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An Overview of Dual Sensory Impairment in Older Adults: Perspectives for Rehabilitation

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Dual sensory impairment (DSI) refers to the presence of both hearing loss and vision loss. The occurrence of DSI is particularly prevalent among the aging population, with studies showing between 9% and 21% of adults older than 70 years having some degree of DSI. Despite this, there is little direction regarding recommended clinical practice and rehabilitation of individuals with DSI. It is assumed that the problems encountered by individuals with DSI are considerably greater than the effects of vision impairment or hearing impairment alone, because when these two sensory impairments are combined, the individual is seriously deprived of compensatory strategies that make use of the nonimpaired sense. In this article, the literature available regarding DSI is summarized, and research needs regarding rehabilitation strategies are outlined and discussed. Simple suggestions for addressing DSI are provided that use available tools and technology.

Keywords: dual sensory impairment; rehabilitation; aging; hearing loss; vision loss

Dual sensory impairment (DSI) refers to the presence of both hearing loss and vision loss. According to the Centers for Disease Control and Prevention,[1] at least 1.7 million people report DSI. Studies show that between 9% and 21% of adults older than 70 years have some degree of DSI[2-4] and that the prevalence increases with age.[4] As pointed out by Desai et al,[1] as the population ages, so will the number of individuals with DSI.

Individuals with DSI can be classified into the following 4 groups: congenital deafblindness, congenital visual impairment with acquired hearing impairment, congenital hearing impairment with acquired visual impairment, and acquired hearing and visual impairment. Herein, we focus on the difficulties experienced by those who have acquired hearing and vision loss associated with age-related changes and pathologic conditions. Most individuals with age-related DSI experience gradual onset of mild to moderate sensorineural hearing loss and vision loss. Awareness of late-onset DSI among older individuals is increasing, presumably because the size of this population is growing rapidly. However, there is almost no research on rehabilitation for this population; therefore, there is a tremendous imperative to develop and test rehabilitation strategies.

Although there are clear definitions of degrees of vision impairment and hearing impairment, definitions of DSI are lacking, and determination of a standardized definition is complex. Proposed definitions are functional in nature and tend to be nonspecific, with few implications for clinical practice. For instance, Davenport[5] suggests that DSI is "any combination of hearing and vision loss that interferes with access to communication and the environment and requires interventions beyond those necessary for hearing or vision loss alone." This generality is in part due to the fact that there is an unknown, and presumably variable, interaction between the two impairments. As

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noted by the Royal National Institute for the Blind of the United Kingdom,[6] "The interaction between varying visual losses and varying hearing losses produces a very heterogeneous population, with widely differing needs." This results in difficulty for practitioners because they may lack the tools to recognize DSI and typically receive little or no cross-disciplinary training to accommodate the needs of individuals with DSI, although such individuals are probably encountered daily. Practitioners also lack clinical testing protocols for impairment classification, best practice guidelines for rehabilitation, and outcomes measures to evaluate rehabilitation. There is a critical need for researchers in vision and hearing to remedy this state of affairs. In this article, we (1) provide an overview of DSI in aging, including the various effects of late-onset sensory loss; (2) suggest practice directives based on current knowledge and available tools; and (3) identify further research and development needs from a rehabilitation perspective.

Causes of DSI Associated With Aging

The aging process results in changes in the auditory and visual systems. Some of these changes are associated with normal aging; others are secondary to age-related pathologic conditions. Both are described herein.

Normal age-related changes associated with vision loss include presbyopia as well as decreased light transmission of the ocular media and decreased pupil size[7], losses in contrast sensitivity, greater sensitivity to and delayed recovery from glare, delayed dark adaptation, and reduced visual field and color discrimination.[8] Many normal age-related changes are not amenable to correction; consequently, strategies that are environmental, design based, or compensatory are required. The most common age-related pathologic conditions resulting in vision loss are macular degeneration, diabetic retinopathy, cataract, and glaucoma. Age-related macular degeneration accounts for 54.4% of blindness among persons of white race/ethnicity, while cataract and glaucoma account for 60% of blindness among black subjects. Cataract is the leading cause of low vision among individuals of white, black, and Hispanic race/ethnicity.[9] In age-related macular degeneration, blood flow to the retinal tissue is diminished, resulting in deterioration of the central part of the visual field but not the periphery. The consequences are an inability to see fine detail or to read fine print, dependence on high luminance, and difficulties seeing distant objects and adapting to darkness. Diabetic retinopathy causes decreased acuity, scattered field loss over the retina, increased sensitivity to glare, and loss of color and contrast sensitivity. Cataract is a progressive disorder that results in blurred vision and poor contrast sensitivity but is readily remedied with lens replacement. Glaucoma is an increase in intraocular pressure due to an abnormality in the flow of aqueous fluid from the anterior chamber and can cause degeneration of the optic disc, loss of visual field, and, if not successfully treated, loss of peripheral fields and blindness.[7,10] Other types of vision loss associated with aging are the occurrence of vision loss secondary to multiple sclerosis, stroke, and malignant hypertension[11,12] and as a result of exposure to tobacco smoke, certain antimicrobials, immune modulators and suppressants, and chemotherapeutic agents that cause toxic optic neuropathy.[13]

