Auditory-visual Speech Perception in Older People: The Effect of Visual Acuity

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This study aimed to investigate the benefit gained by older people in auditory-visual speech perception compared to auditory-only perception and to investigate the correlation between visual acuity and benefit gained. A total of 77 community-based older people participated in the study. Pure-tone audiometry showed that 36% had normal hearing, 40% had a mild hearing loss and the remainder (23%) had a moderate or greater loss. Objective measurements of corrected distance and near visual acuities were obtained using the Bailey-Lovie logMAR distance and near visual acuity tests. According to the criteria used in the present study, 34% had some distance vision impairment and 9% had some near vision impairment. The benefit gained in auditory-visual speech perception was determined by comparing auditory-only and auditory-visual performance on the Bamford-Kowal-Bench Australian Version Speech reading Test. An average visual benefit of 28.8% was achieved by the participants, and, for the vast majority of participants (86%), the benefit gained was statistically significant. A significant correlation was not found between either distance or near visual acuity and benefit gained in auditory-visual speech perception. The implications of these findings are that it is important for audiologists to recommend the use of lipreading to older clients, irrespective of their visual impairment, as the majority will gain significant benefit from the use of visual cues.

Hearing and vision impairments increase with age, as does the co-occurrence of these impairments (see Worrall & Hickson, 2003, for review). In a study of 240 community-based older Australians, Hickson et al. (1999) found that 57% had a hearing impairment, 28% had a distance vision impairment and 19% had dual sensory impairment. Although audition is the primary mode of speech perception, there are many instances in which people use both auditory and visual information to perceive speech. Even people with normal hearing rely on lip-reading cues in difficult listening situations (Erber, 1975). The purpose of the present study was to investigate whether vision impairment in older people adversely affects auditory-visual speech perception.

It is known that auditory-visual speech perception is generally superior to auditory-only speech perception. Walden, Busacco, and Montgomery (1993) investigated the benefit gained from visual cues (i.e., visual benefit) in auditory-visual speech recognition in males aged 35 to 80 years. All participants had an acquired hearing impairment but

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normal distance vision; that is, vision of 6/12 or better as measured by an Illiterate E Chart (Taylor, 1978). There was no difference between benefit gained with visual cues for 20 middle aged (35–50 years) and 20 older participants (65–80 years). The benefit gained in auditory-visual speech perception by older people was also assessed by Helfer (1998) in 15 older listeners aged 61 to 88 years. All participants had self-reported normal, or corrected to normal vision and pure-tone high frequency average hearing levels ranging from 15 to 53 dB. The average difference between auditory-only and auditory-visual speech perception was approximately 18%. There was no significant relationship between age and visual benefit. Thus, these two studies indicate that there is no effect of age on visual benefit; neither study investigated the relationship between visual acuity and visual benefit.

There is some evidence that visual impairment can affect lip-reading. Hardick, Oyer, and Irion (1970) could differentiate good and poor lip-readers on the basis of visual acuity test results. Erber (1979) investigated the effects of artificially induced visual distortion on lipreading and concluded that “under poorer optical conditions it seems that lipreading can serve only as a minimal aid to listening” (p. 222).

It would be beneficial to determine if the visual difficulties experienced by older people influence their ability to interpret speech signals via auditory-visual speech perception. This may have implications for aural rehabilitation, in particular for the kind of hearing tactics that are recommended to older clients. For example, if an older person has a visual impairment, is it appropriate for audiologists to stress the value of lipreading? The aims of this study were (a) to investigate the benefit gained by older people in auditory-visual speech perception, compared to auditory-only speech perception, and (b) to determine if there is a correlation between visual acuity and benefit gained in auditory-visual speech perception in noise for older people.

METHOD

Participants

Seventy-seven older adults (41 females and 36 males) volunteered to participate in this study. Participants ranged in age from 60 to 97 years (mean = 73; *SD* = 7.2). All participants were community-based, living independently in their own homes or retirement villages. They all spoke English as a first language and had no history of neurological incidents or head trauma.

The majority (75.3%) did not wear hearing aids, 11.7% wore one aid and the remaining 13% wore hearing aids binaurally. All participants wore glasses. Distance glasses only were used by 1 participant (1.3%); reading glasses only were used by 22.1% of participants; and the remainder (76.6%) used either bifocals, trifocals, or graduated lenses for both near and distance vision.

