The effects of blurred vision on auditory-visual speech perception in younger and older adults

Abstract
Speech understanding is improved when the observer can both see and hear the talker. This study compared the effects of reduced visual acuity on auditory-visual (AV) speech-recognition in noise among younger and older adults. Two groups of participants performed a closed-set sentence-recognition task in one auditory-alone (A-alone) condition and under three AV conditions: normal visual acuity (6/6), and with blurred vision to simulate a 6/30 and 6/60 visual impairment. The results showed that (1) the addition of visual speech cues improved speech-perception relative to the A-alone condition, (2) under the AV conditions, performance declined as the amount of blurring increased, (3) even under the AV condition that simulated a visual acuity of 6/60, the speech recognition scores were significantly higher than those obtained under the A-alone condition, and (4) generally, younger adults obtained higher scores than older adults under all conditions. Our results demonstrate the benefits of visual cues to enhance speech understanding even when visual acuity is not optimal.

It is well documented that older adults, even those with normal (or near normal) hearing sensitivity, have more difficulty processing auditory speech than younger adults, especially in background noise (CHABA, 1988; Pichora-Fuller et al, 1995; Humes, 1996; Pichora-Fuller, 2003; Larsby et al, 2005; Pichora-Fuller & Singh, 2006). It is also known that under poor acoustic conditions, speech understanding can be facilitated when the person can both hear and see their communication partner. The purpose of the present study was to investigate the effects of visual acuity on auditory-visual speech recognition in noise among younger and older adults with normal hearing sensitivity.

For normal sighted younger adults (with or without hearing loss) speech recognition performance improves when the task is performed audiovisually (AV) rather than auditorily (A-alone) or visually (V-alone) (Sumby & Pollack, 1954; Erber, 1979; Hack & Erber, 1982; MacLeod & Summerfield, 1987, 1990; Grant & Braida, 1991; Grant et al, 1998; Helfer, 1998; Jordan et al, 2000; Arnold & Hill, 2001; McCotter & Jordan, 2003). Generally, the magnitude of the improvement is inversely proportional to the performance observed when the speech-understanding task is administered under an A-alone condition. For example, under ideal listening situations, a person with normal hearing does not require any visual information to understand a spoken message. However, when a person must process speech in noisy or reverberant surroundings, or through the distortions of a cochlear hearing impairment, being able to see a talker’s face can provide a substantial improvement in speech perception (MacLeod & Summerfield, 1987). Under some experimental conditions the benefits in speech-recognition scores observed when the task is performed in AV conditions can exceed 30 to 40% relative to either the A-alone or the V-alone performance. Macleod and Summerfield (1990) showed that adding visual-speech cues to a distorted auditory speech signal (for example, due to noise or hearing loss) was equivalent to improving the signal-to-noise ratio by as much as 7–11 dB. A gain of this magnitude is not trivial as recent investigations have shown that in addition to performance gains measured in term of accuracy of word recognition, the provision of visual-speech cues can make speech-recognition tasks in noise less effortful (Pichora-Fuller, 1996; Fraser et al, 2010).

As with A-alone speech recognition abilities, it has also been demonstrated that speechreading performance decreases with age...
The effects of blurred vision on auditory-visual speech perception

Auditory-visual speech perception is a complex process that involves the integration of auditory and visual cues to understand speech. The effects of blurred vision on visual perceptual functions, such as contrast sensitivity and dark adaptation, are well established in the literature (CHABA, 1988; Pichora-Fuller, 2003). Similarly, with regards to visual perception, test results indicating normal (or corrected normal) visual acuity do not exclude the possibility that other visual perceptual processes (e.g., contrast sensitivity, dark adaptation, color, visual field, motion perception) may be deficient (Kline, 1991; Owlsley et al., 1991; Spear, 1993; Schneider & Pichora-Fuller, 2000; Erber, 2002). Declines in these various visual functions may have a deleterious effect on perceptual processing (Sekuler, 2010).