Normal age-related changes in the auditory system that result in hearing loss include loss of elasticity in the pinna, narrowing of the external auditory canal, added rigidity of the tympanic membrane, and ossicular atrophy.[14] Inner ear changes include hair cell and organ of Corti degeneration and decreased elasticity of the basilar membrane.[15] Aging of the central auditory system results in neuronal loss and decreased blood flow to the brain, which leads to sensory and neural hearing loss and diminished central auditory processing capabilities. In turn, these result in decreased ability to understand speech, especially in noisy environments. Other causes of hearing loss associated with age include long-term exposure to noise[16-18] and the use of ototoxic medications such as aminoglycoside and macrolide antibiotics, loop diuretics, platinum-based chemotherapeutic agents, some nonsteroidal anti-inflammatory drugs, and antimalarial medications.[19] Tobacco use has also been associated with hearing loss.[20] Hearing loss can also occur following bacterial meningitis, some viral infections such as adenovirus and herpes zoster oticus, Lyme disease, and diabetes mellitus.[21]

With the many causes and types of vision loss and hearing loss associated with aging, it is not surprising that the manifestations and effects of late-onset dual sensory loss are variable and that this population of individuals is rapidly growing. Therefore, awareness of the effect of, and rehabilitative solutions for DSI, in aging must be brought to the forefront of clinical practice and become a priority in innovative research efforts.

Effects of DSI

Although a substantial body of research has focused on the effects of single sensory impairments, the effect of late-onset or acquired DSI has not been well studied. The corpus of studies that have examined effects of DSI demonstrates an overreliance on self-report methods that limit the generalizability and comparability of the findings. Furthermore, these studies do not distinguish between late-onset DSI and other types of DSI. However, we assume that most older individuals reporting DSI in these studies have late-onset DSI.

As with hearing loss alone and vision loss alone, DSI has been shown to have psychological, psychosocial, and functional effects. Three studies have shown self-reported DSI to be associated with depression or depressive symptoms. First, in a study analyzing cross-sectional interview data from 2003 older Chinese subjects,[22] it was found that, relative to individuals with single sensory impairment, those with DSI were more likely to be depressed. Participants in this study rated their hearing and vision on a 4-point scale ranging from 1 (very good) to 4 (almost completely unable to see or hear). Individuals giving a rating of 3 (poor) or 4 were classified as having hearing or visual impairment. Second, Capella-McDonnall[23] reported results of a secondary analysis of the 2001 National Health Interview Survey data from 9832 community-dwelling persons older than 55 years. She found that individuals with DSI had greater odds of experiencing symptoms of depression compared with those with single sensory and no sensory impairments. In this study, participants were classified as having visual impairment if they responded yes to the interview question "Do you have trouble seeing, even wearing glasses or contact lenses?" They were classified as having hearing impairment if they reported having a little or a lot of trouble hearing when asked "Which statement best describes your hearing without a hearing aid?" Respondents who responded yes to both items were classified as having DSI. Third, Lupsakko and colleagues[24] examined 470 individuals 75 years and older. They used self-report to specify the presence of hearing loss, such that if the interviewed participant had clear difficulty in conversing due to poor acuity, if the participant expressed that his or her main problem was hearing, or if the person had earlier been ordered a hearing aid, he or she was classified as having hearing impairment. The presence of vision loss was determined using a Snellen chart such that visual acuity of less than 20/60 (logarithm of the minimum angle of resolution, +0.5) was defined as functional visual impairment. They found that depressive symptoms, but not major depression as defined by *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) criteria, were more common among individuals classified as having DSI than among those having single sensory impairment.

Self-reported DSI has been shown to be associated with poor self-rated health and decreased participation in numerous social activities compared with individuals without sensory impairment.[25] That study examined data from the 1994 Second Supplement on Aging collected from 9447 individuals older than 70 years. Individuals with DSI were identified by a positive response to having "trouble seeing even with glasses" in conjunction with a positive response to 1 of the following: "deafness in one ear," "deafness in both ears," and "any other trouble hearing." Compared with persons who reported no sensory impairment, individuals who reported DSI had approximately 10% lower rates of participation in activities such as visiting friends, telephoning colleagues, going to movies, and attending church. With regard to self-reported health and limitations in activities of daily living (ADL), 16.4% of individuals without sensory impairment reported their health as excellent vs 7.7% of individuals reporting DSI, while only 6.7% of individuals without sensory impairment reported poor health compared with 18.5% of individuals with DSI. Compared with individuals without sensory impairment, participants who reported DSI also had more difficulties conducting ADLs such as difficulty walking (48.2% vs 17.8%), shopping (36.9% vs 10.3%), and preparing meals (23.9% vs 6.3%).

