Visual Impairment and Audiovisual Speech-Perception in Older Adults with Acquired Hearing Loss

Jean-Pierre Gagné, Walter Wittich

Abstract

Speech understanding is generally improved when the visual-speech cues produced by a talker are provided along with the auditory signal. This finding is observed among younger and older adults with hearing loss as well as among people with normal hearing who process speech under poor acoustical conditions. Few studies have investigated the effects of visual impairment on the auditory-visual integration of speech. Yet, clinically this issue is important given that it is estimated that more than 20% of adults above 70 years of age have a dual sensory (hearing and vision) impairment. The present chapter addresses issues related to auditory-visual integration of speech in older adults. The chapter is divided in five sections. First, the benefits of providing visual-speech cues in addition to auditory-speech cues are illustrated. Second, relevant findings related to only visual and audio-visual speech-perception in older adults with normal (or near-normal) visual acuity are summarized. Third, information is provided on the visual impairments that are most commonly observed among older adults. Fourth, what is known concerning the effects of reduced visual acuity on audio-visual speech-perception in younger as well as older individuals is described. Finally, suggestions are made concerning the audiologic rehabilitation services that should be provided to older adults with hearing loss regardless of whether or not they have an accompanying visual impairment.

Introduction

Most of everyday conversations take place in less than ideal acoustic environments, often due to background noise. Under those conditions, speech understanding is facilitated when the interlocutor can both hear and see the communication partner. For normally sighted younger adults with hearing loss, as well as those with normal hearing, speech recognition performance is improved when the task is administered audiovisually (AV) rather than only auditorily (A-alone) or visually (V-alone). The purpose of the present chapter is to summarize the current state of knowledge related to AV speech-perception in older adults. More specifically, the focus will be placed on the effects of visual impairments on AV speech-perception in this population. Discussion of this topic is relevant, given the high incidence of visual impairments among older adults (Elliott, et al., 1997; Maberley, et al., 2006; Pascolini, et al., 2004).

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Benefits of Providing Visual-Speech Cues in Speech Understanding

It is widely recognized that speech understanding is improved when the visual-speech cues produced by a talker are provided along with the acoustic speech signal (Arnold & Hill, 2001; Erber, 1972; Grant & Braida, 1991; Grant, Walden, & Seitz, 1998; Hack & Erber, 1982; Helfer, 1998; Jordan, McCotter, & Thomas, 2000; MacLeod & Summerfield, 1987, 1990; McCotter & Jordan, 2003; Sumby & Pollack, 1954). Generally, the magnitude of the improvement is inversely proportional to the performance observed when the speech-understanding task is completed under an auditory-alone (A-alone) condition. The results reported by Grant and Braida (1991) illustrate this point. In Figure 1, the A-alone and AV sentence recognition performances obtained for a group of young adults with normal hearing sensitivity are plotted as a function of the signal-to-noise ratio (SNR) at which the task was performed. At a SNR of -8 dB, the mean performance for the A-alone condition was approximately 23% correct. At the same SNR, the improvement observed by providing the visual-speech cues (i.e., the difference between the %-correct performance for the A-alone condition and the %-correct for the AV condition) was approximately 37%. When the same tasks were performed at a SNR of -4 dB, the mean A-alone performance was approximately 68% and the improvement observed when the visual-speech cues were provided was approximately 20%.

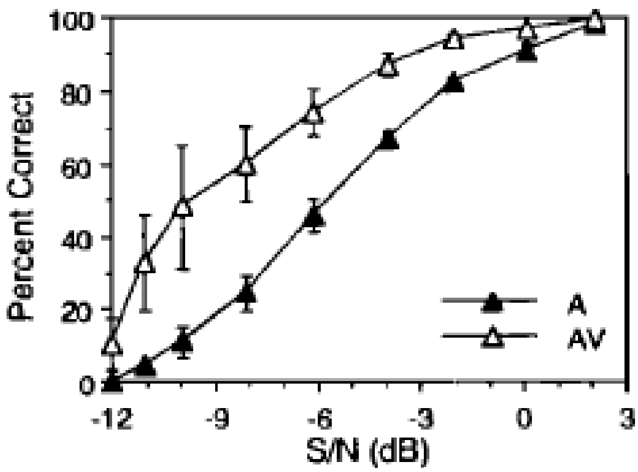


Figure 1. Results of study reported by Grant and Braida (1991). Auditory-alone and audiovisual performance curves for 23 normal hearing subjects as a function of signal-to-noise ratio. Data are averaged across four talkers. Data shown at a signal-to-noise ratio of –12 dB are for speechreading alone. Error bars indicate on standard deviation. Reprinted with permission.

