Visual Enhancement in Consonant Identification by Younger and Older Adults

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The present study examined the speech perception abilities and associated confidence of 23 younger and older adults with normal hearing in auditory-only (AO), visual-only (VO), and auditory-visual (AV) conditions for a limited set of consonant-vowel (CV) stimuli. The use of visual cues has been shown to improve communication in difficult situations. However, older adults generally have poor lipreading abilities and don't demonstrate as much improvement in response to training when compared to their younger counterparts. Anecdotal reports suggest that the use of auditory-visual cues may improve confidence and/or ease of communication for older adults. Results indicated no age differences in benefit from visual cues or in confidence ratings.

INTRODUCTION

The use of visual cues has been shown to improve communication in difficult listening situations (Sumby & Pollack, 1954; Summerfield, 1987, 1992). It may be that utilizing both auditory and visual modalities increases the amount of information available, as well as the redundancy of speech, leading to improved perception and greater ease of communication (Summerfield, 1992). This may be especially important for older adults who have more difficulty than younger adults understanding speech in listening situations degraded by noise (Fozard & Gordon-Salant, 2001; Halling & Humes, 2000) or multiple talkers (Sommers, 1997). It is well documented that older adults are less likely to perform as well

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on perceptual tasks as younger adults with similar peripheral sensitivity (Halling & Humes, 2000; Humes et al., 1994; Sommers, 1997; Sommers, Tye-Murray, & Spehar, 2005; Strouse, Ashmead, Ohde, & Grantham, 1998). This may be attributed to the effects of physiological and perceptual changes that occur as part of the aging process (Salthouse, 1991).

Yet older adults in general have been shown to perform more poorly on unimodal lipreading tasks than their younger counterparts (Cienkowski & Carney, 2002; Sommers et al., 2005; Walden, Busacco, & Montgomery, 1993). Moreover, studies of the benefits of lipreading training to enhance auditory-visual (AV) speech perception have been equivocal (Binnie, 1977; Gagné, Dinon, & Parsons, 1991; Small & Infante, 1988; Tye-Murray, 1992). Although older adults have shown poorer performance than young adults for visual-only (VO) tasks, they may be equally able to benefit from the integration of auditory and visual information (Grant & Seitz, 1998; Sommers et al., 2005). Cienkowski (2002) and Cienkowski and Carney (2002) found no significant difference between old and young adults in the ability to integrate AV information when peripheral sensitivity was normal or near-normal. However, the results of these studies are difficult to interpret because AV integration was measured indirectly through the use of the McGurk effect (McGurk & MacDonald, 1976) for discrepant signals. Recently, Sommers and colleagues (2005) reported no age differences in visual enhancement for consonants, words, or sentences although the older adults in their study had significantly poorer performance than younger adults in the AV and VO modalities.

Anecdotal reports also suggest that the use of both auditory and visual cues during communication may improve confidence and/or ease of communication. Demorest and Bernstein (1997) stated that the ability to monitor one's reception of speech is an important component of communication. In their study of adults aged 45 and younger with normal hearing or with severe to profound hearing loss, they found subjective ratings of speechreading performance to be highly correlated with objective measures. Empirical investigations of communication confidence among older adults have largely focused on unimodal tasks and have yielded mixed results. Early work by Craik (1966) and Rees and Botwinick (1971) found that, for tonal stimuli presented at or near threshold, older adults used a more conservative response criterion. In contrast, Yanz and Anderson (1984) and Gordon-Salant (1986) found no difference on the basis of age or found that older adults used a more liberal response criterion when rating their confidence. Similarly, Baracat and Marquie (1993) found no difference between the confidence ratings of older and younger adults on perceptual tasks in the visual modality. No comparisons between self-rated communication confidence and measures of visual enhancement have been made.

It is difficult to draw firm conclusions about the benefit of visual cues for older adults in speech communication. Mixed findings between studies may reflect differences in stimuli, presentation levels, test conditions, measures of visual benefit, and response criteria. Further, no one investigation has examined both objective and subjective measures of benefit for unimodal and bimodal conditions. Therefore it would seem appropriate to investigate the relationship of AV speech perception, visual enhancement, and self-reported communication confidence for older adults. The purpose of the present study was to measure and compare AV integration, visual enhancement, and self-rated confidence levels of younger and older adults.