Studies showing the effect of DSI on functional independence include a study by Raina et al.[26] In this study, 16 613 individuals older than 66 years completed the 1991 Health and Activities Limitation Survey in interview format. Data on ability to conduct instrumental ADLs (IADLs) such as shopping, meal preparation, money management, and home maintenance were collected. The presence of DSI sensory impairment was determined via self-report of difficulty with at least 1 seeing-related ADL such as dressing or bathing and at least 1 hearing-related ADL such as using the telephone or grocery shopping. The data showed that individuals with DSI reported the most IADL restrictions, followed by those with visual impairment alone and then by those with hearing impairment alone. Those with more severe sensory disabilities were more likely to report IADL restrictions and were less likely to have decision-making control and to be happy with their lives. In another study[27] comparing the ability of individuals with DSI, single sensory impairment, and no sensory impairment to conduct ADLs and IADLs, data from 576 participants between the ages of 56 and 102 years (mean age, 78.4 years) were examined. In this study, visual impairment was assessed using the Lighthouse Near-Visual Acuity Test. Individuals with a Snellen-equivalent visual acuity of 20/70 were classified as having visual impairment. Hearing loss was assessed using the Whisper Test. Failure to respond correctly to an easily answered whispered question resulted in a diagnosis of hearing impairment. It was found that participants with DSI had ADL and IADL scores that were statistically significantly lower than those without sensory impairment (no sensory impairment: ADL score, 21 of 24; IADL score,14 of 23; and DSI: ADL score, 18 of 24; IADL score, 8 of 23). Similar data were reported by Brennan et al,[28] who examined data from the Longitudinal Study on Aging, which is composed of 5151 individuals 70 years and older. These data were collected via interviews and self-report ratings. Sensory impairments were defined based on responses to the question "Which statement best described your vision [hearing] even when wearing glasses or contact lenses [hearing aid]: no trouble, a little trouble or a lot of trouble?" Those replying "a lot of trouble" were classified as having severe impairment, those reporting "a little trouble" were classified as having moderate impairment, and those replying "no trouble" were classified as having no impairment. Anyone who was deaf or blind in both eyes or ears was classified as having severe impairment. Participants then rated their difficulties conducting ADLs and IADLs on a scale of 0 (no difficulty) to 1 (difficulty). Compared with individuals without sensory impairment, results showed that those having severe DSI had statistically significantly more difficulty in bathing, while those having moderate DSI had statistically significantly more difficulty in dressing, getting in and out of bed, and walking. In terms of IADLs, compared with individuals without sensory impairment, results showed that those having severe DSI had statistically significantly more difficulty in preparing meals, shopping, managing money, using the telephone, and conducting housework, while those having moderate DSI only differed statistically significantly from the unimpaired group in terms of the difficulty they encountered in conducting housework.

Another aspect of function associated with DSI is that of cognitive and functional decline.[29] In a study[30] of 6112 women 69 years and older participating in the Study of Osteoporotic Fractures, cognition was measured using a modified version of the Mini-Mental State Examination, and functional decline was measured using self-reported ability to conduct various ADLs and IADLs. These investigators assessed binocular visual acuity using Bailey Lovie Targets.[31] Those individuals with corrected binocular vision worse than 20/40 were considered to have visual impairment. Hearing loss was measured using a handheld screening audiometer. Participants unable to hear a 40-dB hearing level tone at 2 kHz in their better ear were considered to have hearing impairment. The data showed that individuals with DSI had greater odds of experiencing cognitive decline and functional decline than those without sensory impairment.

In contrast with the studies already reviewed, Chia et al[32] studied DSI effects using objective tests of vision and hearing to define DSI. They examined 2015 individuals aged 55 to 98 years from the Blue Mountains Eye Study at year 5 of participation in the longitudinal study. Air and bone conduction thresholds at octave frequencies from 0.25 to 8 kHz were measured using pure-tone audiometry in a sound-treated room, and monocular distance logarithm of the minimum angle of resolution visual acuity and cataract examinations were conducted to specify hearing impairment and vision impairment, respectively. In addition, participants completed the Australian adapted version of the Medical Outcomes Study 36-Item Short-Form Health Survey.[33] Chia and colleagues[32] found that individuals with DSI had statistically significantly poorer physical function, general health perceptions, vitality, and mental and social well-being than individuals without sensory impairment.

Many of the effects of DSI seem to be primarily mediated by vision loss in that hearing impairment has been shown not to add to the likelihood of depression when vision loss is already present.[22,23] Likewise, Keller et al[27] reported no statistically significant differences in IADL scores for individuals with DSI and visual impairment alone but found differences between those with DSI, hearing impairment alone, and no sensory impairment. Similarly, Brennan et al[28] did not find statistically significant differences in IADL restrictions between those having DSI and those having visual impairment alone but did between those having DSI and those having hearing impairment alone. Lin et al[29] reported that, although participants having DSI had the greatest odds of cognitive and functional decline, the confidence intervals for those odds overlapped those for participants having visual impairment alone. Findings from these studies suggest that the added presence of hearing loss does not further diminish abilities above and beyond those of visual impairment alone. Nevertheless, more studies are needed to better understand the interaction of visual and hearing impairment in older adults relative to the effects described herein.

In sum, DSI affects physical, psychological, and psychosocial well-being; however, most of these effects have been identified by studies relying predominantly on self-reported sensory impairment. Although the studies reviewed have provided several important insights regarding the experience of individuals who report DSI, the lack of clinically valid objective measures of hearing and vision and of a consistently used operational method for defining sensory impairment across studies indicates that the current body of literature on DSI is lacking. These caveats relate not only to the generalizability and comparability of study results but also to the validity of self-reported sensory impairment. Self-report depends on valid interpretation of the questions posed, accurate patient recall, and the emotional and psychological state of the patient.[34] In addition, a patient's response is often affected by perceptions of what he or she believes the examiner wants to hear. Furthermore, older adults tend to overestimate their capabilities[35] and to underestimate their degree of impairment.[36] Correlations between degrees of reported and measured sensory loss are low,[37] and discrepancies exist between self-report and objective ratings.[38,39] Of 3 studies[27,29,32] that included some form of objective measures of hearing and vision impairment, 2 studies[27,29] used measures of hearing impairment that are not considered clinically valid (the Whisper Test and threshold screening at a single frequency). All but the study by Chia et al[32] should be interpreted with caution. The DSI literature should probably not be used as a basis from which to develop rehabilitative strategies. Nonetheless, study findings of DSI to date seem to suggest that vision loss has a greater effect than hearing loss on daily function but that DSI has the greatest effect of all. Further research is needed to validate such a conclusion and to better understand the breadth of DSI effects on functional abilities and quality of life.