Another approach to characterizing the benefits provided by the provision of visual-speech cues is to quantify the change in SNR that is observed when the performance obtained under an A-alone condition is compared to the same level of performance obtained when the task is completed under an AV condition (e.g. MacLeod & Summerfield, 1990; Middelweerd & Plomp, 1987; Plomp & Mimpen, 1979; Sumby & Pollack, 1954) For example, MacLeod and Summerfield (1990) plotted the mean sentence recognition scores that a group of young adults with normal hearing obtained at different SNRs. The sentence recognition task was performed under two experimental conditions: A-alone and AV (see Figure 2). Based on the two psychometric functions obtained, the investigators determined the SNR that yielded the same level of performance (50% correct responses) under the A-alone condi-

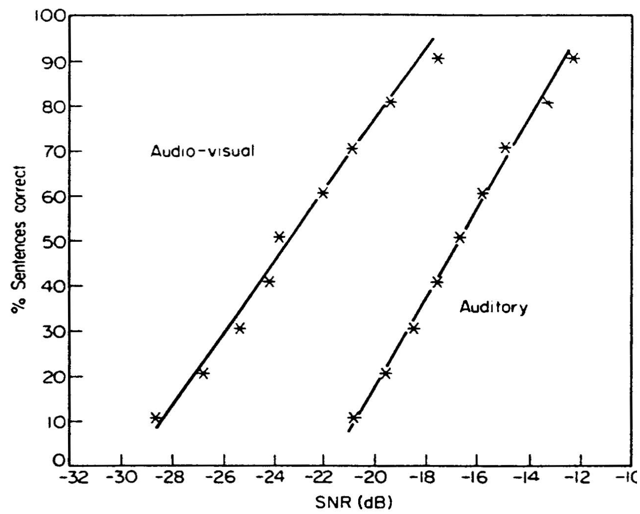


Figure 2. Psychometric functions obtained from a group of normally sighted young adults with normal hearing. Data are from a study reported by Macleod and Summerfield (1990). The plot depicts the percentage of recognition for keywords presented in sentences as a function of the signal-to-noise ratio at which the speech was presented. The task was performed under two experimental conditions: auditory-alone and audio-visually. Reprinted with permission.

tion (approximately –17 dB) and under the AV condition (approximately –24 dB). Based on these computations, one can conclude that in this experiment providing visual-speech cues along with the auditory-speech information was equivalent to an improvement in SNR by approximately 7 dB. Using a similar approach, with a different group of participants and different speech material, Sumby and Pollack (1954) reported that the addition of visual-speech cues can boost speech understanding in a manner that is analogous to an improvement in the SNR of approximately 5–18 dB.

In a recent investigation, Fraser, Gagné, Alepins & Dubois (2009) used a divided attention task, incorporated into a dual-task paradigm, to quantify the effort required to perform a speech-perception task in noise under two different perceptual conditions: A-alone vs. AV. In this investigation, the primary task consisted of a sentence recognition task that was performed in a background of noise. The SNR was set to a level that yielded a mean recognition score of approximately 80% correct when the speech-recognition task was administered by itself (single task), under an A-alone condition. The secondary task was a tactile pattern recognition task that consisted of recognizing a sequence of two elements. The two tactile elements differed from each other by their duration; short vs. long. The two experimental tasks were administered alone as well as concurrently. In one experiment, the speech-recognition task in noise was administered under two different conditions: A-alone and AV (at the same SNR). For all experimental conditions, the percent correct recognition scores as well as the response times were recorded for both the primary and the secondary tasks. The results of the investigation showed that under the dual-task conditions the performance levels were higher and the response times were shorter when the speech-recognition task was administered under the AV condition rather than under the A-alone condition. The investigators concluded that at a fixed SNR, speech recognition tasks are less effortful when they are performed under an AV condition than when they are under an A-alone condition.

In summary, several investigators have shown that, in young adults with normal hearing, the provision of visual-speech cues improves auditory-speech perception in noise (e.g. Grant & Braida, 1991; MacLeod & Summerfield, 1990; Sumby & Pollack, 1954). Furthermore, it has been demonstrated that the provision of visual-speech cues improves speech understanding in individuals with hearing loss (Erber, 1972; Sommers, Tye-Murray, & Spehar, 2005; Tye-Murray, Sommers, & Spehar, 2007; Walden, Busacco, & Montgomery, 1993; Walden, Prosek, & Worthington, 1974) as well as in older adults with normal (or near normal) hearing (Sommers, et al., 2005) or with a permanent hearing loss (Campbell, Preminger, & Zeigler, 2007; Helfer, 1998; Tye-Murray, et al., 2007; Walden, et al., 1993).