Furthermore, it has been demonstrated that older adults are largely influenced by task complexity (noise, dual task), that reduce their performance (Schneider & Pichora-Fuller, 2000; Faubert, 2002). These changes may lead to a distorted representation of the visual world which consequently might potentially explain (at least in part) the poorer visual speech processing performances observed in older adults. The experimental evidence suggests that, compared to their A-alone or V-alone performances, normally sighted older individuals show improvements when they integrate auditory and visual speech information (Helfer, 1998; Sommers et al., 2005; Campbell et al., 2007). Furthermore, the results suggest that both younger and older adults use similar perceptual and cognitive processes to integrate auditory and visual speech cues when they perform speech recognition tasks in noise (Walden et al., 1993; Helfer, 1998; Ballingham & Cienkowski, 2004; Spehar et al., 2004; Sommers et al., 2005; Campbell et al., 2007; Tye-Murray et al., 2007). However, at the present it is still not unequivocally established whether or not older adults are as proficient as younger adults at integrating auditory and visual speech (Gagne & Wittich, in press).

The prevalence of vision 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). These prevalence rates increase substantially when only the population of people over 65 years of age is considered (Tielisch et al., 1990; Attebo et al., 1996; Klaver et al., 1998; Congdon et al., 2004). In older individuals the main causes of visual impairments acquired in adulthood are: cataracts, age-related macular degeneration, diabetic retinopathy, and glaucoma (for a review, see: Gagné & Wittich, in press). It is estimated that as many as 8.5% of adults over 55 years of age may have a visual impairment that reduces their ability to perform many activities of daily living (Miller, 2004). Consequently, in various communication situations, older adults with vision loss rely extensively on auditory cues to communicate. Communication difficulties are exacerbated when both vision and audition are impaired.

The prevalence of the dual sensory impairment (hearing and vision) varies between 9% and 21% in adults who are 70 years of age or older (Brennan et al., 2005; Smith et al., 2008). Generally, it is reported that the deleterious effects of dual sensory impairment are greater than the effects of either hearing loss or vision loss, alone (Smith et al., 2008). Dual sensory impairment has been shown to have a greater effect than a single impairment on one’s physical, psychological, and psychosocial well-being. Chia and colleagues (2006) reported that individuals with dual sensory impairment have poorer physical function, general health perceptions, vitality, mental health, and social well-being than individuals without sensory impairments. Dual sensory impairment has a negative impact on self-reported health and on participation in social activities such as visiting friends, telephone conversations, going to movies, and attending religious services. Compared to individuals without sensory impairments, people with dual sensory impairment report having more difficulty conducting activities of daily living such as: walking, shopping, preparing meals, speech communication, and ambulation (Keller et al., 1999; Crews & Campbell, 2004; Millar, 2004; Brennan et al., 2005). Erber and Scherer (1999) reported that approximately 20% of adults, 70 years of age or older, who consult a hearing health care professional will have visual impairment that can limit the clarity of a person’s face at a conversational distance. Few studies have investigated the effects of visual impairment on audiovisual speech perception in older adults with normal hearing and those with hearing loss.

Hickson et al. (2004) investigated the effects of visual acuity on AV speech-perception in a group of 77 older adults. The participants included some individuals who had distance visual acuity impairment, some who had near vision impairment, and others who had both. In addition, hearing sensitivity varied across the participants. The participants performed a sentence-recognition task under two conditions: (1) A-alone in noise and, (2) AV in noise. The mean improvement observed for the AV condition was 29%. However, due to the variability in hearing sensitivity, as well as the reported differences in the type of visual impairment displayed across the participants, the results did not make it possible to isolate the specific effects of impaired visual acuity on AV speech integration.

Hardick et al. (1970) investigated speechreading proficiency among young adults with varying degrees of visual impairment. They observed a relationship between visual acuity and speechreading performance. Furthermore, they concluded that even minor deviations in distance visual acuity had a deleterious effect on speechreading. Romano and Berlow (1974) investigated the relationship between visual blurring and audiovisual word recognition in a small group of adolescents who had a profound hearing loss. The authors reported that visual-speech cues provided useful speech information even when vision was blurred to simulate visual acuity scores of 6/60. Johnson and Snell (1986) investigated speechreading among college students with hearing loss. They observed that there is a negative effect of 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.