Single Sensory Impairment

Much can be learned about the effects of DSI by considering studies of the effects of vision and hearing impairment separately. One community-based prospective study[37] found visual impairment to be predictive of subsequent functional impairment in older persons, while other studies[40-42] have shown it to be associated with a decline in cognition and functional activities. Adjusting for sociodemographic characteristics and chronic conditions, self-reported and standard measures of vision were predictive of 10-year mortality and ability to conduct ADLs and IADLs.[37] Similar data exist for hearing impairment. For instance, Raina et al[26] found hearing impairment to be associated with restrictions in conducting activities such as grocery shopping, meal preparation, and personal finances, while Cacciatore et al[43] showed a strong relationship between decreased hearing ability and lower scores on the Mini-Mental Status Examination. Appollonio et al[44] found that hearing deficit was predictive of increased risk of mortality among men but not among women. In terms of social and mental well-being, vision loss and hearing loss have each been shown to be associated with depression, social isolation, anxiety, paranoia, and decreased self-esteem.[45-47] They have also been shown to have a negative effect on intimate relationships[48] and can result in poor self-efficacy in the workplace.[49] As shown by Kochkin and Rogin[45] in a study conducted for the National Council on Aging, hearing impairment affects many aspects of quality of life. They showed that individuals with hearing impairment who did not use hearing aids participated in statistically significantly fewer social activities and reported statistically significantly more anxiety, depression, emotional instability, and paranoia than individuals who used hearing aids. In addition, the hearing aid nonusers reported lower self-esteem and less warmth in their interpersonal relationships. Clearly, sensory loss can have far-reaching effects on health status and daily life.

In studies in which the comparative effects of hearing loss and vision loss have been examined within a single study, it has been shown that vision impairment is more likely to affect mood level and social relationships, while hearing deficits are more associated with reduced self-sufficiency in ADLs.[50] Conversely, Wahl and Tesch-Romer[51] suggest that hearing is more socially based and that vision is more spatially and physically based. Therefore, while both hearing and vision are required for effective functioning within a given environment, vision is most immediately necessary for interaction with the physical and spatial world, and hearing is most needed with the social world. Little is understood about how such effects differ in DSI, in which one sensory modality cannot be used as the compensatory sense for the other. Research to understand how individuals function with DSI is needed, and while we can learn from studies comparing the effect of single sensory impairments, the real need is for studies focusing on the interactive effects of the two.

Effects of Aging

Assessment, intervention, and rehabilitation for age-related DSI are complicated by the fact that, in addition to the sensory losses, aging individuals likely face a host of other challenges, including losses in cognitive capacity, decreased manual dexterity, and changes in communication needs and lifestyle. Therefore, DSI in older individuals occurs in a larger context of changing capacities and abilities that must be considered or accounted for by researchers aiming to answer important empirical questions about DSI in aging, and by practitioners aiming to use rehabilitation strategies with their older patients having DSI. The effects of these capacities and abilities are considered in turn.

Cognitive Capacity

Aging is accompanied by a gradual decline in some cognitive functions, independent of dementia or other brain pathologic conditions.[52] The coexistence and association of sensory and perceptual aging with cognitive aging[53] are critical considerations in DSI because older individuals with DSI are more likely to experience added compensatory challenges when faced with difficult visual, auditory, or cognitive tasks and because such difficulties hold implications for rehabilitative strategies and success. Several hypotheses regarding covariation of perceptual and cognitive performances are described by Schneider and Pichora-Fuller.[54] A first hypothesis is that perceptual declines cause cognitive decline.[55] A second hypothesis is that perceptual and cognitive declines are common indicators of systemic aging.[53] A third suggestion is that cognitive declines contribute to age-related differences on sensory measures of performance. A fourth hypothesis is that cognitive performance declines as a result of imperfect perceptual information. These hypotheses each provide a way to conceptualize the interrelations between sensory, perceptual, and cognitive function. More research is needed to determine which applies in the case of older individuals with DSI.