Visual-Alone and AV Speech-Perception in Normally Sighted Older Adults

The results of several studies have revealed that older adults perform more poorly than younger adults on speechreading tasks (note: in the present text speechreading and lipreading are used interchangeably to indicate speech recognition under V-alone conditions) and performances decrease with age (Campbell, et al., 2007; Cienkowski & Carney, 2002; Dancer, Krain, Thompson, Davis, & Glenn, 1994; Lyxell & Ronnberg, 1991; Middelweerd & Plomp, 1987; Shoop & Binnie, 1979). It appears as though a decline in speechreading performance may occur as early as the 5th decade of life. However, it is well established that by age 65–70 years, older adults score significantly more poorly than younger adults on speechreading tasks involving words and sentences (Dancer, et al., 1994; Shoop & Binnie, 1979). Tye-Murray et al. (2007) reported that older adults with hearing loss perform better on visual-word recognition tasks than their peers with "typical hearing levels". Walden et al. (1993) compared the V-alone and AV-speech recognition performances for syllables and words obtained from a group of younger adults and a group of older adults. Both groups of participants had moderately-severe hearing loss. The results of the V-alone speech recognition task revealed that the older adults performed significantly more poorly than the younger adults on the syllable and sentence tasks. However, a detailed scrutiny of the responses obtained for the test syllables indicated that there were no differences in the pattern of visual-consonant confusions made by the two groups of participants. In summary, it is established that speechreading declines as a function of age. However, based on the fact that younger and older adults have the same patterns of confusions, it would appear that the perceptual and cognitive processes used to perceive speech in the V-alone modality may be similar for younger and older adults.

The evidence available suggests that both younger and older adults use similar perceptual and cognitive processes in speech understanding tasks that require the integration of auditory and visual speech cues (e.g. Ballingham & Cienkowsky, 2004; Campbell, et al., 2007; Helfer, 1998; Sommers, et al., 2005; Spehar, Tye-Murray, & Sommers, 2004; Tye-Murray, et al., 2007; Walden, et al., 1993). The benefits observed by providing visual-speech cues in addition to the auditory-speech cues were investigated by Helfer (1998). Fifteen older adults (between 61 and 88 years of age) with normal (or corrected normal) visual acuity took part in the investigation. The pure-tone high frequency average hearing threshold level of this group of participants ranged from 15 to 53 dB HL. The results revealed that on average the provision of visual-speech cues improved speech recognition scores by 18%, relative to the A-alone performance in noise. Helfer (1998) failed to observe a relationship between the age of the participants and the benefits provided by visual speech cues. Specifically, Helfer (1998) concluded that the older participants displayed the same magnitude of benefit as younger adults.

Sommers et al. (2005) measured the A-alone, V-alone, and AV speech recognition performances of younger adults with normal hearing and older adults with typical age-related hearing acuity. Specifically, for the A-alone condition, the signal to speech-babble ratio was individually adjusted so that the performance of each participant was approximately 50% correct. The results of the investigation revealed that the older adults performed more poorly than the younger adults under the V-alone as well as the AV condition. However, the data analyses revealed that, once the differences in V-alone performances were taken into account, there were no differences in the AV integration abilities displayed by both groups of participants.

Using data from three different tasks (recognition of phonemes, recognition of words in isolation and recognition of sentences), Campbell, Preminger and Ziegler (2007) showed that there was a correlation between a measure of visual-enhancement score [i.e., (AV-A)/(1-A)] and age, in a group of adults (55–75 years of age) who wore hearing aids. The investigators attributed the discrepancy between their results and those of previous investigators to the difficulty of the speech-perception tasks used in their investigation. Typically, in AV integration studies the experimental conditions chosen yield a mean A-alone performance level of approximately 50% correct. In their experiment, Campbell et al. (2007) set the experimental conditions so that their participants obtained scores of approximately 50% correct under the AV condition (note: under that at that SNR, the A-alone performances ranged from 15–40% correct). The authors concluded that age influences AV integration processes for difficult listening conditions, but not for easier listening conditions.

Musacchia, Arum, Nicol, Garstecki and Kraus, (2009) used cortical evoked potentials to investigate the effects of hearing loss on the neural mechanisms of AV integration in older adults. Twelve older adults with normal hearing and 12 older adults with a mild to moderate hearing loss took part in the investigation. Electrophysiological recordings were obtained for the syllable /bi/ presented in one of three perceptual modalities: A-alone, V-alone, and AV. The results revealed that, despite controlling for the level of the auditory signal (i.e., for each individual, the auditory signal was presented at 30dB sensational level), in the AV condition, the influence of the visual stimulus was less pronounced for the participants with a hearing loss. The investigators concluded that older adults with hearing loss display poorer AV integration processes. In addition, based on their analyses of the electrophysiological data, the investigators hypothesized that, relative to older adults with normal hearing, those with hearing loss may be using the same (but to a lesser extent) underlying neurophysiological mechanisms when integrating auditory- and visual-speech cues. Furthermore, the investigators showed that older adults exhibit the same qualitative pattern of AV integration than the pattern displayed by younger adults presented with auditory and visual speech. These observations suggest that, contrary to A-alone processing, aging alone may not alter mechanisms of AV integration. However, the hearing loss typically observed among older adults does have a deleterious effect on both A-alone and AV speech processing mechanisms.

In summary, the experimental evidence suggests that, relative to A-alone speech recognition, normally sighted older individuals do show improvements when they integrate auditory and visual-speech information. However, at this time it has not been established unequivocally whether or not older adults are as proficient as younger adults with normal hearing at processing speech audiovisually. Notwithstanding this fact, recent electrophysiological data suggest that older adults with hearing loss use the same underlying perceptual and cognitive processes as individuals with normal hearing when they integrate auditory and visual speech information. Based on the body of literature available there is no reason not to encourage and train older adults with hearing loss to make use of visual-speech cues to improve their A-alone speech understanding.