Materials

Audiometric Equipment

Pure-tone audiometry was conducted with a Madsen Micromate 304 Screening audiometer with supra-aural headphones in the community locations. An Interacoustics Clinical Audiometer AC30 was used for testing conducted at The University of Queensland Audiology Clinic. The audiovisual component of the speech test was administered using a 34 centimetre Samsung television (Model number CB-B351F) and a Samsung Quick Start video cassette recorder (Model number PB-990R). The four-speaker babble component of the speech test was delivered via an AKAI AJ-W312CD cassette recorder. A Realistic Sound Level Meter (Cat. number 33-2050) was used to measure the volume of both the television and cassette recorder, and to monitor the signal-to-noise ratio.

Bailey-Lovie LogMAR Distance Visual Acuity Test

The visual acuity letter chart formulated by Bailey and Lovie (1976) consists of 14 rows, each containing five letters from the 10 British Standard letters (D, E, F, H, N, P, R, U,V, Z) which are approximately equal legibility. The letter size progression follows a logarithmic scale throughout the chart, such that calculations can accommodate use of nonstandard viewing distances, as may be required to assess people with severe visual impairment. Careful consideration was given to inter-letter and inter-row spacing in the design of this chart. Inter-letter spaces are equal to one letter width while inter-row spaces are equivalent to the height of the letters in the smaller row.

Bailey-Lovie LogMAR Near Visual Acuity Test

The objective of near vision testing is to assess visual capacities relating to reading. The near vision chart designed by Bailey and Lovie (1980) uses unrelated words arranged in a logarithmic (geometric) progression of size. The chart contains 16 rows of words; each word is 10, 7 or 4 letters in length. The decision to use a range of word lengths stems from an observation that word length affects readability for people with central retinal disturbance. The inter-word and inter-row spaces were standardised by setting the types with the closest spacing that would be used in regular typesetting. The number of words is restricted for the larger font sizes where space limitations apply, in an attempt to keep the chart to a manageable size.

Bamford-Kowal-Bench/Australian (BKB/A) Speechreading Test

The BKB/A Speechreading Test is a colour video-recorded test of lipreading/speechreading (Bench, Doyle, Daly, & Lind, 1993). It consists of 21 sentence lists each containing 16 sentences. Version A, which consists of a videocassette with talkers speaking sentences in quiet and an audiocassette of four-speaker babble, was used in this study. This version of the test allows adjustment of the signal-to-noise ratio. Sentence lists were presented in noise to avoid the possibility of ceiling effects expected to occur for sentences in quiet. The BKB/A was selected to assess auditory-visual and auditory-only speech perception for the following reasons:

- it is standardised for Australian speakers with normal hearing and hearing impairment (Bench, Daly, Doyle, & Lind, 1994; Bench, Daly, Doyle, & Lind, 1995a)
- it uses sentence material which has been shown to be more sensitive to variations in speechreading ability than consonants, nonsense syllables, words or story stimuli (Hardick et al., 1970; Shoop & Binnie, 1979)
- the signal and noise levels can be adjusted independently
- homogeneity of test sentence lists and the four different speakers in the test has been verified (Bench et al., 1994, 1995a; Bench, Daly, Doyle, & Lind, 1995b).

Procedure

Testing was conducted in a number of different locations, including community centres, retirement villages and in the audiology clinic at The University of Queensland. Attempts were made to complete testing in a suitably quiet room in the community centre locations. It has been found that visual acuity scores of approximately 50% of visually impaired persons are dependent on the level of illumination (Cornelissen, Kooijman, Dumbar, Van der Weldt, & Nijland, 1991). Attempts were made to maintain consistent photopic levels of illumination at all testing locations to avoid shadows, or alternatively, glare.

Assessments were conducted as follows:

Auditory Tests

Pure-tone thresholds were obtained at 500, 1000, 2000 and 4000 Hz in both ears using a modified Hughson-Westlake technique (Carhart & Jerger, 1959).

