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Auditory, Visual, and Audiovisual Speech Intelligibility for Sentence-Length Stimuli: An Investigation of Conversational and Clear Speech

Jean-Pierre Gagné, Carol Querengesser, Paula Folkeard, Kevin G. Munhall, and Valerie M. Masterson

Previous investigators have shown that the use of clear speech improves the auditory speech intelligibility of talkers. In the present study, the differences in speech intelligibility for sentences spoken conversationally and in a clear manner were investigated under three different experimental conditions: Auditory-only, visual-only, and audiovisually. Six talkers were videotaped while saying a list of 17 sentences twice: first while using conversational speech and then while using clear speech. The recorded stimuli were randomized and presented to subjects under one of the three experimental conditions. A broadband noise was mixed with the audio signal for the auditory-only and the audiovisual conditions. An auditory, visual, and audiovisual speech intelligibility score was obtained for the tokens of conversational and clear speech spoken by individual talkers. Overall, in each experimental condition, speech intelligibility improved significantly for the tokens of clear speech. However, for the auditory-only and the visual-only conditions there was a significant interaction between talker *and* manner of speech. *In those sensory modalities, the speech intelligibility of some talkers improved when they used clear speech. For other talkers the use of clear speech did not improve speech intelligibility. The results suggest that for an individual talker there is not a direct association in the amount of improvement provided by the use of clear speech across sensory modalities.*

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There is growing evidence that communication partners play an important role in the success of a conversation with a person who has a hearing impairment (DeFilippo, 1991; Erber 1988, 1993; Tye-Murray & Schum, 1994). One of the variables that can influence speech communication is the talker's speech intelligibility. Speech intelligibility refers to that aspect of speech-language output that allows a communication partner to understand what the talker is saying (Carney, 1986). Anecdotal reports and research findings indicate that a talker's speech intelligibility can influence the speech perception performances of individuals who receive the spoken message. Individuals with hearing impairments report that: "Mrs. Jones is easier to understand than Mr. Smith," or "Mr. Brown articulates more clearly than Mr. Smith." Experimentally, several investigators have demonstrated that differences exist in speech intelligibility across talkers (e.g., Cox, Alexander, & Gilmore, 1987; Creelman, 1957; DeFilippo, 1986; Hood & Poole, 1980; Kreul, Bell, & Nixon, 1969; Mullenix, Pisoni, & Martin, 1989).

There is evidence that individual talkers can modify their speech intelligibility. One theory of speech production claims that talkers can adjust their speech intelligibility according to the conversational situation (Lindblom, 1990). For example, the speech intelligibility of a talker is likely to be less intelligible during a conversation that takes place under ideal conditions for communication. Alternatively, talkers will modify their speech to produce more intelligible speech when communication is more difficult, such as when they converse in a noisy environment, when they speak to someone whose primary language of communication differs from theirs, or when they communicate with someone who has a significant hearing impairment. One manner of speech that has been reported to produce highly intelligible speech is clear speech (Picheny, Durlach, & Braida, 1985). Several studies have shown that the use of clear speech can significantly improve a person's *auditory* speech intelligibility by more than 15% relative to conversational speech (Chen, 1980; Payton, Uchanski, & Braida, 1994; Picheny et al., 1985; Uchanski, 1988). Gagné, Masterson, Munhall, Bilida, and Querengesser (1994) investigated the effects of clear speech for words spoken in isolation. The results showed that, for some talkers, attempts to produce clear speech resulted in improvements in auditory speech intelligibility by more than 30% relative to their intelligibility for words spoken in a conversational manner.

Findings related to the production of clear speech have potential applications for aural/oral rehabilitation. For example, it is likely that the speech perception performances of individuals with hearing impairments could improve if the persons who frequently interact with them improved their speech intelligibility by speaking more clearly (e.g., DeFilippo, 1991; Erber, 1988, 1993; Kaplan, Bally, & Garretson, 1987; Tye-Murray & Schum, 1994). However, several issues related to the production of clear speech require further investigation. Among them are the effects of clear speech on visual and audiovisual speech intelligibility. This question is important because of the concomitant effects of speech intelligibility on speech perception. Operationally, a person's speech intelligibility is often defined by the speech perception performances obtained by a group of subjects for speech stimuli produced by the talker. Many individuals with hearing impairments rely on the visual as well as the audio signal to perceive speech. Few studies have investigated the effects of clear speech on visual and audiovisual speech intelligibility. The present study investigated the effects of clear speech on auditory, visual, and audiovisual speech intelligibility.

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There have been some investigations of how the manner in which speech is produced can have an effect on visual speech intelligibility. For example, Franks (1979) used consonants, words, and sentences to investigate the effects of *exaggerated* mouth movements on *visual* speech intelligibility. A female talker was trained to speak with exaggerated mouth movements, while making an effort not to alter her rate of speech production. Tokens of conversational and exaggerated speech were presented live to two groups of subjects: one group had normal hearing and the other group had hearing impairments. The results obtained for both groups of subjects were similar and revealed that the exaggerated mouth movements: (1) reduced the talker's visual speech intelligibility for consonants, (2) did not have a significant effect on her visual speech intelligibility for words, and (3) had a beneficial effect on her visual speech intelligibility for sentence length materials.