Prevalence of Sensory Impairments in Older Adults

A detailed account of the prevalence of hearing loss and visual impairment in older adults is beyond the scope of the present chapter. Prevalence data are eloquently discussed in other chapters of the present proceedings (see Davis, Gates, Lemke). For the present discussion suffice it to state that the prevalence of hearing loss increases with age. It is estimated that approximately 30% of people in their sixties have hearing loss; while for people who are 70 years of age and older, the prevalence of hearing loss is estimated to be between 40 and 60% (Davis, this volume; Schoenborn, 1988).

In developed countries, the prevalence of visual impairment ranges between 0.3 to 2.5%, depending on the definition used: “being visually disabled” vs. “having difficulty reading newsprint with glasses” (Maberley, et al., 2006). However, independently of the classification systems, these prevalence rates are generally estimated to be higher when only the population of people over the age of 65 years is considered (Attebo, Mitchell, & Smith, 1996; Congdon, et al., 2004; Klaver, Wolfs, Vingerling, Hofman, & de Jong, 1998; Tielsch, Sommer, Witt, Katz, & Royall, 1990). Furthermore, it is specifically projected that the prevalence of age-related vision loss will dramatically increase over the coming decades (Congdon, et al., 2004).

Prevalence data on dual sensory impairment are not available in great abundance. One study reported that more than 20% of the veteran population in the USA over 85 years of age are affected by both vision and hearing loss (Smith, Bennett, & Wilson, 2008). Similar results were reported by Brennan, Horowitz and Sue (2005) who found that 20% of seniors over the age of 70 years presented with dual sensory impairment. In a pooled analysis of Dutch studies the results indicated that the prevalence of dual impairment increased with age, ranging from 0.5% in those 65 to 80 years old, up to 6% in those over the age of 80, whereby the rates reached 25% among nursing home residents and up to 13% in individuals with mental retardation (Slaets, 2007). The variation in these numbers may in part be due to how hearing impairment and visual impairment are operationally defined across studies.

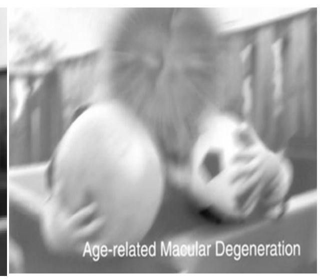
Based on their interpretation of the prevalence data on duals sensory impairment Erber and Scherer (1999) reported that approximately one in five adults, 70 years of age or older, who consults a hearing health care professional will have a visual impairment that can limit the clarity of a person’s face at a conversational distance. Given the importance of visual cues in speech communication, these data must be considered seriously. Hearing health care professionals should be familiar with the most common visual impairments observed among older adults. Furthermore, they must be aware of the potential impact of visual impairment on speech communication. Ideally, within the framework of audiological rehabilitative services, including the fitting of personal amplification systems, AV speech-perception abilities should be evaluated. When warranted, people with non-optimal corrective lenses should be referred to vision health care professionals.

Common Visual Impairments in Older Adults: Description and Perceptual Manifestations

In developed countries, the four most common causes of age-related visual impairment are: cataracts, macular degeneration, diabetic retinopathy and glaucoma. This section provides a summary description of each of these pathologies. For a more detailed account of the major visual impairments observed among older adults, the reader is referred to more specialized publications (Harvard Medical School, 2000; Rosenbloom & Morgan, 1993).

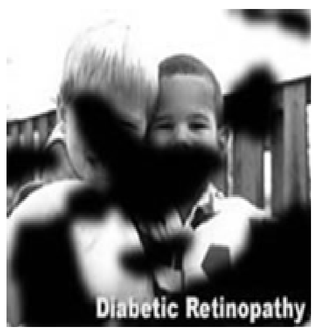
Cataract, a clouding of the lens, results in general and progressive blurring of vision and is generally considered a normal side effect of aging (see Figure 3a). Cataracts are the most common cause of vision loss, but are easily treatable through surgery whereby the

A. Cataracts



B. Age-related Macular Degeneration

C. Glaucoma



D. Diabetic Retinopathy

Figure 3. Photographic simulation of visual perception among people with visual impairment most commonly observed in older adults. Photographs were taken from: http://www.nei.nih.gov/photo/keyword.asp?narrow=Eye+Disease+Simulation.

blurred lens is removed and replaced with a plastic lens implant. Given that in developed countries this condition is treatable and vision is usually restored to normal or near-to-normal levels, cataracts are no longer considered a noteworthy cause of low vision. However, in developing countries, cataracts remain the leading cause of blindness (Lewallen, Mousa, Bassett, & Courtright, 2009).

