help them understand conversational speech.<sup>19</sup> Table 2 summarizes conclusions and key research gaps identified during the “Sensory Loss and the Aging Brain” session.

## **BENCH-TO-BEDSIDE INNOVATIONS AND OPPORTUNITIES**

As the population ages, comorbid sensory loss and cognitive impairment will become even more common. The number of centenarians will grow, and it will be important to know what normal cognitive and sensory aging means in these older adults so that sensory measurements can be adjusted to age and cognitive status. According to the Framework for Understanding Effortful Listening, listening requires effort and is tiring for those with impaired hearing, which can reduce motivation to listen, and a better understanding is needed of effortful listening.<sup>20</sup> The same is likely to be true for vision.

Although it is unclear whether sensory loss drives accelerated brain aging or brain aging drives accelerated sensory loss (or both), tools are available to track these changes prospectively in large-scale longitudinal studies. One such study used a new approach to medical image analysis for a cross-sectional analysis of associations between aging and brain changes in 2,705 adults.<sup>21</sup> The results showed varied rates of changes in different brain regions associated with cognitive function. Furthermore, participants in the Baltimore Longitudinal Study of Aging had differences according to sex on most tests of cognitive

ability, with better performance in women for verbal memory tasks and in men for visual spatial abilities.<sup>22</sup> Amyloid and tau positron emission tomography has revolutionized research on Alzheimer's disease, making it possible to track the progress of the disease over time.

Debate continues about which interventions are most effective for influencing cognition later in life. For example, moderately strong evidence supports the benefits of exercise (e.g., brisk walking) for improving cognitive and brain function in older adults, and exercise holds promise as an effective treatment approach.<sup>23</sup> Although exercise affects every part of the body, the mechanisms underlying the link between exercise and cognitive function need to be better understood. Potential explanations include cellular or molecular mechanisms, psychosocial changes, and effects on sleep. The evidence supporting cognitive training interventions is mixed, and it is not clear whether learning during training in one task is transferable to other tasks. There has been little discussion of the potential effect of these interventions on sensory function or how sensory status might modify their effects on cognition.

In addition to treating cognitive impairment directly, treating hearing and vision loss in older adults is important for ensuring healthy aging and continued active participation and engagement by adults with sensory and cognitive impairment. Restorative sensory care can consist of pharmacological interventions, surgery (e.g., cochlear implants, cataract surgery), or rehabilitation (e.g., assistive devices (e.g., hearing aids or portable magnifiers), strategies (e.g., speech reading, improved lighting)). Treatment for hearing loss reduces caregiver-identified problem behaviors, depressive symptoms, and neuropsychiatric symptoms.<sup>26</sup> Similarly, in addition to improving visual acuity, low-vision rehabilitation can improve health-related quality of life, memory, and independence in older adults with cognitive deficits.<sup>27</sup>

Rehabilitation for age-related hearing loss and low vision is underused. For example, fewer than 20% of the more than half of adults aged 70 to 79 with hearing loss use hearing aids.<sup>28</sup> Simple, low-cost, community-delivered solutions for hearing and vision care are critical for low-income and minority older adults.

A variety of office-based sensory system evaluation tools, including questionnaires and clinical techniques, are available. The challenges of using these tools in individuals with cognitive impairment include the uncertainty of test characteristics (e.g., their sensitivity and specificity might not have been determined in populations with cognitive impairments), lack of time to administer the tests, and logistics of arranging multiple clinic visits for follow-up assessments. Furthermore, the U.S. Preventive Services Task Force has determined that the evidence is insufficient to support vision or hearing screening in the primary care setting in adults aged 50 and older, resulting in less impetus for screening.<sup>29,30</sup>

It is possible to modify a standardized cognitive test to accommodate individuals with visual impairment by, for example, asking them to say a sentence aloud instead of writing it down, and individuals with visual impairment do better on vision-independent test versions. Standardized protocols to ensure that sensory impairments do not directly confound

cognitive test administration (someone with hearing loss misunderstands a spoken word in a verbal memory task) are not routinely used despite the high prevalence of hearing and vision loss in older adults. Table 3 summarizes conclusions and key research gaps identified during the “Bench to Bedside Innovations and Opportunities” session.

## FUTURE RESEARCH PRIORITIES

### Mechanisms Underlying the Sensory–Cognitive Interface

**Effect of Sensory Loss on the Aging Brain**—High-priority research questions include whether changes in sensory systems drive cognitive changes or whether any causal relationships between sensory and cognitive function may be bidirectional. We need to understand the roles of cardiovascular disease, metabolic dysregulation, genetics, and inflammation as common pathways to cognitive and sensory impairment. We also need to learn when the response to cognitive load becomes maladaptive and whether this differs according to system.