The association between aging and diminished ability to understand speech in noise, speeded speech, and speech under cognitively challenging conditions[54,56,57] reveals the interrelationship between cognitive aging and sensory-perceptual aging. Findings by Schneider and colleagues[58] suggest that age-related changes in functional hearing may be exacerbated due to changes in higher-level cognitive processes such as language comprehension, memory, attention, and cognitive slowing-processes that may otherwise enable compensation for impaired auditory function. More specifically, studies[59-61] have shown diminished temporal processing abilities among older individuals even when normal thresholds are present. Wingfield et al[62] reported an interaction between age, hearing acuity, and characteristics of spoken messages, such that age and hearing loss had minimal effects on comprehension of spoken language when the content of the sentences was simple and when speech was presented at normal rates and at rapid rates. However, when sentences became more complex, hearing loss and age were associated with poorer performance; this performance decrement was made worse by increasing speech rate. Other studies have shown that deficits in working memory affect the ability of older individuals to understand time-compressed speech,[63] while other authors report that interhemispheric processing is disrupted as a result of the aging process[56] and that older adults are disadvantaged in dual-task conditions if hearing thresholds are increased even 10 dB.[64]

The findings with regard to the interrelationship between visual performance and cognition are, in many ways, similar to the findings reported between hearing and cognition. Visual impairment has been shown by some[65,66] to be a risk factor for cognitive decline among the elderly. Visual acuity in participants aged 20 to 80 years predicted about half of the age-related variance in a general cognition factor,[67] and artificially blurring the near vision of young healthy participants resulted in poorer performance on nonverbal cognitive tests.[68] Older adults demonstrate greater text comprehension ability under more favorable high-contrast visual conditions relative to low-contrast ones.[69] Anstey et al[70] recently conducted a study to determine if reduced contrast would simulate the performance difficulties associated with aging in a sample of older adults. A moderate to strong association between visual contrast sensitivity and cognitive performances was found, supporting the notion that visual aging is associated with slower encoding of information.

A few studies have examined the effect of DSI on cognitive task performance and aging. For instance, in a study[71] to determine whether there was an independent association between sensory and cognitive impairment, it was found that, relative to older individuals without sensory loss, persons having vision impairment and persons having moderate to severe hearing loss had lower Mini-Mental State Examination scores. Evidence for covariation in longitudinal rates of change in vision, hearing, and memory performance has also been demonstrated.[72] Given the relationships among hearing, vision, and cognition, it is clear that the cognitive abilities of individuals with DSI, as well as the cognitive load of any given rehabilitation strategy, must be considered in the development, testing, and application of rehabilitation for older individuals having DSI. This is particularly the case because age-related decrements in cognitive ability may compromise learning, decision making, safety, socialization, and personal well-being,[73] all of which are likely to affect the use and success of rehabilitative interventions.

Manual Dexterity

With advancing age comes diminished manual dexterity.[74] This has direct effects on several aspects of hearing aid use and aural rehabilitation, with the most obvious being hearing aid insertion, manipulation of the hearing aid controls, and handling of the battery. Indeed, research has shown strong associations between poor manual dexterity and poorer hearing aid outcomes, less daily use, and lower satisfaction with hearing aids.[75-77] Furthermore, Meister et al[78] found that ease of handling a hearing aid was considered to be the third most important attribute after speech in quiet and speech in noise for individuals aged 74 to 91 years, yet it was the least important attribute for individuals aged 20 to 52 years. In another study,[79] it was concluded that ease of use of a hearing aid was a major factor in hearing aid preference among a group of elderly first-time users. Even more dramatically, Parving and Philip[80] reported that 40% of hearing aid users in their tenth decade (≥ 90 years) could not use the volume control wheel, 36% could not change the hearing aid battery, and 34% could not clean the hearing aid ear mold. Therefore, manual dexterity must be considered when addressing DSI rehabilitation of older individuals.

Communication Needs and Lifestyle

As lifestyles change with age, so do communication needs[81] and the priorities individuals have regarding what they want from hearing aids, as shown in the study by Meister et al[78] already described. In that study, 4 groups of participants ranging in age from 20 to 91 years were provided descriptions of 8 hypothetical hearing aids in terms of the relative strengths and weaknesses of each hearing aid on the following 6 attributes: hearing speech in quiet, hearing speech in noise, hearing aid sound quality, ease of handling, how much feedback the user would experience, and how well the user could localize sounds while using the hearing aid. Participants were asked to rank order the hearing aids in terms of their preference for each. The results showed that, until the age of 73 years, hearing speech in noise was the most important attribute, followed by hearing speech in quiet, while the remaining attributes held similar but much lower importance. After age 73 years, hearing speech in quiet became the most important attribute, followed by hearing speech in noise. There is also considerable evidence that older individuals are more accepting of hearing impairment than younger individuals. For the same degree of impairment, older individuals report fewer difficulties than younger individuals,[36,82,83] and the level of impairment at which older individuals report hearing difficulties is greater than the level of impairment at which younger individuals report difficulties.[84] There are several possible explanations for this. First, it may be that older individuals expect a degree of hearing impairment as they age and accept it. Second, older individuals judge their hearing ability in relation to that of others in their age group and tend to underestimate their hearing impairment.[85] Third, some older individuals may be simply unaware that their hearing has deteriorated because the onset was so gradual. Regardless of the underlying explanation, misperception of hearing impairment probably manifests as a reluctance to acquire hearing aids or to participate in other types of aural rehabilitation.

Audiological Rehabilitation of Individuals With DSI

Dual sensory impairment affects patient-provider communication and the approaches taken toward rehabilitation. These issues are discussed herein, with reference to the ways in which audiological rehabilitation can be modified to accommodate individuals who have concomitant vision loss.