Thorn and Thorn (1989) compared the effects of visual blurring on speechreading performance in younger and older adults. In both groups, some participants had normal hearing and some had hearing loss. Convex lenses were used to blur vision during AV-sentence recognition tasks. The results revealed that both the younger and the older adults were relatively unaffected by high levels of visual blurring level (i.e. 4 diopters of blur). Because in each group, some participants had normal hearing and some had hearing loss, the effects of visual acuity impairment on speech-perception could not be isolated. Also, because the sentences were presented in a V-alone modality, the findings of this study do not directly apply to our understanding of the effects of reduced visual acuity on AV speech perception.
Erber (1979) investigated the effects of reduced optical cues on V-alone and AV word recognition performance. A rough-surfaced piece of plexiglass was used to produce a simulated visual deficit. As the distance between the talker and the piece of plexiglass was increased, the facial image was increasingly blurred. Erber used an eye chart to measure the visual acuity of a group of participants under different talker-to-plexiglass distances. With this procedure he produced experimental conditions that simulated different levels of visual acuity, ranging from 20/20 to 20/400. Three experiments were conducted. The first experiment was performed with two younger adult females who had normal hearing and vision. A second study was performed with two adolescents. Both had normal vision and a severe-to-profound hearing loss. The final experiment was conducted with two groups of six normally-sighted adolescents. One group had severe to profound hearing impairment while the other group had profound hearing loss (with no measureable residual hearing). Overall, the results revealed that the benefits of providing visual speech cues decreased as visual acuity decreased. Based on his findings, Erber (1979) concluded that visual cues for speech do not contribute significantly to AV speech perception if visual acuity is poorer than about 20/200.

Notwithstanding the importance of the early work by Erber, several aspects of this study warrant further elucidation. First, it is important to investigate the effects of reduced optical cues on AV speech perception among a larger sample of young-adult participants. In addition, it would be of interest to replicate the experiment using longer speech segments (e.g. sentences rather than words in isolation) and recorded stimuli to ensure the equivalency of the speech utterances across experimental conditions. Finally, it would be of interest to include an A-alone experimental condition in order to directly quantify the benefit that providing undistorted and distorted visual cues provides to A-alone speech-perception.

In sum, the results of previous studies do not make it possible to characterize unequivocally the effects of impaired visual acuity (and blurring) on AV speech perception. Moreover, to our knowledge no research has compared the effect of reduced optical cues on AV speech perception in younger and older adults. Thus the present investigation was designed to investigate the effect of reduced visual acuity on AV speech recognition for sentences presented in a background of noise. In addition, cohorts of younger and older adults were recruited to investigate whether the effects of blurring differ as a function of age.

Methods

Participants

Sixteen younger adults (mean age 23.5 years, SD 2.64) and 16 older adults (mean age 67.6 years, SD 3.14) participated in this study. All participants had normal hearing sensitivity (≤ 25 dB HL between 250 Hz and 3000 Hz, re: ANSI, 1996) in both ears and normal (or corrected normal) 6/6 binocular visual acuity. For both group of participants visual acuity was measured in the laboratory using an Snellen chart positioned at a distance of 1 metre from the participant. The older adults were recruited from the School of Optometry at the Université de Montréal where they had undergone a routine vision test. At this clinic vision examination for older adults includes (but is not limited to) the following tests: refraction, visual field, retinoscopy, binocular fusion, lens examination, and blood pressure. The older participants invited to participate in the study were identified by a certified optometrist. The older participants who took part in the investigation had clinically normal results on all of the vision tests administered. The older adults all had clinically normal cognitive function as determined by the mini-mental state examination (Crum et al, 1993). The mean score for the older participants was 29.6/30 (range 26–30/30). All of the older participants were highly independent and came to our laboratory on their own. Both the younger and older participants reported using Québec-French as their primary language for everyday communication. Finally, the investigation was approved by the Ethics Review Board of the Institut universitaire de gériatrie de Montréal. All of the observers signed a consent form prior to taking part in the investigation and they were compensated monetarily for the time they spent as participants.