Another research priority is to determine whether sensory treatment has a downstream effect on cognition, including elucidation of the temporal sequence of peripheral and sensory changes and cognitive decline, and whether comorbid sensory impairment accelerates the downward trajectory of cognitive decline in dementia.

**Neural Mechanisms**—Major gaps in knowledge about brain pathways and networks at the interface of cognitive and sensory research include how top-down processes and bottom-up activity intersect and how generalizable these processes are across sensory systems. Studies could include comparisons of human and animal models of the same sensory and cognitive functions and between different sensory systems to assess shared top-down cognitive processes. Another research gap is the lack of knowledge as to which genetic and biological factors contribute to good sensory and cognitive function in older adults.

More research is needed to understand how senses beyond audition and vision (e.g., vestibular and olfactory systems) influence cognitive health and what happens when more than one sensory system is impaired. Small-vessel disease, a reasonable common pathway for vision, hearing, and cognitive impairment, has been understudied. Leveraging large population studies and existing study data is one potential means of addressing this question. Research gaps also exist regarding the influence of inflammation on sensory and cognitive function. Animal models of human sensory and cognitive processing would help advance this research.

Research is needed to identify the primary and secondary mechanisms of the benefits of exercise and healthy lifestyle, genetics, and other factors for cognitive and sensory health and the biology that these activities affect. Research should be conducted to determine whether exercise provides additional benefits, such as enhancing directed attention in background noise, visual acuity, or executive function. More collaboration is needed between those who study the interaction of sensory and cognitive processes and those seeking mechanisms that affect sensory and cognitive function.

**Disparities**—Most of our knowledge about prevention and treatment of cognitive impairment is based on white populations of higher socioeconomic status. Knowledge is limited on visual, hearing, and cognitive impairment in older under-represented minorities and other underserved populations.

Research should be conducted to determine the trajectory of sensory and cognitive function in older adults without depending on self-reports. These data need to be stratified according to sex, race and ethnicity, socioeconomic status, education level, and healthcare use. This research needs to include the oldest, most vulnerable adults who live in assisted living and retirement communities.

Few epidemiological datasets are available with minority representation that are not based on self-reported measures. When there is sample bias, the co-prevalence of sensory and cognitive impairments might be underestimated because individuals with sensory impairments might be less likely to participate in research or be excluded.

## Measurement

**How to Measure**—Portable, cost-effective, user-friendly measures of sensory and cognitive function that can be used in different populations (e.g., those who speak different languages and are of different ages, sexes, and races and ethnicities) must be developed. These new measures will be more successful if they are freely available to clinicians and researchers, so they should be usable in research environments and transferable to clinical environments.

Research should be conducted to determine how best to assess cognition in people with sensory loss, given the need to maintain fidelity with validated cognitive tests. To distinguish cognitive from sensory deficits, researchers might develop standardized test administration protocols that can ensure that a person's inability to perceive the stimuli or understand the instructions correctly does not directly confound existing cognitive tests with auditory or visual stimuli.

Traumatic brain injury and chronic traumatic encephalopathy affect central visual and auditory processing, but peripheral sensory is often minimally affected. Studies of traumatic brain injury function and chronic traumatic encephalopathy might provide opportunities to study the effect on cognition of changes in vision and hearing function in the absence of peripheral vision or hearing loss.

Although cognitive function is traditionally assessed by observing behavior, the workshop considered the role of a theoretical biomarker of cognitive or brain function. Such a biomarker might be valuable in individuals whose cognitive function is difficult to measure because of sensory deficits.

**What to Measure**—Surveillance research is needed to describe cognitive, hearing, and vision over the lifespan in different populations. Measurements and analytical tools are required to assess cognition fairly and accurately in the presence of sensory loss, including dual sensory impairment. We need cognitive and sensory tests that are more objective (e.g.,



brain activation) and more ecologically valid. We also need to collect information on social network, personality, occupational, and other factors that could affect cognitive and sensory health and treatment patterns.

Valid measures of sensory function are needed for animal studies, as are cross-species models of cognition in individuals with hearing and vision loss.

## Interventions

**Intervention Development Research**—More data are needed on individual differences in treatment effect and differences between healthy older adults and those with impaired sensory function, impaired cognition, impaired sensory and cognitive interactions, and poor effort and motivation. Intervention development research should be conducted to examine adults who are and are not aging “successfully.”

Intervention development requires multidisciplinary, long-term longitudinal studies to establish trajectories of changes in sensory function and cognition and their interactions. Studies are also needed to determine the mechanisms of successful interventions and their clinical relevance to people.

Triggers of decline and protective factors should be identified. A precision medicine type of approach could be developed to provide individualized care because the cognitive and functional limitations of older adults probably differ in degree and type of sensory impairment. Research is also needed to identify specific sensory (within domain) or cognitive impairments and address functional problems associated with these deficits.