Cognitive Considerations

Gatehouse and colleagues[86,87] examined the relationships between cognitive ability, performance, and hearing aid compression characteristics of 50 hearing aid users. In their earlier study,[86] they measured cognitive ability using a visual digit-monitoring task and speech-in-noise ability using a closed-set word test at 55, 65, and 70 dB sound pressure level for signal-to-noise ratios of +5 and +10 dB. Each speech-in-noise condition was tested for aided listening using 5 different hearing aid settings. Two settings were linear, and the other 3 settings were nonlinear compression fittings with differing compression release times. The findings pertinent to this article are, first, that individuals with poor cognitive ability were more adversely affected by a poorer signal-to-noise ratio than those with higher cognitive ability. Second, individuals with poorer cognitive ability showed less aided benefit than those with higher cognitive ability. Third, individuals with higher cognitive ability gain more benefit from the use of temporal dips in background noise than individuals with lower cognitive ability, suggesting that they can better benefit from hearing aids with complex fast-acting signal processing than those with lower cognitive abilities. In their later study,[87] the authors continued this work, examining the relationships between compression characteristics and individual differences. They tested a further 50 experienced hearing aid users aged between 54 and 82 years on measures of cognitive capacity, speech in quiet, and speech in noise processed via 5 hearing aid settings and self-reports of the listening environment and the ease of listening for each. Regarding cognitive capacity and function, they found that listeners with higher cognitive capacity derived greater benefit from fast-acting wide dynamic range compression fitting than slow-acting automatic volume control, while individuals with lower cognitive capacity benefited more from automatic volume control than wide dynamic range compression fitting. Wide dynamic range compression fitting increases moment-to-moment audibility but decreases spectral and temporal contrasts. The authors conclude that, for individuals with higher cognitive capacity, audibility is more beneficial in the trade-off between audibility and contrasts, while the converse is true for individuals with lower cognitive capacity. These data demonstrate the importance of considering cognitive status when selecting hearing aid characteristics.

Patient-Provider Communication

Older adults have a higher prevalence of chronic disease than younger adults. Therefore, they have the greatest need to engage in health-promoting behaviors but face the challenge of doing so with vision and hearing impairment. Dual sensory impairment is particularly detrimental to patient-provider communication because most interactions are verbal. Verbal communication relies on both auditory and visual input in the form of speech-reading cues and subtle nonverbal cues such as gestures, facial expressions, and body posture. Speech reading can enhance verbal communication by up to 50% to 60% over the use of auditory or visual cues alone,[88] while subtle nonverbal cues are critical for communication. Tone of voice provides information about mood and intent, facial expressions and posture can reveal the emotions of the speaker, gestures often provide information that supplement the verbal content, and eye contact provides an emotional link between the speaker and the listener. Consequently, although the literal content of the understanding may not be lost, subtle information is. individuals with DSI are at a substantial disadvantage over individuals with single sensory impairment. The problem is exacerbated by the fact that even mild to moderate hearing impairment affects memory,[89] presumably because the extra perceptual effort required to decode speech taxes processing resources allocated to encode content into memory.[90] Patients also need to read printed instructions such as pharmaceutical labeling and take home informational materials. DSI can limit a patient's ability to understand and recall the information provided and to successfully integrate self-care into daily life. Although little is known about the effects of DSI on the ability of older persons to comprehend, remember, and follow health care instructions, it has been shown that generally older individuals have the greatest prevalences of lower health literacy[91] and related adverse health outcomes than younger individuals.[92-94] Therefore, patient-provider communication should be optimized to accommodate the sensory needs of older individuals to the extent possible. Some ideas are proposed as follows.

Ensure the environment is optimized. The patient care room should be optimized to enhance visual and auditory communication. To improve hearing, the room should be as quiet as possible and without extraneous noise. Using sound-absorbent furnishings such as heavy curtains, carpeting, and cushions can decrease reverberation in an office, making speech easier to understand. Vision is enhanced when the room is well lit but without glare. The clinician should optimize visibility of his or her face by not sitting in front of a window.

Provide redundancy. Delivery of information via multiple perceptual channels (visual, auditory, and tactile) will increase the patient's opportunity to perceive and process all information provided. The content of spoken information can be supplemented in written and graphical form, and written materials can be verbally reiterated during the encounter. Furthermore, the provider can use tactile information as a redundant source of input. For instance, the provider may suggest that the patient think about how the hearing aid faceplate feels and where the on-off switch is relative to other switches on the hearing aid, or the provider can point out the difference in the feel of the positive and negative faces of a hearing aid battery. Medication bottles may be made more easily distinguishable by the addition of raised and textured stickers that are palpable. The patient teach-back method for verification of information comprehension provides an additional level of redundancy and improves comprehension and learning.[95] In this method, the patient repeats back in his or her own words what was said by the provider or demonstrates the procedures indicated by the provider, as appropriate.

Speak clearly. The use of jargon should be avoided; providers often fallaciously assume that common medical terms are well known. In addition, efforts to clearly enunciate and to increase the spacing between spoken words, decreasing the rate of speech, will likely enhance the ability of elderly individuals with hearing impairment to perceive spoken information correctly.