Age-related Macular Degeneration (AMD) is a degenerative retinal disease that affects the central area of the retina, the macula, which is predominantly involved in fine detail vision. The risk factors involved in the development of this disease include smoking, poor diet, increased age, gender (women are more affected) and family history. The hallmark symptoms of AMD are decreased visual acuity (the ability to resolve fine detail) and the development of scotomas (islands of reduced or total vision loss in the central visual field; see Figure 3b). At present, two main types of AMD are recognized: the dry type (atrophic) which develops slowly, often over years, and very gradually decreases visual function, and the wet type (exudative) which involves sudden leaking of blood vessels in the retina and rapid decline of vision. At present, treatment options are limited. Vitamin supplement that slow down progression of the dry type of AMD have been developed and continue to be evaluated and improved (Raniga & Elder, 2009). In addition, intraocular injections of anti vascular endothelial growth factor (anti-VEGF) have recently shown to arrest progression and, in some cases, improve vision in the wet type of AMD. With the changing demographics in developed countries, AMD has become the leading cause of uncorrectable vision loss in the Western world (Harvey, 2003).

AMD is closely followed by diabetic retinopathy (DR) as a cause for acquired vision loss in adulthood. DR is a potential consequence of diabetes mellitus, a hormonal disease that is associated with an inability to properly regulate insulin levels. As a result, blood circulation within the body can become impaired due to glucose accumulation. Within the eye, this can result in the growth of unstable new blood vessels which are prone to leakage and scaring, thereby impairing vision. Treatments include the reduction of oxygen demand in the retina through panretinal photocoagulation (i.e., small laser burns that destroy retinal patches in the periphery). This treatment reduces the growth of new vessels. Given the unpredictable location and size of bleeding blood vessels, scotoma in DR can create patchy vision loss, sometimes referred to as "Swiss-cheese vision" (see Figure 3c). In addition, vision loss due to DR is known to be unstable and affected individuals report good and bad vision days, making adjustment and rehabilitation more difficult.

Finally, the fourth main cause of age-related vision loss is glaucoma, which describes a family of diseases of the optic nerve head that slowly degenerates and kills the retinal ganglion cells that relay visual signals from the eye to the brain. The diagnosis of glaucoma generally relies on the detection of increased ocular pressure (not related to hypertension), changes in the appearance of the optic nerve head during inspection by an ophthalmologist, and/or the presence of peripheral visual field loss. Certain types of glaucoma can be controlled with eye drops if the person adheres to a daily treatment regimen, or with surgical interventions. However, any loss of peripheral vision that occurred prior to treatment is irreversible. In early stages of the disease, the size of the visual field is reduced very gradually. Thus, its effects on functional vision may go unnoticed by the affected individual since we do not pay much attention to information in the periphery (see Figure 3d). Due to is gradual progression, glaucoma has been called "the silent thief of vision" (Halvorson, 2005). As the disease progresses, the visual field becomes more and more constricted. Should it remain undetected or untreated, glaucoma can eventually result in total blindness. In the later stages, central visual functions, such as visual acuity, are also affected and begin to decline.

Regardless of the cause, diagnosis or prognosis, from the perspective of the person with an ocular pathology, the main concern is the impairment of central vision. In clinical settings, the most common test of central visual function is visual acuity as measured by a letter eye chart. Even though this type of acuity measurement leaves many aspects of visual function untested, it remains universally understood and used. As for measures of hearing detection thresholds, the measurement of visual acuity makes it possible to characterize aspects of vision in a simplified and simplistic fashion. Measuring visual acuity makes it possible to identify changes in a person's visual abilities as a function of time. This type of measurement can also be used to compare visual acuity across individuals.

Visual acuity refers to the ability to resolve high contrast information (such as black letters on a white background) and then to recognize the symbols used on the chart by identifying them verbally. The smaller the read letters are at a fixed distance, the better the spatial resolution ability of the person and thus the finer the detail they can resolve. Standardized eye charts, such as the

ETDRS chart (Ferris, Freidlin, Kassoff, Green, & Milton, 1993), are used to measure visual acuity.

Visual tasks associated with the measurement of visual acuity are used in order to estimate the visual abilities as they relate to everyday tasks, such as reading and performing daily chores. However, the correlations between this clinical measure and activities of daily living are not always consistent, whereby even mild decreases in visual acuity can result in decreased subjective perception of functioning (Laitinen, et al., 2007). An additional measure that is commonly used to gain a better understanding of visual function is contrast sensitivity, preferably across several spatial frequencies. Contrast sensitivity refers to the ability to differentiate visual information that is presented at similar levels of intensity. For example, it is easier to detect a black letter on white paper (full contrast) than to see a dark grey letter on a light grey background (low contrast).

Good contrast sensitivity may be an important feature for speechreading, especially in older adults. It has been suggested that individuals who display high facial contrast sensitivity (e.g., whereby the person's lips are easily discerned from the rest of the face, either naturally or because of the use of lipstick and/or make-up) may be easier to speechread than people with low contrast sensitivity. Erber (2002) recommends that people who frequently interact with older adults attempt to optimise the contrast sensitivity at the level of their face. This may be achieved by wearing high contrasting clothing and speaking before a contrasting background. In addition, females should consider using contrastive lipstick, and make-up. The ability to perceive subtle differences in visual contrast are measured with standardized contrast sensitivity tests, such as the Mars Contrast Chart (Arditi, 2005). Spatial frequency refers to the density of the visual information contained within a specific area of visual space. High spatial frequency thereby indicates that a large number of visual components are contained in a small spatial area, such as in the fine detail of newsprint.

