Connections Between Vision, Hearing, and Cognitive Function in Old Age

By Hans-Werner Wahl and Vera Heyl

What are the implications for everyday competence?

Vision and hearing are basic forms of interchange between the person and the environment, and both senses are subject to pronounced age-related losses that begin quite early in adult life (see Fozard and Gordon-Salant, 2001, for a recent review). Cognitive functioning encompasses a variety of phenomena, including different interpretive and thinking abilities such as inductive reasoning, identification of similarities, and recognition of figural relations; perception; verbal abilities; memory; and everyday problem solving. There can be no doubt that at least a substantial portion of these abilities, particularly those frequently described as the mechanics of intelligence (e.g., perceptual speed), undergo pronounced age-related decrements (P. B. Baltes, 1993; Schaie, 1996). The close association between a person's age and level of function in the domains of vision, hearing, and cognition suggests that there may be significant similarities in the extent to which function in these domains changes as people age. This article summarizes what we currently know about changes in function with age and includes implications for practice.

Cognitive functioning, vision, and hearing are all closely related to higher cortical functions. Indeed, one of the "big stories" of perceptual research in gerontology (Fozard, 1990) has been the idea that sensory functioning must be understood from a central nervous system perspective and not reduced to the peripheral functioning of the end organs. Another important issue is that the everyday competence of older adults, reflected in daily activities such as shopping, taking medication, banking, or using public transportation, has been found to be strongly related to both cognitive capacity and sensory functioning (e.g., Burmedi et al., in press; Marsiske, Klumb, and M. Baltes, 1997). However, there is still not enough evidence to demonstrate any definite causal relation between cognitive functioning, hearing, vision, and day-to-day functioning in later life. That is, while we know that these functions are related, we do not know the exact nature of the relationship. For example, the idea that loss in cognitive functioning in later life is triggered by (earlier) loss in vision and hearing—once thought to be clear—is still very much subject to debate.

Empirical Studies

Research examining vision, hearing, and cognitive functioning in normally aging adults is far from new. Galton (1883) was among the first to address sensory and cognitive links, and he was also among the first to conduct empirical research with older adults. This search for connections between sensory and cognitive functions, also addressed in earlier gerontological research (e.g., Schaie, P. B. Baltes, and Strother, 1964), found a renaissance during the 1990s in gerontology, particularly because of findings from the Berlin Aging Study on older adults from 70 to 100 years old (Lindenberger and P. B. Baltes, 1994). This, in turn, has stimulated additional research by other excellent research groups in cognitive aging (e.g., Salthouse et al., 1996) and strengthened the insight that only longitudinal designs will bring us nearer to answers about what causes what (Ghisletta and Lindenberger, 2002; Wahl, Tesch-Römer, and Rott, 2000).

Cross-sectional findings. Since the beginning of the 1960s, a number of major cross-sectional studies have examined the relationship between vision, hearing, and cognitive functioning across the adult lifespan.

Needless to say, it is rather difficult to compare the findings of studies that differ in terms of sample size, setting (private household, laboratory, nursing homes), age range (from early adulthood to very old age), assessment quality (differences in the reliability of instruments both in the cognitive and sensory domain), consideration of sensory modalities (assessment of both vision and hearing versus consideration of only one of these senses), measurement device (a wide range of indicators for vision, hearing, and cognition), and complexity of data analysis. However, on the positive side, all of the studies discussed below used objective measures of vision or hearing or both and—taken from a multimethod point of view—any pattern that is found is all the more robust if different measurement and study-design approaches produce convergent lines of empirical evidence.

By and large, the findings support the view that the links between vision, hearing, and cognitive functioning—either explored separately for vision or hearing or in a simultaneous manner—are substantial. That is, most of the major studies found at least modest significant relationships between sensory and cognitive measures based on diverse assessments and design methods.

The work of Lindenberger and P. B. Baltes, based on the sample of the Berlin Aging Study (base) but also including additional studies with a wider range of subjects, is central in support of a strong connection between vision, hearing, and cognition as people age. The base (P. B. Baltes and Mayer, 1999) is noteworthy because it assessed sensory functioning in a heterogeneous sample of old and very old subjects (70–103 years) by means of standardized and reliable procedures (for details, see Lindenberger and Reischies, 1999).