Provide clear written materials. When providing supplementary written materials, the content and presentation should be carefully prepared. Forty-four percent of persons older than 65 years read at fifth-grade level or below, while another 30% read at approximately fifth-grade to eighth-grade levels.[96] Therefore, the materials should be presented at an appropriate reading level, they should be written in the active voice, personal pronouns should be used, and they must be direct, specific, and concrete.[97] Research shows that the print should be a minimum of 14 points, it should have wide spaces between the lines, and a sans serif font should be used.[98] Multiple columns on a page should be avoided, the text should be justified on the left but unjustified on the right, and the materials should be printed in high-contrast black and white or in saturated colors to optimize contrast sensitivity on matte paper to prevent difficulties related to glare.[99,100]

Provide assistive devices. Assistive technology to help with hearing and seeing should be made available if possible. Assistive listening devices could consist of hardwired personal amplification and frequency-modulated hearing systems. As recommended by Smith et al,[101] provision of a handheld magnifier to assist with reading of written materials is helpful. Such magnifiers can provide magnification of between 1.5 and 20 times and can be equipped with battery-operated lights. A superior solution, although more costly, is a video magnifier (closed-circuit television). A closed-circuit television is superior to a handheld magnifier because it frees up both hands of the user, does not require steady hands during use, and can provide greater magnification than that provided by a handheld magnifier. A closed-circuit television consists of a stand-mounted video camera that projects magnified objects or text onto a video screen. The image can be shown in black and white or color and can be used in conjunction with a personal computer. These are especially useful when demonstrating the use and upkeep of a hearing aid.

Research Needs

Much research is still needed in this area. Specifically, we need research to determine how best to train providers to recognize DSI, how best to communicate essential health information clearly, and how to maximize adherence to instructions and treatment protocols. Although guidelines to optimize patient-provider health communications with older adults exist,[102,103] little is known about how to most effectively apply them to enhance communication with persons who have DSI.

Rehabilitation

It is assumed that the effect of DSI will far exceed the effect of vision or hearing impairment alone, because when these two sensory impairments are combined, the individual is deprived of compensatory strategies that make use of the nonimpaired sense. Similarly, DSI poses challenges for rehabilitation in which assistive technology relies on the use of the unimpaired sense. For example, although flashing fire alarms and closed captioning are often provided to compensate for hearing impairment, they will be of reduced benefit to someone with vision and hearing loss. Similarly, talking clocks and spoken medication reminders are helpful to individuals with visual impairment who have intact hearing but will be ineffective if hearing loss accompanies vision loss.

The primary rehabilitative device for hearing loss is a hearing aid, which by nature is small. Hearing aids usually have poorly marked controls and require tiny batteries that must be inserted in the correct orientation for the hearing aid to work. Although larger hearing aids usually use bigger batteries, even the largest hearing aid batteries are only a few millimeters in diameter and are difficult to see and handle for many older individuals. Clearly, DSI poses problems for the use of such devices. However, by carefully considering the needs and limitations of the patient, effective auditory rehabilitation can be practiced. A few suggestions are provided as follows.

Consider the Hearing Aid Style, Features, and Accessories

There are pros and cons to each style of hearing aid. Behing-The-Ear (BTE) hearing aids provide the most power without feedback and generally use larger batteries than other styles that are easier to handle and see. However, they can be difficult to insert and are considered by some to be more prominent and more embarrassing than other styles. On the other hand, In-The-Ear (ITE) and In-The-Canal (ITC) hearing aids are smaller and, being one piece, are usually easier to insert than BTEs, but they require correspondingly smaller batteries than BTE hearing aids. Finally, Completely-In-The-Canal (CIC) hearing aids are difficult to handle and have tiny batteries but are considered to be almost invisible to others. Empirical data regarding the ease of handling of different styles of hearing aids are mixed. Upfold et al[104] found that ITE hearing aids were the easiest style to manipulate in terms of insertion, removal, battery replacement, switching the aid on and off, and adjustment of the volume control. The ITC aids were second easiest, with BTE hearing aids being most difficult. Johnson et al[105] came to the same conclusion. On the other hand, Stephens and Meredith[106] found that BTE hearing aids were more easily handled than ITE devices. These studies underscore the need for clinicians to consider carefully the individual patient's physical limitations and his or her needs and preferences, especially when both vision and hearing are compromised. Whether to include hearing aids with additional features is another factor to consider when providing hearing aids to an older individual having DSI. An individual with compromised cognitive skills would likely encounter difficulties trying to manipulate and select settings from a hearing aid with multiple programs; that individual may similarly have difficulties handling and understanding a remote control device and even a volume control wheel. Decisions regarding inclusion of such additional features should be made by considering the user's needs, lifestyle, and abilities.

Choice of Battery

As already discussed, many hearing aid batteries are difficult to see and handle because of their diminutive size. At least two manufacturers of hearing aid batteries have worked on solutions to this problem. Duracell has designed "Easytab" batteries that incorporate a one-inch-long battery tab that is easy to see and hold. The tab can be used to pick up and place the battery in the hearing aid battery compartment. Energizer has developed the "EZ Change" battery pack that uses a magnet and a plastic arm in the battery pack to help guide the battery into the hearing aid compartment. These approaches avoid the need for the user to hold the battery and may help him or her place it correctly in the hearing aid. Although they do not fully solve the problem of hand tremor that is common in older individuals, they improve the ease of battery handling.

Use Assistive Technology in Addition to, or in Place of, Hearing Aids

The home-based lifestyle of some older individuals should perhaps result in provision of assistive listening devices for the home in lieu of hearing aids. Such devices could include amplified telephones with raised big-button keys to improve visibility when dialing, infrared systems for listening to the television, and a personal frequency modulation system for communicating with others. Such devices are generally easier to see and handle than hearing aids and may substantially improve the quality of life of an individual with severe vision and hearing DSI who may not otherwise use assistive technology.