Stimuli

The stimulus set consisted of sentences spoken by a female audiologist whose native language was Québec-French (Fraser et al, 2010). The talker had extensive prior experience as a talker employed for audiovisual recordings of experimental test sentences. Each sentence had the same syntactic structure and contained three critical elements (subject, verb, and adjective) which served as the keywords in the closed-set speech recognition task. Seven interchangeable alternatives were used for each critical element. Thus, a total of 343 different sentences were available for the investigation. Within each critical element, the foils had the same number of syllables but the words were distinct from each other visually and acoustically. The test words incorporated into the sentence recognition task are listed in Table 1. For the present study four lists of 50 sentences were selected.

A customized computer software (Leclab) was used to administer the test stimuli. The sentences could be presented in either an audiovisual or auditory only modality. When the visual cues were provided, they consisted of the talker's head-and-shoulders which appeared in the center of a 43.18 cm color computer monitor (a ViewSonic, Professional series P75f+) that was placed at eye-level at a distance of 1 m from the participant who was seated directly in front of the computer monitor. The monitor's luminance intensity was calibrated using a photometer. The mean luminance of the display was 29 cd/m². Gamma-correction was verified on a regular basis.

Table 1. Test foils used to generate the closed set sentence recognition task. This set of foils may generate a total of 343 unique sentences.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Verb</th>
<th>Adjective</th>
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<tbody>
<tr>
<td>amis</td>
<td>cherchent</td>
<td>beiges</td>
</tr>
<tr>
<td>élèves</td>
<td>donnett</td>
<td>bronzes</td>
</tr>
<tr>
<td>garçons</td>
<td>gonflent</td>
<td>jaunes</td>
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<tr>
<td>madames</td>
<td>soufflent</td>
<td>mauves</td>
</tr>
<tr>
<td>messieurs</td>
<td>tiennent</td>
<td>noirs</td>
</tr>
<tr>
<td>parents</td>
<td>trouvent</td>
<td>rouges</td>
</tr>
<tr>
<td>soldats</td>
<td>voient</td>
<td>verts</td>
</tr>
</tbody>
</table>

Note: Example of a possible sentence: «Les parentsₐ trouventₐ les ballons rougesₑₐ.» Where a = subject, b = verb, and c = adjective; these are the interchangeable critical elements used to generate the test sentences. Translated, in English the test sentence would be: ‘The parents found the red balloons’. Another test sentence could be: ‘The soldier held the green balloon’. Each of these critical elements can be replaced by a set of alternatives.
to ensure precise calibration. In addition to the display presented on the computer monitor, the 21 possible test words (seven for each critical element) were positioned in three columns on a cardboard panel placed at a distance of 1.5 m from the participant, slightly above the computer monitor. The font size used to print these words was large enough (approximately 2 degrees of visual angle) to be recognized even when viewed under the greatest amount of blurring used in the investigation. As a result, each participant could refer to the test words regardless of experimental condition.

The audio signal was presented via a loudspeaker (Realistic, Minimus-77) located directly above and behind the top of the computer monitor. The stimuli were always presented in a background of pink noise. Both the audio speech signal and the background noise were routed to an amplifier mixer (Inkel model MX-880). The output of the mixer was connected to the loudspeaker. Before each testing session a free-field acoustic calibration was completed to ensure that the acoustic speech signal (57 dBA) and the noise (69 dBA) were presented at the intended sound level (as measured acoustically at the estimated center of the head of the participants who would take part in the investigation).

Visual blurring

Speech-recognition performance was measured under four experimental conditions: (1) Auditory-alone; (2) AV with normal (6/6) binocular visual acuity; (3) AV with a moderate amount of visual blurring (to simulate a binocular visual acuity level of 6/30); and (4) AV with a severe amount of blurring (to simulate a visual acuity level of 6/60). By adding convex lenses in front of participants’ eyes, we induced an amount of blurring to simulate a visual acuity of 6/30 in one test condition and 6/60 in another. To calibrate the lenses a logarithmic visual acuity chart « EDTRS » 2000 series (i.e. charter optometric Precision Brand Vision™), was used to measure the desired level of visual acuity (the amount of blurring) experienced by each participant under each experimental condition. The simulation was deemed successful when, while wearing the lenses selected specifically for that individual, the participant could identify the letters at the desired level of visual acuity (but not smaller letters representing better levels of visual acuity). The optical effect of the lenses was verified for each participant and for each visual blurring condition.