In their first and now classic research report on the relationship between sensory and cognitive development, Lindenberger and Baltes (1994) found that general intelligence correlated just as strongly with visual as with auditory ability. Sensory measures also correlated quite strongly with age, as did general intelligence. Furthermore, in a model conjoining age, sensory functioning, and intelligence, visual and auditory functioning predicted the largest portion of individual differences in intelligence measures. The exclusion of subjects suffering from severe sensory impairments or from dementia did not alter the results in any significant manner.

In their later work, Baltes and Lindenberger (1997) used a larger sample with a mean age of 84.9 years for their analysis. According to the findings of this study, sensory measures were better predictors of intelligence than sociobiographical variables, such as years of education and social class. In addition, these researchers added a heterogeneous younger adult sample varying in age from 25 to 69 years, with a mean age of 48.2 years. The results again showed a close link between sensory and intellectual functioning in old age: Age gradients in five different intellectual abilities (perceptual speed, memory, reasoning, fluency, and knowledge) were extremely well predicted by individual differences in vision and hearing. Also, by comparing data from the younger with the older sample, Baltes and Lindenberger found that vision and hearing are more closely related to intelligence (particularly regarding mechanical components of intellectual abilities) in old age than during earlier periods of life. This suggests that age-related decrements in basic cortical information processing lead to an increasingly closer connection between cognition and sensory functioning as people age.

Longitudinal findings. Although longitudinal research can better address causal links between vision, hearing, and cognitive performance, work of this kind is still quite rare. One example is a reanalysis of the data of the Bonn Longitudinal Study on Aging (BOLSA) (Lehr and Thomae, 1987) reported by Rott (1995). The main focus of Rott's analysis was whether sensory and intellectual deficits in old age occur simultaneously or successively. For this purpose, data from 156 BOLSA participants (83 men and 73 women age 65 at the first measurement occasion) were analyzed based on an observation period of about twelve years. Three main results were found: First, changes in cognitive performance were more marked in those older adults with severe sensory deficit than in those with less severe sensory deficit. Thus, slight visual impairment did not have a strong effect on changes in the visual intelligence component, while severe visual impairment did. Second, hearing impairment produced more drastic reductions in cognitive performance than did visual impairment. Severe hearing loss and memory had the strongest relationship observed. Conversely, visual impairment did not have an effect on the memory component of intelligence. Third, the effects of sensory impairment occur both in a simultaneous *and* in a successive fashion. While the trajectory of visual intelligence parallels that of visual impairment, reductions in memory performance occur before and after the onset of hearing impairment.

Results like these suggest that we are still far from understanding the "exact" causal complexities associated with the transactions of vision, hearing, and cognition as people age. In fact, recent longitudinal findings from the Berlin Aging Study over a four-year interval provide clear support for a dynamic system view of what happens between these sets of functions (Ghisletta and Lindenberger, 2002). Based on a sophisticated data analysis of longitudinal trajectories, the findings tell us that, even if we only look at visual functioning (near and far vision), change in a single indicator of vision function does not play a consistent role in predicting change in other vision and cognitive variables.

Vision, hearing, and severe cognitive impairment. Research on vision, hearing, and severe cognitive impairment targets the prevalence of sensory impairments among demented patients as well as the association between sensory impairments and cognitive decline in demented populations. The results of one large study of 45,500 adults with intellectual disability who were age 35 years and older indicate a prevalence of sensory impairment comparable to or greater than that found in the general population (Janicki and Dalton, 1998). For example, 50 percent of those age 80 and older suffered from visual impairment or blindness, and 62 percent suffered from hearing impairment or deafness. Moreover, for some quite specific mental disorders such as Lytico-Bodig (a dementia complex of amyotrophic lateral sclerosis and Parkinsonism), a variety of ocular deficits seems to be characteristic (Lepore et al., 1988).