When it comes to speechreading the main concern for individuals with visual impairment is their ability to see the talker's lips and facial expression. Previous work has indicated that contrast sensitivity is an important factor in face recognition. Contrast sensitivity declines as chronological age increases (Owsley, Sekuler, & Siemsen, 1983). Therefore, it is not surprising that in normally sighted older adults increased contrast facilitates face recognition (Owsley, Sekuler, & Boldt, 1981). Research with seniors who are visually impaired has indicated that improved visual contrast can facilitate face recognition (Peli, Lee, Trempe, & Buzney, 1994). However, the link between contrast sensitivity and face perception has been questioned by other researchers because this association is not always equally strong.

Bullimore and colleagues (1991) found that the ability to recognize faces that were presented in an eye-chart format was better predicted by reading acuity as well as letter acuity than by measures of contrast sensitivity. Similar reports have emphasized the correlation between face recognition and letter acuity when using familiar famous faces and reading acuity when detecting differences in facial expression (Tejeria, Harper, Artes, & Dickinson, 2002). These authors speculated that the relationship between reading acuity and face perception is based on similarity because both tasks require the viewer to engage in visual scanning and cognitive integration of information in order to achieve the goal. Reading requires the scanning of letters and their assembly, parsing them into words that are recognized and remembered; face perception requires the scanning of facial components and their integration into a face that is then recognized from memory.

Problems with face perception are among the most common symptoms reported by the people with visual impairment. The level of difficulty associated with this task is clearly revealed by the database of the Montreal Barriers Study (access provided by Dr Olga Overbury (PI), funded by the Réseau Vision de la Fonds de la recherche en santé du Québec). In a survey of 619 individuals with low vision (visual acuity poorer than

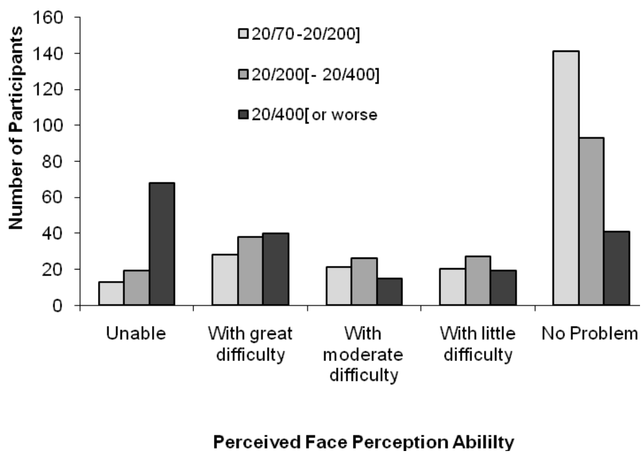


Figure 4. Face perception ability of low vision participants in the Montréal Barriers Study, grouped by visual acuity (mild = 20/70 to 20/200 included, moderate = 20/200 excluded to 20/400 included, severe = worse than 20/400).

20/70), 44% of the respondents reported that they had moderate or severe problems recognizing faces or that they were unable to perform this task. This result is based on the respondents responses to one specific item of the Visual Function Index VF-14 (Steinberg, et al., 1994, see Figure 4). This was especially the case for participants whose visual acuity was poorer than 20/400 (see Mwilambwe, Wittich, & Freeman, 2009 for additional details on the Montreal Barriers Study).

Based on the results of the Montreal Barriers study, one would assume that face recognition is impaired if central vision is affected by disease. Recently, however, research involving individuals with peripheral vision loss has indicated similar effects. Individuals with retinitis pigmentosa (RP), a progressive genetic disease that results in tunnel vision and eventual blindness, also experience problems with face recognition. Specifically, in later stages of the disease, when acuity is not as drastically affected as in AMD patients, people with RP take longer and are less accurate than normally-sighted individuals with comparable central visual acuity when detecting and identifying faces (Barnes & Schuchard, 2009). Specifically, people with RP report visual distortions and increased difficulties in face recognition (Wittich, Collin, Dubuc, Brasgold, & Overbury, 2009).

In summary, it is established that difficulties in face recognition are a characteristic of many ocular pathologies that occur in older adults. Given that the recognition of fine lip movements and facial expressions are required for speechreading as well as for face-to-face recognition in general (Argyle, Lalljee, & Cook, 1968; Erber, 2002; Parke, Shallcross, & Anderson, 1980), it seems likely that older adults with ocular pathologies may perform less than optimally on visual-speech perception tasks. Unfortunately, there are few data available on the effects that specific ocular pathologies may have on speechreading performance.