Mixed-methods approaches to implementation science are critical for ensuring that interventions that are developed are actually used. The best timing for interventions must be determined, as must strategies to ensure feasibility and uptake.

## Health Services and Comparative Effectiveness Research

Research is needed to establish the efficacy of assistive devices, such as hearing aids and low-vision assistive devices, including training in their use, for functional outcomes in individuals with visual, hearing, and cognitive impairments. Policymakers, funding agencies, researchers, and training programs are needed to consider vision, hearing, and cognition in an integrated system of health, not in discrete silos.

Comparative effectiveness research could be conducted to determine the efficacy of vision and hearing screening for older adults in primary care for improving individual and population health outcomes, including cognitive outcomes. Such research could compare treatments, including usual care, disease treatment, and rehabilitation interventions, and assess multiple outcomes (e.g., vision, hearing, cognitive function, quality of life, activities of daily living, cost effectiveness, caregiver concerns).

Researchers should also exploit medical specialty registries that collect electronic health records (e.g., IRIS [Intelligent Vision in Sight] and the Reg-ent ear, nose, and throat data registries) to address research questions.

Table 4 provides a summary of the highest-priority research gaps.

## CONCLUSION

The evidence reviewed in the tenth annual Bedside-to-Bench research conference, “Sensory Impairment and Cognitive Decline,” indicates that vision, hearing, and cognitive impairments co-occur in older adults more often than would be expected by chance alone. Presenters and participants identified many research gaps and questions, and the top priorities fell into 3 themes: mechanisms, measurement, and interventions. This workshop delineated specific research questions that provide opportunities to improve outcomes in this growing population. The full report of the Conference is included as a Supplement Appendix to this Executive Summary.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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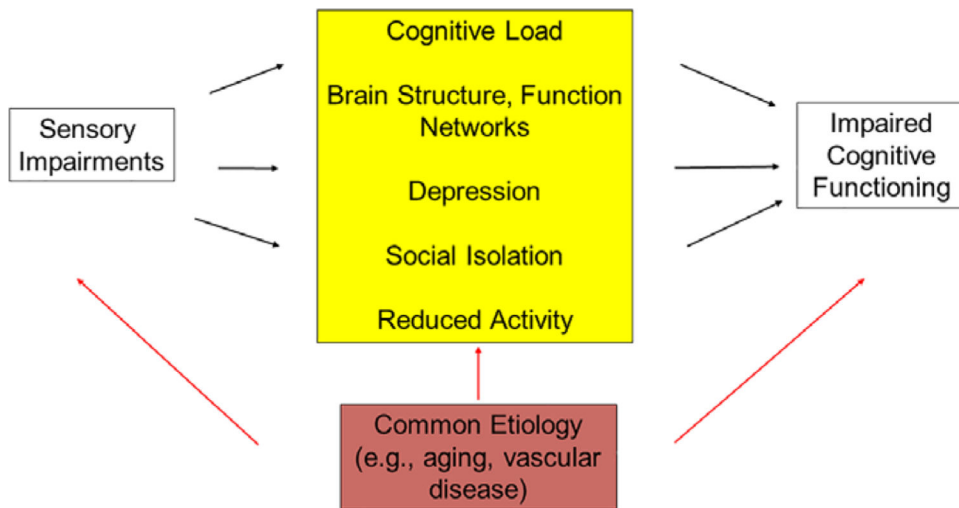
The information and views in this manuscript do not necessarily reflect those of the sponsors; the authors retained full independence in the planning of the conference agenda and the summary provided herein.

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**Figure 1.**

Hypothesized relationships that may explain the epidemiological link that has been described between sensory (vision, hearing) impairments and cognitive impairment. The yellow box depicts possible causative pathways by which sensory loss leads to reduced cognitive performance. For example, sensory impairment may increase “cognitive load,” or the total amount of demand placed on the brain at any given time. Assuming cognitive capacity is a fixed resource, high cognitive load could impair performance on cognitive tests. Another possibility is that sensory impairment interferes with physical or cognitively stimulating activities (e.g., exercise, reading) and that the lack of activity has a detrimental effect on cognitive function. The red box depicts the possibility that the relationship between sensory impairment and cognitive impairment is correlational. If this is the case, the impairments may co-occur more frequently than expected because they share common risk factors (e.g., age, smoking, genetics). Any or all of the pathways depicted here may explain a link between sensory and cognitive impairment.

**Table 1.**

**Comorbid Sensory and Cognitive Impairment: Current Knowledge and Gaps**

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What we know:

- Associations between hearing, vision, and cognitive impairment are unlikely to be due solely to chance.
- Environmental and genetic factors, as well as aging and comorbidities, affect the risk of hearing, visual, and cognitive impairment.