Test procedure

All the testing was conducted in a quiet laboratory at the research institute. The speech-perception tasks were conducted in free-field. Before each test session acoustic measurements were conducted to calibrate the test equipment and to confirm that the ambient noise level of the laboratory was sufficiently low so as not to interfere with the level of the test signals, namely the pink noise and the speech signal. During a test session the main light source emanated from the computer monitor. A low incandescence lamp was added to allow the participants to read the test stimuli displayed on the cardboard panel. Precautions were made to ensure that no light source was pointed directly at the participant’s face or at the computer monitor.

Each participant took part in one test session of approximately 90 minutes. Before testing, each participant was told about the components of the study and what they were expected to do. To ensure that recruitment criteria were met, hearing sensitivity and visual acuity screening tests were administered to each person. The cognitive screening test was administered to the older adults only. A practice session was used to familiarize all participants with the format of the test sentences and the experimental task. Prior to testing, each participant was asked to read aloud (without blurring) each of the test words that appeared on the cardboard panel. In addition, each person was required to complete two blocks of practice trials. The first block consisted of eight sentences presented in the A-alone modality, without background noise. The second block consisted of eight sentences presented AV. During this block of trials, the background noise was mixed with the speech stimuli during the last four sentences.

A Latin-square design was used to determine the order in which the lists of sentences and the four experimental conditions would be administered to a given participant. For each experimental condition, once the sentence list was selected, the software program presented the recorded sentences in a random order. After each sentence, the participant had to report the three critical elements that were presented. The experimenter used a computer mouse to click on the selected test words. This strategy was used because under the visual blurring conditions, the participants could not see well enough to recognize the test words that appeared on the computer monitor. The responses were recorded by the computer, and at the end of each experimental condition (i.e. a block of 50 sentences) the software program calculated the percentage of keywords recognized correctly.

Results

The mean scores obtained by each group of participants under each experimental condition are displayed in Figure 1. To explore the effects of age (younger adults vs. older adults) and experimental condition (i.e. A-alone, AV 6/6, AV 6/30, AV 6/60), using the general linear model (GLM) a 2×4 ANOVA was conducted. For this analysis, ‘AGE’ was the between-subjects variable and ‘EXPERIMENTAL Conditions’ was the within-subjects variable.
CONDITION’ was the within-subjects variable. The alpha criterion was set to 0.05. Effect sizes were calculated as partial eta squared ($\eta_p^2$) values. Significant main effects were analysed by post hoc comparisons and when appropriate, Bonferroni corrections were applied to account for multiple comparisons.

The AGE × EXPERIMENTAL CONDITION interaction was not significant ($F(3,28) = 0.961$, $p = .415, \eta_p^2 = .031$); however, the analysis revealed a main effect for EXPERIMENTAL CONDITION ($F(3,28) = 70.797$, $p < .0001, \eta_p^2 = .702$). Pairwise comparisons revealed that the mean difference between the A-alone condition and each AV condition was significantly different (i.e. $p < .0001$). In addition, there was a significant difference (i.e. $p = .007$) of 7.8 percentage points between the 6/6 AV condition and 6/60 AV condition. In contrast, the difference of 2.94 percentage points observed between the 6/6 and 6/30 AV conditions was not significant (i.e. $p = .698$), nor was the 4.54 difference in percentage points observed between the 6/30 and 6/60 AV conditions significant (i.e. $p = .069$).

The results also revealed a significant AGE effect whereby, overall, the younger adults obtained significantly better speech recognition scores than the older adults ($F(1,30) = 4.609$, $p = .040, \eta_p^2 = .133$). The age effect was mainly accounted for by the significant difference obtained between the groups under the A-alone condition ($F(1,30) = 10.932$, $p = .002, \eta_p^2 = .267$). Notwithstanding the discernable trend observed for the AV speech recognition conditions, there was no significant age difference when the visual acuity was set to the 6/6 ($F(1,30) = .800$, $p = .378, \eta_p^2 = .026$), 6/30 ($F(1,30) = .935$, $p = .341, \eta_p^2 = .030$) or 6/60 condition ($F(1,30) = 2.251$, $p = .144, \eta_p^2 = .070$).