Vision Tests

Visual acuity scores increase with unlimited time available to read a chart, but decrease when items are presented rapidly (Newell, 1996). In this study, participants were allowed to read at their own pace but were not permitted to dwell on a difficult line for more than 30 seconds.

Bailey-Lovie logMAR Distance Visual Acuity Test. Participants were asked to stand (or sit, if necessary) at a distance of 6 metres from the letter chart (Bailey & Lovie, 1976). They were asked to begin reading aloud the letters on the chart starting at a line they found easy to read. Individuals were asked to guess if they were unsure. If the person owned glasses they were asked to wear them as normal. Participants were instructed to guess when they were unsure of any letters and were encouraged to read the letters until three out of the five letters on a line were read incorrectly. Distance visual acuity was recorded in logMAR (the logarithm of the minimum angle of resolution) notation, giving credit for each letter read correctly (Kitchin & Bailey, 1981).

Bailey-Lovie logMAR Near Visual Acuity Test. Participants were instructed to hold the near visual acuity chart (Bailey & Lovie, 1980) at a comfortable distance and to read aloud the smallest line that they could see comfortably. They were encouraged to spell out words they could not recognise. The individual was allowed to adjust the focus by moving the chart. The reading distance between the eyes and the chart was measured for the final row correctly read by the participant. If the individual owned reading glasses they were asked to wear them as normal. The last line from which the participant could read at least four words correctly (i.e., produce no more than two errors) was taken as the threshold. Participants were encouraged to guess if they were unsure.

BKB/A Speechreading Test

If individuals owned glasses or hearing aids, they were asked to wear them as normal. The test was conducted in this way in order to approximate the everyday performance of the participants (which was the aim of the study). Individuals were seated 1.5 metres from the television screen which was situated at approximately head height. The four-speaker babble background noise was presented by a cassette recorder placed directly above the television. Two equivalent sentence lists from the BKB/A test were used (i.e., lists 3 and 5). Each participant was administered one list auditory-only (i.e., with the television screen blank) and one list auditory-visually. They were asked to respond by repeating the sentence, or as much of it as they could. The order of presentation of both lists and conditions was counterbalanced to avoid the possibility of any order effects. Each of the sentence lists contains 16 sentences and 50 key words for scoring purposes. In accordance with the standardisation studies (Bench et al., 1994, 1995a), participant responses were scored for the number of key words correctly identified using the Loose Key Word method (Bamford & Wilson, 1979). Thus, on the basis that the word-stem carries the burden of meaning, a word was marked correct if the word-stem was correctly identified (e.g., "walk" for "walking"). The cumulative key word scores for each sentence list resulted in a total out of 50.

Sentence stimuli were presented at 65 dB SPL, as measured by a sound level meter situated at the position of the participant's head, using the test calibration tone. A pilot study was conducted to determine the optimal signal-to-noise ratio for the presentation of the test, avoiding a ceiling or floor effect. Participants for the pilot study were four females and four males, aged between 60 and 85 years (mean = 68.5 years). One participant wore binaural hearing aids, and all wore glasses either all the time or for reading only. Based on the four-frequency pure-tone average hearing threshold levels in the better ear (.5, 1, 2, and 4 kHz), 2 participants had normal hearing (< 25 dB), 5 had a mild hearing impairment (25–40 dB), while 1 participant had a moderate impairment (40–60 dB). All participants had normal corrected near and distance visual acuity.

Participants were allocated to either an auditory-only or an auditory-visual trial and were each presented with three lists (numbers 3, 5 and 7) at +6, 0 and –6 signal-to-noise ratios. The results of the pilot study are shown in Table I. The largest range of scores for both auditory-visual and auditory-only

TABLE I
Percentage Correct on the BKB/A Speechreading Test with Varying Signal-to-noise Ratios for the Eight Participants in the Pilot Study

Condition	Participant	Signal-to-Noise Ratio +6	0	–6
Auditory-visual	1	42	24	0
	2	78	26	26
	3	80	86	24
	4	46	32	12
	Range	42–80	24–86	0–26
Auditory-only	5	56	44	0
	6	44	10	0
	7	42	12	8
	8	62	12	0
	Range	42–62	10–44	0–8

conditions, without either a ceiling or a floor effect, was for the 0 dB signal-to-noise ratio condition. Thus, this signal-to-noise ratio was chosen for the presentation of the BKB/A Speechreading Test for the main study. The level of the four-speaker babble was set at 65 dB SPL based on the sound level meter measurement taken at the position of the participant's head.