Knowledge gaps:

- Are vision or hearing changes early warning signs of neurodegenerative disease?
  - How does comorbid sensory and cognitive impairment affect prognosis?
  - Which comes first—changes in hearing, vision, olfaction, or cognition? To what degree are the relationships bidirectional, or do they arise concurrently?
  - What is the effect of hearing or vision loss early in life on cognitive function?
  - What is the effect of sensory and cognitive comorbidities on quality of life in older adults?
  - How often does sensory impairment lead to decreases in social engagement? What is the effect on cognitive function? How can volitional withdrawal from socially engaging activities (checking out) be measured?
  - What factors may precipitate the “fall” of a person with mild to moderate sensory loss and mild cognitive impairment “over the cognitive cliff”? What compensatory strategies can be used to prevent this?
  - Are vision and hearing loss modifiable risk factors for dementia?
  - Are there race- or sex-based disparities in the relationships between sensory and cognitive health?
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**Table 2.**

**Sensory Loss and the Aging Brain: Current Knowledge and Gaps**

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What we know:

- Age-related changes in the central nervous system can drive cognitive decline directly or by weakening the potential for plasticity.
- Cognitive training in healthy older adults might be able to reverse some of the functional and structural brain changes associated with age.
- Animal models are valuable for understanding fundamental principles of the aging brain and cognition and the underlying neuronal mechanisms of age-related changes in perception in humans.
- Impaired vision compromises visual cognition, and cognitive deficits might impair visual perceptual processes.
- Vision is particularly important to adults with hearing impairment, who depend more than those without hearing loss on visual cues.

Knowledge gaps:

- How can we enhance neuroplasticity after sensory loss using pharmacological approaches or other interventions?
  - How can we establish causality between structural or functional changes and cognitive decline?
  - Are the sensory and cognitive functions in different animals similar or are they served by the same neural machinery?
  - How do age-related changes in the central sensory system affect cognition in aging animal models?
  - Can visual brain training exercises mitigate or postpone aging-related cognitive declines? How generalizable are brain training outcomes? Is brain training most effective during a particular window of time?
  - How does dual sensory impairment, or concurrent vision and hearing impairment, relate to brain and cognitive changes, as well as efforts to rehabilitate them?
  - How do individual differences relate to the topics above?
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**Table 3.**

**Bench-to-Bedside Innovations and Opportunities: Current Knowledge and Gaps**

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What we know:

- Tools are available to track sensory and cognitive changes prospectively in large-scale longitudinal studies.
- Exercise has promise for improving cognitive function in older adults.
- Sensory rehabilitation has potential to improve independence, and possibly cognitive function, in older adults.
- It is possible to modify cognitive function tests for individuals with sensory impairment or to use test administration protocols to ensure that sensory impairments do not directly confound test performance.

Knowledge gaps:

- How can we develop and implement standardized protocols to measure cognition in older adults while taking into account visual impairment, hearing impairment, or both in clinical and research settings?
  - How do practice effects influence cognitive test results in older adults?
  - How can people with severe sensory impairment be included in studies that measure cognitive function?
  - How can we measure the practical (vs statistical) significance of changes resulting from interventions to improve cognitive function?
  - Can sufficient evidence be generated to justify hearing and vision screening in older adults, especially if the focus is on adults aged 60 and older or at highest risk of cognitive decline?
  - Is the effect of physical exercise on cognitive function clinically significant? Is there an effect of physical activity on sensory health?
  - What are the risks and benefits of physical activity in older adults with sensory impairments (e.g., might they slow progression of cognitive decline but increase risk of falls)?
  - Do simple sensory rehabilitation solutions that nonspecialists can provide have positive results?
  - Can sensory rehabilitation improve performance on cognitive tests and actual cognitive function? Can it slow cognitive decline?
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**Table 4.****Top Research Gaps in Sensory and Cognitive Impairment in Older Adults**

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Mechanisms underlying the sensory cognition interface
<ul style="list-style-type: none"><li>• Causality of the relationship between sensory and cognitive function</li><li>• Identification of neural and biological mechanisms (emphasis on targets to improve care) that affect sensory and cognitive health</li></ul>
Measurement
<ul style="list-style-type: none"><li>• Norms of existing tools across populations, including those that are underserved</li><li>• Development and validation of new tools and protocols to measure cognition in the setting of hearing impairment, visual impairment, and dual sensory impairment and new approaches to measure sensory deficits in older adults with cognitive impairment</li><li>• Inclusion of broad measurements of cognitive, hearing, and vision impairment in existing studies</li></ul>
Interventions (including screening)
<ul style="list-style-type: none"><li>• Effect, feasibility, and accessibility of existing interventions in people with cognitive, hearing, and vision impairment</li><li>• Innovative interventions and protocols designed to improve sensory and cognitive outcomes or to accommodate sensory and cognitive impairments</li></ul>

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