Additional analyses were conducted to determine whether there were group differences in the amount of improvement in performance observed when visual-speech cues were provided. The dependent variable used for these analyses was a linear visual enhancement (VE) score which was calculated individually for each participant and for each of the three AV experimental conditions. Specifically, the VE score was defined as the difference between the percent correct score for the A-alone condition and the percent correct score for a given AV condition (Campbell et al, 2007). The mean percent VE score obtained for each group of participants are plotted as a function of the three AV experimental conditions in Figure 2.

Using the GLM, a 2 × 3 ANOVA was conducted using ‘AGE’ as the between-subjects variable and ‘AV EXPERIMENTAL CONDITION’ as the within-subjects variable. The results revealed that neither the AGE x AV EXPERIMENTAL CONDITION interaction ($F(2,29) = 0.435, p = .651, \eta_p^2 = .015$) nor the main effect of AGE were significant ($F(1,30) = 2.452, p = .128, \eta_p^2 = .076$). However, there was a significant effect of AV EXPERIMENTAL CONDITION ($F(2,29) = 6.228, p = .006, \eta_p^2 = .300$). Pairwise main comparisons revealed that the 7.33 percentage point difference in VE score observed between the AV 6/6 condition and the AV 6/60 condition was significantly different (i.e. $p = .004$), as was the 4.35 percentage point difference in VE observed between the AV 6/30 and the AV 6/60 (i.e. $p = .042$) conditions.

**Discussion**

One of the primary objectives of this investigation was to determine whether the effect of simulated reduction in visual acuity would be the same for younger and older adults. Our findings indicate that overall the older participants performed more poorly on the speech recognition tasks than the younger participants. However, the group differences occurred only when the speech-recognition task was performed under the A-alone condition. This finding agrees with the literature in that numerous investigators have reported that older adults (even with normal or near normal hearing sensitivity) perform more poorly than younger adults on speech recognition tasks administered in noise (Pichora-Fuller et al, 1995; Humes, 1996; Pichora-Fuller, 2003; Larsby et al, 2005; Pichora-Fuller & Singh, 2006). In contrast, we did not obtain significant age-related differences for any of the AV conditions.

Using the A-alone and AV data to calculate the VE scores, we did not observe a significant age effect. For the AV-6/6 condition, whereby no optical distortion was applied there were no significant group differences in the amount of VE displayed by the two groups of participants. This finding is consistent with the results of previous investigations who failed to observe age differences in VE scores between younger and older adults (Walden et al, 1993; Helfer, 1998; Cienkowski & Carney, 2002; Ballingham & Cienkowski, 2004; Sommers et al, 2005).

The VE analysis revealed a significant main effect of AV CONDITION. The VE score displayed by the younger participants under the AV-6/6 experimental conditions are consistent with those previously reported. Specifically, the data show a significant improvement in performance between the AV condition in which the participants had normal (or corrected normal) visual acuity (i.e. AV-6/6) and the A-alone condition. Previous investigators have reported that speech understanding is significantly improved when visual-speech cues are added to the auditory-speech signal (Sumby & Pollack, 1954; Erber, 1979; Hack & Erber, 1982; MacLeod & Summerfield, 1987, 1990; Grant & Braida, 1991; Grant et al, 1998; Jordan et al, 2000; Arnold & Hill, 2001; McCotter & Jordan, 2003). The older participants also displayed a significant VE effect when non-distorted visual-speech cues were provided along with the auditory signal. This finding is consistent with the results reported in previous studies in which VE was investigated in older adults (Walden et al, 1993; Helfer, 1998; Sommers et al, 2005; Campbell et al, 2007; Tye-Murray et al, 2007). Therefore, for the non-distorted AV speech-perception condition, the results obtained in the present study confirm findings previously reported.