Use Tactile Information

Many types of vibrating devices are available to assist the individual with DSI. Such devices include vibrating alarm clocks, doorbells, and smoke alarms. There exist all-in-one systems that provide vibratory signals for multiple-alerting devices.

Research Needs

Once again, the suggestions provided are simple strategies, for use singly or in concert, aimed at increasing awareness of DSI during rehabilitation. There is a considerable lack of research concerned with the development of rehabilitative technology designed specifically to address DSI. In fact, many devices designed to address single sensory impairment are potentially unusable by individuals with DSI, and empirical data substantiating the use of one strategy over another are lacking. In September 2004, the Veterans Affairs Rehabilitation Research and Development Service, in conjunction with the National Center for Rehabilitative Auditory Research, convened a consensus conference on DSI. At that meeting, groups of experts in the fields of hearing and vision met to discuss the current state of knowledge about DSI among the aging population as a whole and to identify research and clinical needs. A working group was specifically assigned to discuss technology for rehabilitation of individuals with DSI. They identified the following 3 categories of devices that are needed: (1) devices to improve communication, (2) devices to increase environmental awareness, and (3) devices that address usability for individuals with DSI.

The working group suggested that, when developing communication devices, redundancies should be incorporated into all technology. For instance, it was suggested that visual and auditory cues should be enhanced by provision of tactile stimulation, or that signal processing algorithms should be developed that combine the visual and auditory information in real time to improve the signal-to-noise ratio and to enhance the speech information in the signal. This approach is being investigated at the National Center for Rehabilitative Auditory Research in collaboration with the Oregon Health and Sciences University School of Science and Engineering. A system is being developed in which a video camera will be mounted on the lapel of a hearing aid user's clothing. The data collected from the hearing aid will be combined with that from the camera. By examining the combined information, it will be possible to differentiate signal from noise. Signal processing will be used to attenuate the noise to improve the signal-to-noise ratio, and the mutual information in the auditory and visual inputs will be used to enhance the auditory signal by enhancing localization cues.

In terms of environmental awareness, the working group considered that enhancement of sound localization as a means of improving way-finding and safety was a critical need. They suggested that hearing aids that enhance localization and alerting cues should be designed. With sophisticated signal processing algorithms and the availability of real-time processing to extract and enhance localization cues, this is becoming a real possibility.

For usability, the group proposed that hearing and vision devices with the capability of interconnectivity be developed. Such devices can potentially provide several advantages over independent devices. First, there would presumably be fewer settings for the user to select and fewer controls to navigate. Second, interconnectivity would permit the mutual information in the auditory and visual signals to be combined in a manner similar to that already described. Third, interconnectivity will ensure that systems are working in synchrony. It was also pointed out that industry standards should consider usability by individuals with DSI. Similarly, industry partnerships between hearing and vision device manufacturers would likely lead to improved product design.

From a different source, it has been suggested that virtual reality has potential to help individuals with DSI. Dale[107] suggests that virtual reality could be used to augment orientation and mobility, and to provide remote artificial personal support systems and flexible access to environmental information by using haptic, tactile, vestibular channels to provide realistic virtual representations.

In addition to research directly addressing the development of rehabilitative technology, many questions exist that must be answered to optimize rehabilitation of DSI. For example, little is understood about the everyday functional effects of DSI. It is generally assumed that the effect of the combination of vision loss and hearing loss will be greater than the sum of the two individual impairments. However, no studies addressing this have been published, to our knowledge. Similarly, how should the effect of DSI be measured? There are many disease-specific tools for evaluating the activity limitation and participation restrictions associated with hearing loss and vision loss.[108-110] However, such questionnaires are not applicable to DSI because they focus on one impairment only. Similarly, performance measures assessing speech understanding and reading ability exist,[111,112] but none attempt to measure performance on a task that requires both hearing and vision. In a similar vein, how should success of rehabilitation be measured? As already noted, current outcome measures are disease specific and do not address overall functional improvement in terms of both vision and hearing. Another pressing need is for determination of who is responsible for rehabilitation of individuals with DSI. In current practice, audiologists address hearing impairment, and optometrists address vision problems. Practitioners rarely consider function of the other sense, nor do they necessarily realize the extent to which dysfunction is a barrier to rehabilitation.

Summary

Much research remains to be performed before the effects of DSI will be fully understood. Consequently, it is not possible now to develop fully informed rehabilitation programs for individuals with DSI. The simple-to-apply suggestions outlined in this issue should make clinicians aware of some of the issues faced by this growing population, but further research to understand the functional effects of DSI is critical for the development of standard definitions and measurement of the problem. Such work will allow the development of practice and communication guidelines that are specific to DSI. These studies should also address factors such as age, cognition, personality, and duration of impairment, which likely affect the effect and the efficacy of rehabilitation. Furthermore, any technologies that are developed must be tested for objective and subjective aspects of usability. A device that enhances functional performances but that is subjectively rated to have low usability will not achieve the goal of its developer that the device will provide assistance and in fact be used. Finally, interdisciplinary training of hearing and vision professionals is critical if rehabilitation for DSI is to progress from provision by two independent services to a single integrated system.

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