Data Analyses

Hearing level results were categorised as normal, mild impairment and moderate+ impairment based on the four-frequency pure-tone average hearing threshold levels at .5, 1, 2 and 4 kHz in the better ear (Hickson & Worrall, 1997): normal hearing = average < 25 dB, mild impairment = average between 25 and 40 dB and moderate+ impairment = average > 40 dB. Distance vision results were classified as follows, adapted from Johnston (1991): normal vision = ≤ 0.15 logMAR (approximately 6/9), mild vision impairment = 0.16 to 0.55 logMAR (approximately 6/9 to 6/21) and moderate+ vision impairment = > 0.55 logMAR (worse than 6/21). The degree of corrected near visual impairment was classified according to the criteria generated by Hickson et al. (1999) based on the vision results of 240 community-based Australians over the age of 60: normal vision = ≤ 0.33 logMAR (equivalent to approximately 6-point print at 40 centimetre), mild vision impairment = 0.34 to 0.59 logMAR (approximately 6 to 12-point at 40 centimetre) and moderate+ near vision impairment = > 0.59 logMAR (worse than 12-point at 40 centimetre).

The auditory-only and auditory-visual scores on the BKB/A were compared using a paired samples *t* test. In addition, the visual benefit (i.e., the auditory-visual score–auditory-only score) obtained by the individual participants in the auditory-visual condition was examined using the 95% critical difference for statistical significance as described by Thornton and Raffin (1978).

The relationships between sensory measures and age, and between age and visual benefit were examined using one-tailed Pearson's *r* correlation coefficients.

RESULTS

Hearing and Vision

Table II contains a summary of the hearing and vision impairment results for the 77 participants. The better ear four-frequency pure-tone average hearing threshold levels ranged from 10 to 65 dB (mean = 31.4, *SD* = 12.33). The majority of participants (76.7%) had either normal hearing or a mild loss only.

TABLE II
The Number and Percentage of Participants in Each of the Hearing and Vision Categories

	Hearing	Distance Vision	Near Vision
Normal	28 (36.4%)	51 (66.2%)	70 (91%)
Mild Impairment	31 (40.3%)	24 (31.2%)	3 (4%)
Moderate+ Impairment	18 (23.3%)	2 (2.6%)	4 (5%)

Thirty-four percent of participants had a distance vision impairment and 9% had a near vision impairment. The 7 participants who had a near vision impairment also had a distance vision impairment. The corrected distance visual acuity levels of the participants ranged from –0.02 to 1.06 logMAR (mean = 0.11, *SD* = 0.20). The corrected near visual acuity levels of the participants ranged from –0.1 to 1.4 logMAR (mean = 0.16, *SD* = 0.23).

As expected, hearing, distance vision and near vision results were all significantly correlated with age, such that as age increased the level of impairment increased (r = .34, p < .01 for hearing; r = .51, p < .001 for distance vision; r = .5, p < .001 for near vision).

Speech Perception

The auditory-only speech perception of participants ranged from 0 to 80% (mean = 23.09, *SD* = 19.2). Figure 1 shows the distribution of scores for the 77 participants and it can be seen that the majority of participants (87%) scored less than 50%. The auditory-visual speech perception of the group ranged from 14 to 96% (mean = 51.95, *SD* = 20.39; see Figure 2). The majority of participants (57%) achieved a score of between 36 and 66%.