METHODS

Participants

Participants were 12 young adults ranging in age from 19 to 30 years of age (mean age: 25.0; *SD:* 5.3) and 11 older adults ranging in age from 65 to 85 years of age (mean age: 68.2; *SD:* 6.1). Participants were recruited by flyers distributed at the University of Connecticut and in surrounding areas. Additional selection criteria included normal hearing, vision, otologic history, and cognitive function by self-report. Prior to participating in the study all participants received a hearing and vision screening. Hearing thresholds were measured at octave intervals from 250 to 8000 Hz bilaterally. Testing was conducted in a double-walled sound-treated booth using a Maico MA40 portable audiometer and Maico supra-aural earphones with TDH 39 cushions. Hearing was considered normal if thresholds were better than 20 dB HL (American National Standards Institute, 1989) bilaterally at all test frequencies. Table 1 displays the peripheral sensitivity measures. The older adults had slightly elevated thresholds at 4000 and 8000 Hz when compared to their young adult counterparts; however, results for the older adults were consistent with normative data published from the Baltimore Longitudinal Study of Aging (Morrell, Gordon-Salant, Pearson, Brant, & Fozard, 1996). Visual acuity for both eyes together was measured using a

Table 1

Mean (and *SD*) of Pure Tone Thresholds in dB HL,
and Measures of Distance Visual Acuity and Contrast Sensitivity of Study Participants

	Frequency (Hz)					
	250	**500**	**1k**	**2k**	**4k**	**8k**
Young	4.1 (4.2)	4.0 (5.5)	3.5 (3.5)	2.1 (4.1)	4.6 (6.2)	6.3 (9.5)
Old	7.5 (5.3)	8.2 (5.5)	10.5 (6.7)	12.0 (11.7)	21.8 (9.8)	28.4 (17.9)

	Visual Measures	
	Snellen	**Pelli-Robson**
Young	20/20	1.89 (0.08)
Old	20/20	1.67 (0.19)

Snellen chart at the standard distance of 20 ft (Karp, 1988). Contrast sensitivity was measured using a Pelli-Robson chart (Pelli, Robson, & Wilkins, 1988) at a standard distance of 3 ft. Vision was considered normal if participants achieved a Snellen acuity of 20/25, with correction if needed, and a contrast sensitivity score of 1.80 (Kline & Schieber, 1985).

Stimulus Preparation

Stimuli consisted of the consonant-vowel (CV) syllables /bi/, /di/, and /gi/ produced by 10 talkers, 4 male and 6 female. Each talker was a native speaker of English with a General American dialect and without professional voice training (for recording procedures, see Cienkowski & Carney, 2002). Previous investigations have shown these talkers to produce equivalent auditory intelligibility but a range of responses for visual-only and discrepant auditory-visual stimuli (Carney, Clement, & Cienkowski, 1999; Cienkowski, 2002). Tokens were of two types: congruent and incongruent. Congruent tokens were those in which the auditory and visual stimuli matched (e.g., auditory /bi/ and visual /bi/). Incongruent tokens were generated by combining an auditory /bi/ with a visual /gi/ (the McGurk stimulus) or an auditory /gi/ with a visual /bi/ (the combination stimulus). The incongruent tokens elicited the McGurk effect, in which listeners may report a fused response (typically a perceived /di/) or a combination response (typically a perceived /bigi/).

Pre-recorded, digitized, and edited tokens used in this study were prepared using the Broadway Video Editor 5.01 (Ulead Systems, Inc.) software. Auditory-only (AO) tokens, /bi/, /di/, and /gi/, were created by replacing the visual portion of each stimulus with video black. VO tokens, also /bi/, /di/, and /gi/, were created by using an auditory filter to remove the auditory portion of each stimulus. AV stimuli consisted of the congruent tokens /bi/, /di/, and /gi/, as well as two incongruent stimuli. To create the incongruent stimuli, the original auditory portions of /gi/ and /bi/ were removed using the auditory filter. The auditory portions of /bi/ and /gi/ were then inserted onto the visual files of /gi/ and /bi/, respectively, such that the consonant burst matched that of the original auditory signal with an alignment error of less than 4-6 ms using the Broadway Video Editor.