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**Figure 2.** The mean percent visual enhancement (VE) scores (±1 s.d.) are plotted as a function of the three AV experimental conditions. The filled bars display the results obtained for the younger participants, and the unfilled ones display the results obtained for the older adults.
What about the distorted AV speech perception conditions? In the present investigation, convex lenses were used to simulate a type of visual acuity impairment in a systematic fashion. While the blurring effect created by using lenses is not identical to the effect produced by an actual (non-refractive) vision disorder, our simulation strategy was useful for three reasons. First, others have used simulation approaches to describe the effects of visual impairment on AV speech perception among younger adults (Romano & Berlow, 1974; Erber, 1979). Thus, it was possible to compare the results of our investigation with results previously reported. Second, using individually selected convex lenses, we could achieve the desired levels of visual acuity in a systematic fashion. Consequently, the level of visual blurring could be controlled more precisely. Third, using this approach, data could be collected for the same participants under each of the experimental conditions. Hence any variability in the data associated with individual differences in visual acuity among the participants is reduced. Furthermore, one goal of the present investigation was to compare the AV speech-perception performance of younger and older adults under similar conditions of reduced optical cues. Because of the high prevalence of ocular pathologies that distort vision beyond the effects of reduced visual acuity (i.e. blurring) in older adults, it may have been difficult to recruit older participants (and perhaps even younger ones) who displayed no other ocular pathology than poor visual acuity. Nonetheless, as with the results of previous investigators who have addressed this issue, the present findings need to be interpreted with caution. Strictly speaking, the study investigated the effects of artificial visual blurring only (and not the effect of reduced visual acuity) on AV speech perception.

Not surprisingly, the results revealed that the VE scores decreased as the amount of visual blurring increased. The VE scores were significantly lower in the 6/60 condition relative to the 6/6 or 6/30 AV conditions as seen in Figure 2. A similar pattern of results was observed for both the younger and the older participants. Concerning the results obtained by the younger participants (with normal hearing) the present findings concur with those previously reported. For example, Erber (1979) found that the VE scores displayed by two younger female adults with normal hearing, decreased as the amount of optical blurring increased. Concerning the older adults, the results are somewhat consistent with those reported by Hickson et al (2004), who investigated the VE displayed by older adults. These investigators observed that there was a negative relationship between VE and the amount of impairment in visual acuity.

Perhaps the most surprising finding was that even under conditions of severe visual blurring (i.e. simulating a visual acuity of 6/60), relative to the audio-only condition, both the younger and the older participants showed significantly better word recognition performance, as seen in Figure 1. In the past, similar findings have been reported for younger adults. For example, both Romano and Berlow (1974) as well as Erber (1979) showed that an improvement in performance over an A-alone condition occurred under conditions that simulated visual acuity levels of up to 6/60. In the present investigation, a similar pattern of results was observed for the group of older participants. This finding is noteworthy because, to our knowledge the systematic effects of reduced optical cues (i.e. poorer visual acuity) on AV speech perception have not been previously investigated in older adults. It is somewhat surprising that even under such severe conditions of optical distortion the visual speech cues available produced a significant speech-recognition enhancement effect.

In the field of optics it is known that blurring is a result of filtering the high spatial frequencies. Concerning the recognition of facial features, when spatial frequencies are low-pass filtered only the coarse features of an individual’s face such as the general shape and structure of the person’s head, including the hair and face-shape as well as the location of the mouth and eyes are preserved. The effects of spatial frequency filtering on a person’s face are illustrated in a series of photographs published by Munhall et al (2004). Using approaches in which spatial frequencies were systematically filtered, investigators have demonstrated that perceptually the optical cues required for face recognition appear to be conveyed by middle and lower spatial frequencies (Harmon, 1973; Harmon & Julesz, 1973; Costen et al, 1994; Morrison & Schyns, 2001; Collin et al, 2004). Related to visual-speech, Munhall et al (2004) showed that the visual intelligibility of a talking-face varies as a function of the spatial frequency content of the stimuli. The results revealed that the peak intelligibility of the talking-face occurred when the mid-range spatial frequencies were displayed in the video recordings. These findings are consistent with the present results in that increasing the blurring level (i.e. progressively removing high spatial frequencies) reduced the facial details displayed in the video recordings. However, even under the most severe blurring condition, perceptually, much of the facial information required for visual-speech perception was available. Consequently, the performances of both the younger and older participants were significantly greater for the AV-6/60 condition than for the A-alone condition. As a first approximation, it would appear that the effects of spatial frequency filtering are not age sensitive because perceptually visual blurring had the same consequences on the speech-recognition performance for both groups of participants.