A significant difference was found between the mean auditory-only and auditory-visual scores using a paired sample t test (t = 20.46, df = 76, p < .001). The mean benefit gained in the auditory-visual condition compared to the auditory-only condition was 28.86% (*SD* = 12.38, Range = –2 to 60). The percentage correct auditory-visually was plotted as a function of the percentage correct in the auditory-only condition for all participants (see Figure 3). Only 1 participant performed worse on the auditory-visual condition, obtaining a score of 78% compared to 80% for the auditory-only task. This participant had normal hearing and vision and achieved the

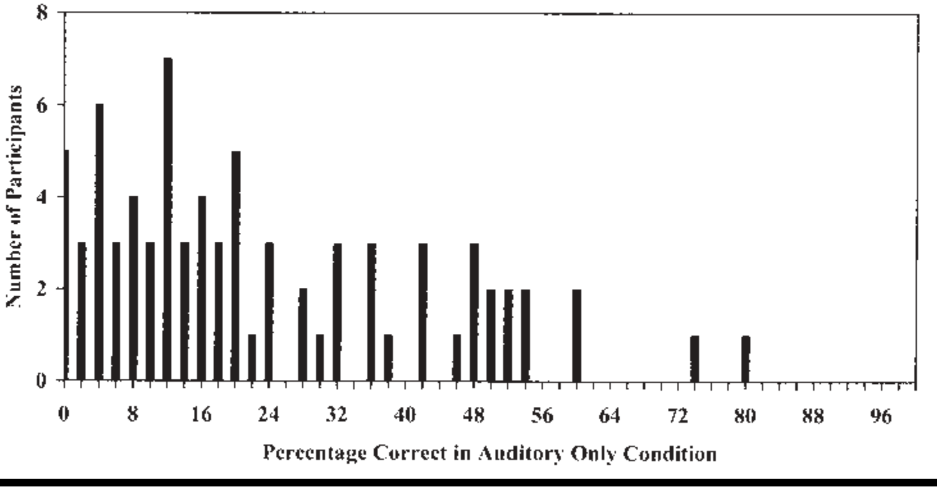

FIGURE 1
Participants' scores in the auditory only condition.

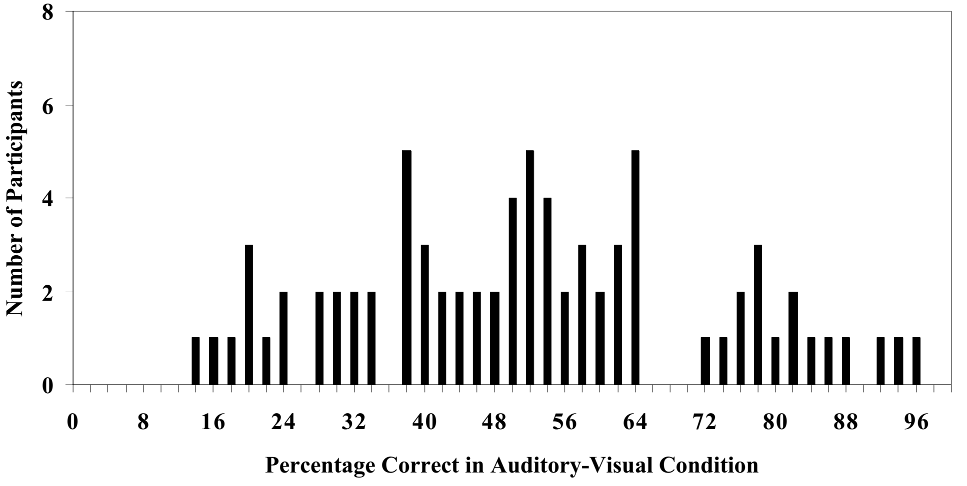

FIGURE 2
Participants' scores in the auditory-visual only condition.

highest score for the group on the auditory-only task.

Thornton and Raffin (1978) proposed a model for interpreting speech discrimination scores as binomial variables. According to the 95% critical difference for statistical significance of speech discrimination scores for a 50-item test, 66 participants (86%) obtained significant benefit in the auditory-visual condition compared to auditory-only ($p < .05$).

Relationship Between Visual Benefit and Visual Acuity

As age was correlated with vision and hearing impairment, it was necessary, prior to assessing the relationship between visual acuity and visual benefit gained in speech perception, to determine if age was correlated with benefit. If so, the effect of age would need to be partialled out in subsequent analyses. No significant relationship was found between age and visual benefit ($r = .04$, $p > .05$).

The relationship between visual acuity (both distance and near vision) and visual benefit approached significance, but did not reach the .05 level *t* ($r = –.16$, $p = .085$ for distance vision; $r = –.17$, $p = .07$ for near vision). Of the 11 participants who failed to show significant gains in BKB/A sentence scores in the auditory-visual condition, 4 had both distance and near vision impairments. Only 7 participants in the total sample had co-occurring distance and near vision impairments.