Since the 1980s, evidence has emerged that Alzheimer's disease is associated with degeneration of the optic nerve and is thus often linked to low visual acuity (Cogan, 1985; Sadun et al., 1987; Tsai et al., 1991). In addition, several studies have reported deficits in other basic visual capacities, such as contrast sensitivity (e.g., Kéri et al., 1999) and color discrimination (e.g., Cronin-Golomb, Corkin, and Rizzo, 1991), among older people suffering from Alzheimer's disease. On the level of complex visual tasks, object vision and spatial vision as well as motion image processing seem to be disturbed in those with Alzheimer's disease (Fujimori et al., 1997; Rizzo and Navrot, 1998). Furthermore, converging evidence shows that visual impairment and severity of visual hallucinations are significantly associated among Alzheimer's patients (McShane et al., 1995; Chapman et al., 1999).

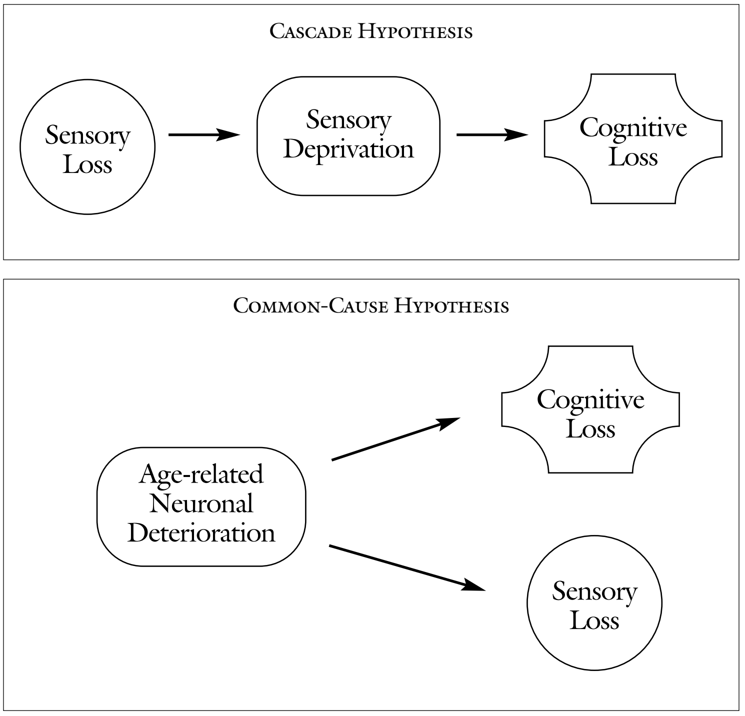
Regarding the association between visual capacities and degree of cognitive dysfunction in Alzheimer's disease patients, the results are somewhat mixed. While Cronin-Golomb, Corkin, and Growdon (1995) found that low spatial frequency contrast sensitivity predicted performance on cognitive tests, the results from a study by Kéri and colleagues (1999) suggest that loss in contrast sensitivity is independent of the cognitive disturbances in Alzheimer's disease. Uhlmann and colleagues (1991), on the other hand, found visual impairment in terms of near- and far-vision acuity to be significantly associated with both an increased risk and an increased clinical severity of Alzheimer's disease. Moreover, there is rather strong evidence for an association between hearing impairment and cognitive decline among demented elders (for review, see Gennis et al., 1991). For example, results from two prospective studies showed that hearing-impaired demented elders declined more strongly on cognitive screening measures than did demented elders with normal hearing (Uhlmann, Larson, and Koepsell, 1986; Peters, Potter, and Scholer, 1988).

To conclude, while there is no doubt that the coincidence of sensory impairments and dementia is high, the causal dynamics leading to the significant associations between sensory impairment and cognitive decline among elders with dementia are rather unclear. Further research is needed to determine whether sensory impairments lead to cognitive decline in people with dementia or instead are markers of disease severity.

Theoretical Approaches

Theoretical models suggested in the literature have so far predominantly addressed the explanation of "normal aging" trajectories in the domain of sensory and cognitive functioning. In particular, two alternative models, the cascade hypothesis and the common-cause hypothesis, have been proposed to interpret the empirical findings on the relationship between sensory and cognitive issues (see Figure 1).

Figure 1
Theoretical models relating sensory functioning and cognitive capacity in old age



The first theoretical approach is based on Birren's (1964) cascade hypothesis. According to this view, age-related performance deficits in the sensory system show a "domino effect" on impairment in other areas of functioning. The basic assumption is that the slackened rate or complete absence of information flow to the brain produces a state of insufficient or imbalanced stimulation, which, in turn, has a negative effect on cognitive performance.