Each of the AO and VO conditions consisted of 120 tokens: four presentations of each of the three CV stimuli recorded for each of the 10 talkers. The AV condition had 240 items: four presentations of each unaltered CV per talker, for a total of 120 congruent tokens (e.g., auditory /bi/ + visual /bi/); and six presentations of each altered CV per talker, for a total of 120 incongruent stimuli (auditory /bi/ + visual /gi/; auditory /gi/ + visual /bi/). Tokens were randomized within conditions and conditions were presented in one of three orders; that is, (AO, VO, AV), (VO, AV, AO), or (AV, AO, VO). Seven seconds of video black were inserted between tokens. The word "Ready" was displayed on screen before each stimulus presentation to direct the participant's attention to the task. Due to the large number of tokens used, stimuli were divided into blocks of 30 tokens each. An additional 3-5 s of video black were inserted between blocks and each block was labeled *Block 1, Block 2,* and so on. Each block was saved as a single audiovisual file and recorded to videotape using Broadway 2.5 software and a JVC Super VHS deck. The auditory signals were calibrated to a presentation level of 75 dB SPL in the sound field at the level of the subject's ear using a Quest Model 1800 Precision Integrating Sound Level Meter. The presentation level was chosen as slightly high conversational speech to ensure audibility for all listeners.

Procedures

Testing took place in a double-walled sound-treated booth. Videotapes were played on a Panasonic PV-S9670 Omnivision Super VHS deck connected to two Grason-Stadler speakers mounted in two corners of the sound-treated booth on either side of a 19-in. Panasonic color video monitor. The monitor displayed a life-size representation of the talker including the head and shoulders. Participants were seated 4.5 ft from the monitor. Participants were randomly assigned to one of the three presentation orders.

Each participant received a practice session in an AO condition. This served to orient the subject to the task, as well as to determine the appropriate signal-to-noise ratio (S/N) for each subject. Stimuli were presented in the presence of a broad band noise. The noise was adjusted on an individual basis to achieve 50% correct in the AO condition. A minimum of five trials consisting of 12 tokens per trial was included in the practice. Practice continued until 50% correct was achieved. All young adults were tested at a -15 dB S/N. The older adults were tested at an average S/N of -11 dB (*SD:* 3.0). Prior to testing, each participant was given a set of written instructions. Participants were instructed to repeat the nonsense syllables that they heard and/or saw in an open set format; that is, the participant responses were not restricted. If participants were unsure of their perception, they were encouraged to guess. They were also asked to rate their level of confidence in their answer on a five-point Likert scale, with a five indicating that they were very confident in their answer and one indicating they were unsure of their response.

The examiner scored all responses with a clear view of the participant at the time of testing. Participants' answers were also recorded using high fidelity audiocassettes and either a Marantz PMD 101 or a Panasonic RQ-2101 portable cassette recorder. These cassettes were reviewed and scored by a second examiner for assessment of inter-judge reliability. Twenty percent of the responses selected randomly across conditions were scored by the second examiner. Interjudge agreement coefficients ranged from 0.87 to 1.0 with an average agreement of 0.95. If a disagreement arose between the examiners a third examiner, the second author, viewed the tape to make the final determination of the response.

RESULTS

Objective Performance Measures

Group and modality effects. The mean correct identification of consonants, as well as the number of fused responses, is shown in Table 2 for older and younger adults as a function of modality. A repeated measures analysis of variance (ANOVA) was used to examine the main effects of participant group (older and younger) and presentation modality (AO, VO, AV-congruent). Responses to the incongruent stimuli were not included in this analysis. Performance differed significantly across presentation modality, $F(2, 42) = 200.1$, $p < .01$, with scores highest for AV-congruent stimuli, followed by AO stimuli, then VO stimuli. Performance between participant groups did not differ significantly, $F(1, 21) = 3.60$, $p = .07$, and no significant interaction was found between participant group and presentation modality, $F(1, 21) = 1.91$, $p = .12$.

McGurk effect across groups. A one-way ANOVA was also used to examine differences between groups in the number of fused responses reported to AV-incongruent stimuli. No significant differences between participant groups were found, $F(1, 21) = 0.20$, $p = .63$. It should be noted that tokens were presented by multiple talkers. Fused responses ranged from 12% to 83% across talkers in the AV-incongruent condition. Similarly, there was a range of scores in the VO condition, from 35% to 59% across talkers, whereas responses to the AO and congruent AV conditions did not differ across talker. These results were not unexpected and consistent with previous studies (Carney et al., 1999; Cienkowski, 2002).