DISCUSSION

The first aim of this study was to investigate older people's visual benefit for speech perception. All except 1 participant showed some improvement from the auditory-only to the auditory-visual condition and the vast majority (86%) gained significant benefit from visual cues. One participant did not show a visual advantage, with a 2% decrease in performance when vision was added. It must be pointed out, however, that this participant achieved the highest auditory-only score of all participants. He had normal hearing, and audition was his primary modality for speech perception.

The participants' average increase in speech perception scores from the auditory-only condition to the auditory-visual condition was 29%, higher than the 18% obtained by Helfer (1998) in a study of 15 older people. This difference is most probably due to the nature of the stimuli used in the two

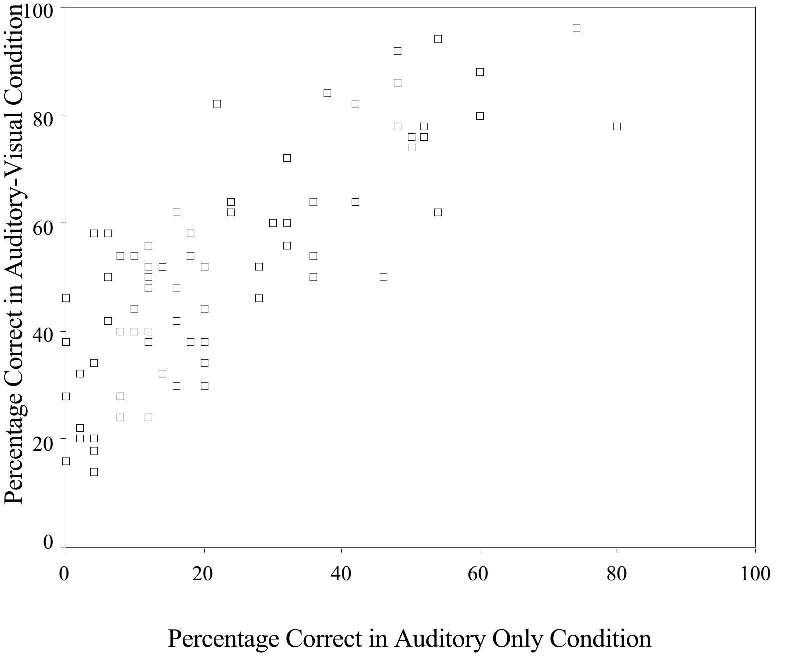

FIGURE 3
Scatterplot of auditory-only and auditory-visual scores for each participant.

studies. Helfer presented sentence material at an intensity of 80 dB SPL and a signal-to-noise ratio of +3 dB, compared to 65 dB SPL and 0 dB signal-to-noise ratio in the current study. The easier test conditions in the Helfer study resulted in higher scores overall and less room for improvement from the auditory-only to the auditory-visual condition.

Visual benefit was not related to the age of participants in the present study, a finding that is in agreement with previous research (Helfer, 1998; Walden et al., 1993).

The second aim of the present study was to explore the correlation between visual benefit and visual acuity. Although it approached significance, the relationship was not significant. It must be remembered, however, that the majority of the 77 participants in the present study had normal corrected visual acuity and a study that includes a greater number of participants with visual impairments is necessary to confirm the results obtained here. The importance of vision is suggested by the fact that 4 of the 11 participants, who did not show significant visual benefit, had co-occurring near and distance visual impairment. It should be stated that the visual acuity tests used in the present study are high contrast, static, chart-based tests. Other vision function tests such as low contrast visual acuity, contrast sensitivity, and/or dynamic visual acuity may be more relevant to auditory-visual speech perception.

Overall, the results of this study suggest the importance of audiological rehabilitation for older people emphasising the speech perception improvements that can be obtained from visual cues. The majority of older people gain significant benefit from watching the speaker's face, irrespective of their visual impairment. Some participants did not benefit and hence it is recommended that, if time permits, the audiologist assess auditory-only and auditory-visual speech perception. In this way, individual rehabilitation can be appropriately targeted.

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