Contrary to the cascade hypothesis, the common-cause hypothesis states that the correlation between sensory performance scores and intelligence can be traced back to a fundamental or common cause: age-related changes in the central nervous system. Hence, according to this model, losses in sensory and cognitive functioning are due to age-related neuronal deterioration that(more or less) equally affects a wide range of variables closely linked to central nervous processing capacity.

If one links these theoretical ideas to the available empirical evidence, there is no clear indication that one or the other explanation is, in fact, the correct one. However, according to the present state of knowledge, the common-cause hypothesis seems to possess more explanatory power than the cascade hypothesis (Baltes and Lindenberger, 1997; Ghisletta and Lindenberger, 2002; Lindenberger and Baltes, 1994, 1997; Salthouse et al., 1996). The major argument is that the link between sensory and cognitive development becomes closer in the later years of the life span, that no clear cause-effect direction can be detected within the realm of sensory and cognitive variables, and that sensory deficits do not consistently manifest themselves before cognitive decline (see also Rott, 1995). Strong evidence for the common-cause model also comes from physiological findings that show that age-related changes in sensory functioning are neuronal in nature and are not restricted to the eyes and ears. Several studies have shown, for example, that deficits in visual acuity can, to some extent, be traced back to neuronal impairment beyond the ocular organs (e.g., Weale, 1987).

Implications for Intervention and Rehabilitation

What are the implications of these basic scientific findings for intervention and rehabilitation?

One important aspect is related to intelligence testing of older adults with vision and hearing problems. It could be argued with respect to much of the empirical research reviewed in this article that there may be a confounding effect such that lowered sensory functioning leads per se to lowered test performance. At least some studies have considered and ruled out this possibility. In particular, Lindenberger and Baltes (1994) have shown that dividing their instrument battery into those measures depending versus those not depending on sensory impairment did not alter the result of a strong connection between sensation and cognition. Nevertheless, the practical issue of sensory impairment causing misleading cognitive test results is an especially crucial one in testing older adults (e.g., Shindell, 1989; Vernon, 1989).

In terms of intervention, a basic question is whether cognitive training leads to improvement in vision and hearing or vice versa, whether training and rehabilitation of vision and hearing might lead to gains in cognitive performance. The common-cause hypothesis points to a basic and naturally occurring decline in central-nervous-system functioning, which calls into question the efficacy of any rehabilitative effort. Obviously, ruling out a rehabilitation effort would be overstating the case. Good visual rehabilitation in the later years, by means of interventions targeting older adults and their environment, has intrinsic value and contributes to the maintenance and optimization of functioning in everyday living, as clinical evidence and empirical outcome studies have repeatedly proved (Silverstone et al. , 2000).

It is another question whether these interventions can also be expected to prevent cognitive loss in old age. As has been argued in the context of hearing impairment in old age (Tesch-Römer, 1997), the positive effects of rehabilitation are contingent on the early onset, duration, and extent of rehabilitation procedures (Gelfand, Silman, and Ross, 1987). The timing of rehabilitation generally is a particularly crucial variable for the success of interventions in old age. Hence, it may be reasonable to assume that an integration of the cascade and the common-cause hypotheses may prove beneficial to the rehabilitation of sensory loss. That is, it could well be that a common cause at the level of the central nervous system affects different human adaptation systems, such as visual and hearing capacity and cognitive functioning. But in the early phase of sensory and cognitive decline, compensation for sensory losses may slow the impact of the naturally occurring loss trajectories. In such a view, the earliest and most effective compensation of visual (and hearing) loss would not principally alter the human aging architecture but could influence its course in a significant manner. We do not know, however, whether this theoretical possibility (which would have strong applied implications) is justified on an empirical level. Another suggestion derivable from the empirical literature as well as the conceptualizations discussed so far is that sensory-impaired older adults might profit from training not only in the sensory domain, but also in the cognitive domain. A classic application area for this could be driving performance in old age (e.g., Ball and Owsley, 2000). There is a clear need for additional longitudinal as well as controlled-intervention outcome research in this field, and such research may ultimately contribute to an understanding of the more fundamental issues of causal connections among vision, hearing, cognition, and aging.

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