Table 2

Means (and *SD*s) of Correct Consonant Identification in Noise by Modality for Younger and Older Adults

	Younger adults				Older adults			
	/bi/	/di/	/gi/	fused	/bi/	/di/	/gi/	fused
AO	24.4 (4.3)	18.7 (3.5)	19.7 (2.9)	NA	25.1 (4.0)	23.3 (5.3)	20.6 (4.5)	NA
VO	39.3 (0.9)	32.5 (3.9)	28.8 (6.2)	NA	39.4 (0.9)	29.6 (4.7)	26.2 (4.9)	NA
AV congruent	39.1 (2.3)	36.8 (2.6)	28.1 (5.6)	NA	39.6 (0.7)	38.1 (2.2)	28.2 (4.8)	NA
AV incongruent	NA	NA	NA	32.8 (8.3)	NA	NA	NA	34.5 (9.2)

Note. AO performance was artificially constrained by adjusting signal-to-noise ratio until a participant averaged 50% identification on a practice list spoken by one talker not used in the experimental conditions. AO = auditory-only; VO = visual-only; AV = auditory-visual.

Visual enhancement on congruent tokens. Mean visual enhancement (VE) was calculated relative to individual auditory performance [VE = (congruent AV-AO)/1-AO] (Sumby & Pollack, 1954). VE quantifies the improvement in speech perception gained from visual information relative to the amount by which auditory performance could possibly improve. The means and standard deviations *(SD)* were 71.8 (15.5) and 69.3 (11.8) for the younger and older participants respectively. Again, an ANOVA found no significant difference between the participant groups, $F(1, 21) = 5.05, p = .11$. Individual AV scores with corresponding VO scores for older and younger participants are displayed in Figure 1. Although it can be seen from this figure that four individuals scored less than 40% in the VO condition and three of those four individuals were older participants, the benefit from visual cues does not appear dependent upon individual lipreading ability.

Auditory-visual integration on incongruent tokens. AV integration was also measured indirectly by responses reported to the incongruent AV stimuli. Table

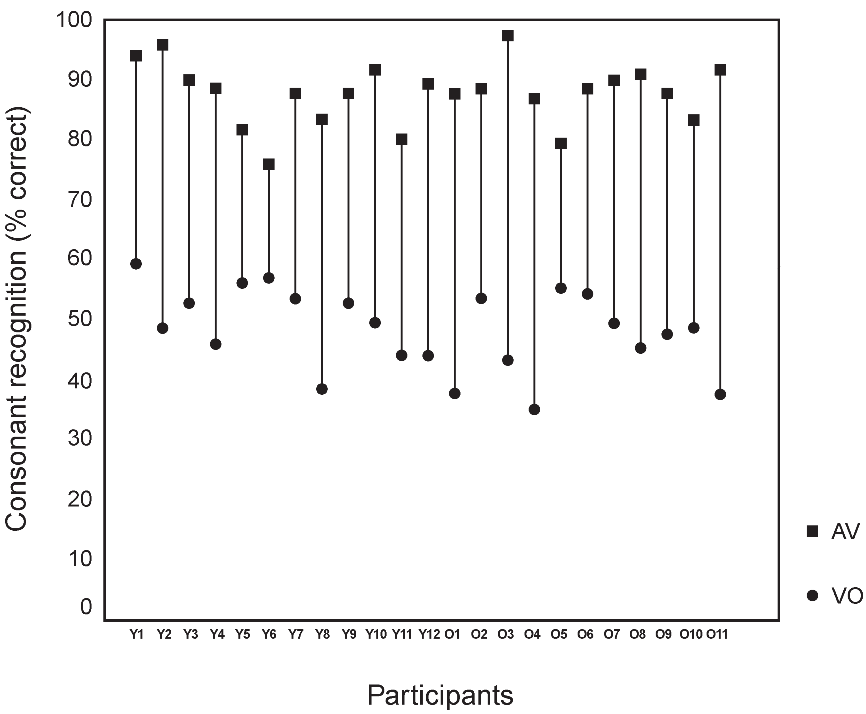

Figure 1. Percent correct identification of Consonant-Vowel (CV) syllables for auditory-visual congruent (AV-congruent) and visual-only (VO) modalities for individual younger (Y) and older (O) participants.

2 shows the mean number of fused responses to the AV-incongruent condition for individual older and younger participants. The mean number of fused responses to the AV-incongruent condition ranged from 16 to 47. However, repeated measures ANOVA found no significant difference between the participant groups, $F(1, 21) = 74.6$, $p = .07$. Less than 1% of participants reported combination responses (e.g., /bigi/) to the AV-incongruent stimulus combination (auditory /gi/ + visual /bi/); therefore, these data were not included in the table or the analysis. Pearson product moment correlations were calculated to evaluate if a relationship existed between (a) the direct measure of AV integration (VE) and VO performance and (b) the indirect measure of AV integration (number of fused responses) and VO performance. No significant correlation was found between any of the measures.