Stoker and French-St.George (1987) investigated the effects of training on the visual speech intelligibility of talkers. CID everyday sentences were recorded from 13 talkers who had completed a 36-hour course designed to train oral interpreters. The course included lessons on how to produce intelligible speech. Each talker was recorded on two different occasions: once before and once after the completion of the training course. During both recording sessions, the talkers were instructed to articulate as if they were speaking to someone who had a hearing impairment. The speech samples were randomized, across talkers and recording sessions, and shown to a group of subjects with normal hearing and a group of subjects with a hearing impairment. The results of the perceptual experiment revealed that there was a substantial amount of variability in visual speech intelligibility among the talkers. The range of visual speech intelligibility scores exceeded 30%. In general, talkers were more intelligible (visually) after they completed the training program. For this group of talkers, visual speech intelligibility improved by 8% for the stimuli recorded during the post-training session. However, the amount of improvement in speech intelligibility varied considerably across talkers. Some talkers displayed no improvement in visual speech intelligibility between pre- and post-training while others showed as much as 17% improvement in their speech intelligibility post-training.

There has been one investigation of the effects of clear speech on *visual* speech intelligibility (Gagné et al., 1994). Specifically, the authors measured differences in visual speech intelligibility for tokens of conversational and clear speech. Ten female talkers were videotaped while they spoke a list of 14 words, once using conversational speech and once using clear speech. The talkers were not instructed on how to produce clear speech. They were simply instructed to articulate each word clearly, as if they were communicating with someone who had difficulty understanding what was said. The speech utterances were randomized, across talkers and manner of speech, and shown to a group of normal-hearing subjects. The results indicated that, for this group of talkers, there was a small but significant improvement in visual speech intelligibility for the tokens of clear speech (3.3%). However, the difference in speech intelligibility between the tokens of conversational and clear speech varied considerably among the talkers. For some talkers there were no significant differences in visual speech intelligibility between the tokens of conversational and clear speech. Other talkers displayed a significant improvement in visual speech intelligibility when they used clear speech rather than conversational speech. In some cases, the use of clear speech improved the speech intelligibility score by as much as 20%. The results obtained from one talker revealed that her visual speech intelligibility was poorer for her tokens of clear speech than for her utterances of conversational speech.

Gagné et al. (1994) also investigated differences in *auditory* and *audiovisual* speech intelligibility using the same speech stimuli. For both those experimental conditions, the audio signal was presented to normal-hearing subjects through HELOS, a hearing loss simulation device shown to emulate the patterns of speech perception errors typically observed among individuals with severe sensorineural hearing losses (Gagné & Erber, 1987). For both the auditory and audiovisual conditions, the differences in speech intelligibility scores between the conversational and clear speech were similar to the *visual* speech intelligibility data. That is: (1) Overall the speech intelligibility scores for the tokens of clear speech were significantly better than the speech intelligibility scores for the tokens of conversational speech; (2) There was a considerable amount of variability in the effects of clear speech displayed by individual talkers. For some talkers, the use of clear speech did not significantly alter speech intelligibility. For others, the use of clear speech improved speech intelligibility. For some talkers, the use of clear speech resulted in poorer speech intelligibility scores; and (3) In each sensory modality, there appeared to be negative relationships between the effects of clear speech and the speech intelligibility scores obtained for the tokens of conversational speech. That is, the talkers with the lower speech intelligibility scores for the tokens of conversational speech tended to display the most improvement in speech intelligibility when they used clear speech. Finally, an analysis of the data reported in each sensory modality suggested that the use of clear speech had differential effects on auditory, visual, and audiovisual speech perception. Specifically, for some talkers, the articulatory patterns that produced improved speech intelligibility in one sensory modality (e.g., auditory speech intelligibility) did not produce similar effects on speech intelligibility in another sensory modality (e.g., visual or audiovisual speech intelligibility).

The findings reported by Gagné et al. (1994) may have important implications for aural/oral rehabilitation. First, they indicate that, when instructed to do so, some talkers were able to improve their speech intelligibility in a given sensory modality. The acoustic and kinematic properties of the speech tokens produced by individuals who can improve their speech intelligibility should be investigated so that the characteristics of intelligible auditory and visual speech production can be identified. Second, the findings reported by Gagné et al. (1994) revealed that not all talkers were able to produce clear speech patterns that improved the speech perception performances of the subjects. Those findings suggest that some talkers could likely benefit from a rehabilitation program that would teach them how to produce clear speech patterns that would enhance their speech intelligibility. Third, the results revealed that there may be some speech patterns that improve speech intelligibility in one but not all sensory modalities. Thus, the beneficial effects of clear speech in one speech modality may be negated by the detrimental effects that those articulation patterns may have on speech intelligibility in another sensory modality.