Finally, in the present investigation the speech perception task consisted of a closed set keyword recognition task embedded in sentences. An advantage of using this type of stimuli is that it makes it possible to use sentence-level material while controlling the variability in the linguistic structure of the iterations, particularly at the syntactic and semantic level. Also, close-set response tasks minimize learning and practice effects when several blocks of sentences are required to accommodate different experimental conditions. A disadvantage of using closed-set sentences is that the semantic and contextual cues are predictable and not as varied as the types of sentences that are typically used in everyday interactions. Communication partners benefit from linguistic and contextual cues that facilitate speech understanding (Kalikow et al, 1977; Pichora-Fuller, 2008). Thus, the present results may not be representative of the effects of reduced optical cues on AV speech-perception as would be typical during everyday conversations. In more naturalistic conversational settings, the effects of reduced optical cues on AV speech understanding may be less relevant as contextual and linguistic cues become more salient. However, this hypothesis needs to be verified experimentally using a different experimental procedure and with appropriate linguistic stimuli.

**Conclusions and clinical implications**

Given the high incidence of dual sensory (hearing and vision) loss in older adults the effects of age-related vision disorders on AV speech perception need to be better understood. In the present investigation, to control for the effects of reduced optical cues on VE, visual acuity was simulated by fitting convex lenses to participants with normal (or corrected normal) visual acuity. It is recognized that this
type of simulation does not incorporate all of the aspects of vision that may be perturbed in individuals with visual impairment. For example, simulations do not account for changes that would occur as a result of brain plasticity in individuals with long-standing perceptual impairments. Nonetheless, this use of simulation strategies makes it possible to systematically vary the degree of visual blurring. Moreover, this approach allows for the comparison of young and older adults under similar experimental conditions.

Our results indicate that increasing the amount of optical blurring reduced the benefit provided by the visual speech cues in the AV speech recognition task. Similar findings were observed in both the younger and older participants. An important finding was that the participants from both age groups were able to benefit from distorted visual speech cues even under blurring conditions that simulated a reduced visual acuity of 6/60. These findings have implications for audiological rehabilitation.

First, the fact that VE decreases as the amount of blurring increases highlights the importance of consulting a vision health care professional on a regular basis. The benefits of visual-speech cues are greatest when visual acuity is as close to normal as possible. Given the increased incidence of vision loss as a function of age, older adults should be encouraged to have their vision examined if it has not been evaluated in more than two to five years. Although many age-related vision disorders are not reversible, some can be controlled. As with hearing, many older adults neglect having their vision evaluated regularly.

Second, the findings reveal that impaired visual acuity does not necessarily preclude the use of visual-speech cues to enhance speech understanding. Our results demonstrate that even with a considerable amount of visual blurring (equivalent to a visual acuity of 6/60) the word recognition performance of both young and older adults improved when visual cues were provided. Hearing health care professionals need to be aware that a loss of visual acuity is not necessarily a contraindication for promoting the use of visual speech cues to enhance speech understanding. Clients with reduced visual acuity and their frequent communication partners should be encouraged to use communication strategies which optimize AV speech perception (e.g. the benefits of face-to-face communication, including the effects of high visual contrast, glare, illumination, and distance on visual-speech perception). Further, as shown by Helfer (1997, 1998) both young and older adults can benefit even more from AV speech perception when the talker uses clear speech. In some instances, for example when a person with poor vision confuses very distinct vowel or consonant visemes, speechreading training may be warranted. In fact, it has been shown that even adults with scotomas can benefit from visual-speech cues by shifting their gaze slightly so that the talker’s face is displayed in the periphery of the retina (Wilson et al, 2008). In conclusion, many individuals who have vision impairment can benefit from AV speech perception.

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