The Effects of Poor Visual Acuity on Audiovisual Integration of Speech Information

Few studies have been designed to investigate the effects of visual impairment on AV speech-perception. Wilson and colleagues reported the AV speech-perception performances of four individuals with central vision loss due to unilateral macular holes (Wilson, Wilson, ten Hove, Pare, & Munhall, 2008). The perceptual task required the participants to identify syllables with conflicting AV information (i.e., McGurk stimuli; as described by McGurk & MacDonald, 1976). The task was administered to each eye individually. Three of the participants showed no differences in performance between their unimpaired eye and their eye with impairment. For the other participant, AV speech-perception was disrupted due to the scotoma. Recordings of eye-movements made during the speech-perception task revealed that this participant did not shift gaze to avoid obscuring the talker's mouth with the scotoma. In a follow-up study, a group of young adults with gaze-contingent artificial scotomas identified sentences presented audiovisually in a background of noise (Wilson, et al., 2008). The results revealed that some participants were able to spontaneously adopt a gaze strategy whereby they shifted gaze to prevent obscuring important regions of the face such as the mouth. On the other hand, other participants were unable to adapt their gaze strategy to permit the use of visual-speech cues even after practicing this task over a period of five days. Based on their results, the investigators concluded that peripheral vision is sufficient for perception of most visual information in speech. Furthermore, they suggested that training in optimizing gaze strategy may be useful for individuals with communication deficits due to visual impairments (Wilson, et al., 2008).

Hardick, Oyer and Irion (1970) conducted a speechreading study among normal hearing young adults with varying degrees of visual impairment. The investigators reported a significant relationship between visual acuity and speechreading performance. Furthermore, they concluded that even minor deviations in distance visual acuity in either one or both eyes had a deleterious effect on speechreading performance. Later, Romano and Berlow (1974) investigated the relationship between visual blurring and audiovisual word recognition scores in a small group of students (aged between 7 and 12 years of age) who had a profound hearing loss. Specially fitted lenses were used to blur vision and thus simulate reduced visual acuity. The investigators reported that in this cohort of participants, visual-speech cues provided useful speech information even when vision was blurred to simulate visual acuity scores of 20/200. Based on this study one would conclude that the provision of visual-speech cues would be beneficial even for people with a profound impairment in visual acuity.

Johnson and Snell (1986) investigated speechreading performance among 786 college students with hearing loss. The investigators reported that as long as visual acuity in one eye is within normal limits (20/30 or better), speechreading performance should be comparable to that of people with normal binocular vision. Also, they observed that there is a negative effect visual acuity on speechreading performance if the visual acuity in the worst eye is 20/60 or poorer, or if the acuity in the better eye is 20/40 and in the poorer eye is 20/100.

Erber (1979) investigated the effect of reduced visual acuity on V-alone and AV speech perception. In this study, a translucent sheet of rough Plexiglas was used to simulate reduced visual acuity, similar to the effects of early cataract. Specifically, the visual image of the talker's face is increasingly blurred as the distance between the talker and the sheet of Plexiglas is increased. Using an eye chart, Erber measured the simulated "visual acuity" of a group of participants under different conditions of blurring (i.e., at different talker-to-plexiglass distances). Using this procedure he was able to determine experimental conditions that simulated different level of visual acuity, ranging from 20/20 to 20/400. AV speech recognition scores for words were measured for two groups of participants: two young adults with normal hearing sensitivity and young adolescents with a severe or profound hearing loss. Based on his findings, Erber (1972) concluded that visual-speech cues do not contribute significantly to speech perception if visual acuity is worse than 20/200.

More recently, Hickson, Hollins, Lind, Worrall and Lovie-Kitchin (2004) investigated the effects of visual acuity on AV speech-perception in older adults. A total of 77 older adults completed an AV sentence-recognition task in noise. Of this cohort, 26 participants had distance visual acuity impairment and 7 individuals had near vision impairment. In addition, approximately 49 (73%) participants had an average pure-tone hearing loss of 25 dB HL or greater. The results of this investigation revealed that only one participant failed to display an improved speech-perception performance when the visual-speech cues were added to the auditory (in noise) speech information. For the vast majority of the participants (86%) providing visual-speech cues in addition to the auditory (in noise) information resulted in a statistically significant improvement in speech-recognition scores. The mean improvement observed was 29%. The authors failed to observe a significant correlation between visual acuity and benefit gained in AV speech recognition. This latter finding may be attributed to the fact that a considerable number of participants (51%) had corrected normal distance visual acuity. Perhaps a significant relationship may have been observed had a greater number of participants with visual impairment taken part in the study.

Based on the available results it is not possible to conclude unequivocally that normally-sighted older adults are able to integrate auditory and visual speech information as proficiently as younger adults. However, there is little doubt that, for younger as well as older adults, speech-performance is improved substantially when visual-speech cues are provided along with the auditory signal.