Self-Report Ratings

Table 3 displays the mean confidence ratings (and *SD*) for the older and younger adults as a function of modality. A repeated measures ANOVA was used to examine the main effects of participant group (older and younger) and presentation modality (AO, VO, AV-congruent). Responses to the incongruent stimuli were not included in this analysis to be consistent with the objective measures analysis. Rated confidence differed significantly across presentation modality, $F(2, 42) = 56.81$, $p < .01$, with confidence highest for AV-congruent stimuli, followed by VO stimuli, then AO stimuli. This may be attributed to the small set of tokens used, which benefited VO performance, or the effects of the noise in the AO condition. Either of these factors, or a combination of their effects, may have created the resulting situation and affected confidence levels. Although mean reported confidence levels were nominally lower for younger participants, confi-

Table 3

Means (and *SD*s) of Self-Ratings of Consonant Identification by Modality for Younger and Older Adults

	Younger adults				Older adults			
	/bi/	**/di/**	**/gi/**	**fused**	**/bi/**	**/di/**	**/gi/**	**fused**
AO	3.0 (0.5)	3.1 (0.5)	2.6 (0.5)	NA	3.4 (0.5)	3.6 (0.5)	3.3 (0.5)	NA
VO	4.4 (0.5)	3.4 (0.5)	3.0 (0.4)	NA	4.2 (0.7)	3.4 (1.0)	3.0 (1.1)	NA
AV congruent	4.3 (0.8)	3.9 (0.6)	3.5 (0.6)	NA	4.4 (0.4)	4.1 (0.5)	3.8 (0.6)	NA
AV incongruent	NA	NA	NA	3.2 (0.6)	NA	NA	NA	3.4 (0.7)

Note. 1 = unsure; 5 = very confident; AO = auditory-only; VO = visual-only; AV = auditory-visual.

dence ratings between participant groups did not differ significantly, $F(1, 21) = 2.04$, $p = .17$, and no significant interaction was found between participant group and presentation modality, $F(1, 21) = 3.64$, $p = .07$. In addition, confidence ratings were not significantly correlated with identification accuracy.

DISCUSSION

The purpose of the present investigation was to evaluate whether the ability to utilize auditory-visual information for the perception of a small set of CV tokens varied as a function of age. Both objective identification scores and self-report ratings were examined. The integration of information across sensory modalities was assessed indirectly by measuring participant susceptibility to a perceptual illusion, the McGurk effect, and directly by measuring visual enhancement, the improvement in consonant recognition with the addition of visual cues. The results indicate that older and younger adults exhibited similar abilities when combining auditory and visual speech information in the task used in this study. Consistent with previous investigations (Cienkowski & Carney, 2002; Sommers et al., 2005) the percentage of reported fused responses did not differ between groups. Similarly, the measured visual enhancement was equivalent for younger and older adults. Although individual older adults were among the poorest lipreaders in the study, results failed to show a significant difference between groups on this task. These findings are in contrast to the decline in VO performance for older adults seen in previous investigations (Shoop & Binnie, 1979; Walden et al., 1993). However, it should be noted that only three tokens (/bi, di, gi/) were used as stimuli in this task, each representing a distinct place of articulation, front, mid, and back, respectively (Binnie, Jackson, & Montgomery, 1976). Performance may have been better than expected because of the small set size. Of greater interest may be that AV integration as measured by susceptibility to the McGurk perceptual illusion and by visual enhancement did not appear to be related to VO performance. This suggests that individuals may receive benefit from the use of visual cues for AV speech perception regardless of level of lipreading skills.

With regard to self-ratings of perception, high levels of confidence were observed for both age groups in the AV condition; that is, the combination of auditory plus visual cues improved confidence ratings over the unimodal conditions. This supports the use of visual cues to improve communication confidence. It is also important to point out that no significant difference was found between groups for confidence ratings in any of the three presentation modalities in this study. This suggests that, in this study, older adults perceived a level of benefit equivalent to that received by younger adults when measured by confidence ratings. One implication of these findings lies in encouraging audiologists to more assertively counsel and train older adults to use visual cues consistently to enhance accuracy of perception. One may also speculate that increased confidence will be reflected in the perception of greater ease of communication. However, such a conclusion is beyond the scope of the present study and may more appropriately be a subject for further research.

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