Summary and Conclusions

The two primary goals of this chapter were to: (1) to present a brief overview of the types of visual impairments frequently observed among older adults with acquired hearing loss, and (2) review the literature concerning AV speech integration in older adults with visual impairments. It is well established that, as with hearing loss, the prevalence of visual impairment increases dramatically as a function of age. Hearing health care professionals should be aware that approximately 20% of their older clients (above approximately 70 years of age) with hearing loss will also have a vision impairment that is of sufficient magnitude to cause some limitations in their everyday activities, including their ability to interact with others.

Hearing health professionals should be knowledgeable of the four major eye pathologies observed among older adults. Also, they should be aware of the visual distortions and the perceptual effects that characterize each one of these four types of ocular pathology. The effects (or the potential effects) of visual impairment on communication, and especially on visual-speech perception (speechreading) should be queried and/or investigated clinically. Rehabilitation programs designed for older adults with dual sensory loss, including the choice of amplification systems to recommend, should take into consideration the visual abilities (and limitations) of the client. Although scant, some authors have discussed the audiological rehabilitative needs of individuals with dual (hearing and vision) loss (Brabyn, Schneck, Haegerstrom-Portnoy, & Lott, 2007; Brennan, et al., 2005; Erber, 2002, 2003; Erber & Scherer, 1999; Saunders & Echt, 2007).

It is well established that providing visual-speech cues along with the auditory-speech signal substantially improves speech understanding, especially when conversing under poor listening conditions (e.g., due to noise or reverberation or because the level of the speech signal too low). In the general population the benefits of providing the interlocutor with both auditory and visual speech cues are well documented. Recently, it has been shown that, for young adults, speech understanding in noise is less effortful when the stimuli are provided bimodally (AV) rather than uni-modally (A-alone: Fraser, et al., 2009). Also, presenting both the audio and the visual components of speech usually results in higher speech recognition scores than when only the auditory-speech signal is available. The benefits of AV integration have been demonstrated in young adults with normal hearing as well as those with hearing loss. At the present time, there is not a unanimous view concerning the AV integration abilities of older adults, particularly those with hearing loss. It is possible that older adults are not as proficient as younger adults at integrating the auditory and the visual components of speech. Further research is required to elucidate the similarities and differences in the perceptual and cognitive processes underlying the AV integration of speech in younger and older adults. Notwithstanding the need for further research, there is no doubt that most older adults, those with normal hearing as well as those with hearing loss, improve their speech understanding performances when they have access to both the auditory and the visual speech cues compared to when the speech signal is available in only one sensory modality (A-alone or V-alone). Consequently, unless clinical assessments (i.e., the results obtained on test material administered clinically) indicate otherwise, AV speech-perception should always be considered beneficial for older adults. Concerning rehabilitation, hearing health care professionals should explain to their clients (as well as to the significant others) the advantages of AV speech-perception. Conversational strategies that make it possible for the interlocutor to receive the speech signal in both sensory modalities should be taught and practiced. The provision of speech-perception training, both uni-modally (typically auditory-training or speechreading training) and bimodally (AV) in noise should be considered if the client fails to display AV speech integration skills.

There is very little data on the AV integration abilities of individuals with visual impairment. However, the results of a recent study revealed that some young adults with visual impairment due to discrete central scotomas (i.e., islands of reduced or total vision loss in the central visual field) were able to make beneficial use of visual speech cues. Specifically, these individuals shifted their gaze so that that they could perceive the visual speech cues in their peripheral visual field. Also, studies have been conducted to investigate the role of reduced visual acuity on AV speech integration. In some cases, artificial methods were used to simulate reduced visual acuity in participants with normal vision (e.g. Erber, 1979; Legault, Jodoin-Fontaine, Rhoualem, & Gagné, 2009; Romano & Berlow, 1974). In one study, some of the participants, older adults, had *bona fide* reduced visual acuity (Hickson, Hollins, Lind, Worrall, & Lovie-Kitchin, 2004). The results of those investigations are convergent and they reveal that even when visual acuity is severely reduced (i.e., binocular visual acuity of 20/200), providing visual-speech cues in addition to the auditory-speech signal (in noise) significantly enhances speech recognition performances. Thus, based on the information available, there is no *a priori* reason to believe that individuals with visual impairments cannot make use of visual-speech cues to improve their auditory-speech perception performances. Clients with dual sensory impairment should undergo some clinical investigation (either formal or informal testing) to ascertain the extent to which they are able to integrate auditory and visual speech information. As with normally sighted older adults with hearing loss, unless there is evidence otherwise, individuals with dual sensory losses (hearing and vision impairments) should also be encouraged to make use of visual-speech cues whenever they are available. Rehabilitative hearing health care professionals should explain to their clients (as well as to the significant others) the advantages of AV speech perception. This may be particularly important for this clientele as many individuals (or their entourage) may assume that a visual impairment may preclude the person from making use of visual speech cues. Of course, clients who consult hearing health care professionals, especially older adults, should always be asked about the status of their vision. Furthermore, they should be encouraged to consult a vision health care professional if their vision has not been evaluated in more than 2 to 5 years. As with hearing, many older adults neglect having their vision evaluated regularly.

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