The present investigation is part of a comprehensive research program designed to investigate the effects of clear speech on speech intelligibility. The long-term goals of the research program are: (1) to describe of the perceptual effects of clear speech on auditory, visual, and audiovisual speech perception; (2) to identify the acoustic and kinematic properties of speech patterns that are intelligible in all sensory modalities; (3) to develop, if warranted, programs designed to optimize the r tokens of clear speech than for her

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speech intelligibility of individuals who frequently communicate with persons who have hearing impairments. The present study was a extension of the investigation reported by Gagné et al. (1994). The main difference between the two studies resides in the types of speech stimuli used to measure speech intelligibility. Whereas words spoken in isolation were used in the previous study, the stimuli used in the present investigation consisted of sentences. It was deemed important to investigate the effect of this variable because of the potential relevance of the research program to aural/oral rehabilitation. It is recognized that sentences are more representative of the type of utterances used in everyday conversations than words produced in isolation. Thus, ecologically, it was important to determine whether the findings reported for words spoken in isolation could be extended to sentence-length stimuli.

The results of the present investigation were difficult to predict for several reasons. First, previous investigators have shown that durational and other temporal cues constitute a major difference between conversational and clear speech. Among other features, clear speech is characterized by longer duration of utterances as well as more pauses and longer pauses between words (Picheny, Durlach, & Braida, 1986, 1989; Uchanski, 1988). It is reasonable to expect that the beneficial effects of those cues would be greater in sentence-length stimuli than in words presented in isolation (Uchanski, 1988). Second, clear speech is also characterized by modifications at the suprasegmental level. It is very likely that those modifications would have differential effects for sentences and words spoken in isolation (Uchanski, 1988). Moreover, modifications in speech at the suprasegmental level may have different effects on auditory, visual, and audiovisual speech intelligibility. Third, it is known that speech recognition scores are influenced by linguistic redundancies and contextual cues (e.g., Boothroyd, 1988; Gagné, Tugby, & Michaud, 1991). Some of the cues known to facilitate speech recognition, such as syntactic and semantic redundancies, are not present when the stimuli consist of words presented in isolation. The differences in linguistic information available in words spoken in isolation and sentences make it difficult to anticipate the effects of clear speech on auditory, visual, and audiovisual speech intelligibility. Uchanski (1988) found that the beneficial effects of *auditory* clear speech were similar for words presented in isolation and for sentences. However, in that investigation the words that were used had been excised from the sentences. Thus, in terms of stress and intonation, the words preserved many of the linguistic cues they had when they appeared in a sentence context. The results reported by Frank (1979) suggest that the effects of speech articulation patterns on *visual* speech intelligibility are different for sentences and for words spoken in isolation. In that study, the use of exaggerated speech had no effect on *visual* speech intelligibility for words but it had a beneficial effect on *visual* speech intelligibility for sentences.

Method

Talkers. The talkers were six English-speaking female adults. Two of them held secretarial positions in the Faculty of Applied Health Sciences at the University of Western Ontario. The other four talkers were first-year audiology graduate students at the same university. None of the talkers had atypical speech characteristics or noticeable oral-facial anomalies as judged by two of the experimenters (J.-P.G. and C.Q.). Also, none of them had prior knowledge of the characteristics of clear speech. None of the talkers reported having extensive experience in the production of clear speech as part of her personal or professional activities. Finally, the talkers were not informed of the specific purpose of the investigation, and they were not remunerated for their participation in the study.

Test stimuli

Selection of the stimulus set. In order to avoid the possibility of floor effects in the visual condition, a pilot investigation was conducted to identify sentences that would yield visual keyword recognition scores that exceeded 30% for tokens of conversational speech. Two talkers who did not participate in the actual study were videotaped while saying a total of 92 sentences. Some of the sentences were selected from the CUNY related sentences test (Hanin, Yeung, & Kishon-Rabin, 1990). Other sentences were generated by the investigators based on the list of words used in a previous study (Gagné et al., 1994). The same recording procedures were used in the pilot investigation as were employed in the actual study (described below). The sentences were randomized and shown to seven subjects with normal hearing. An informal item analysis was performed and the sentences that yielded the desired overall performance level were retained. A total of 48 key words taken from 17 different sentences that were chosen as the stimulus set for the investigation (see Appendix A).

Development of test stimuli. The talkers were videotaped in a double-walled audiometric test suite. The recordings were made with a Sony Video 8 Pro-digital video camera recorder (Sony CCD V220). Each talker was videotaped while she spoke the list of test sentences twice: once while using conversational speech and once while using clear speech. First, each talker was instructed to say all the test sentences in a conversational manner while looking directly into the video camera. Each was then instructed to repeat the same set of sentences while speaking clearly. The talkers were not given specific instructions on how to produce clear speech; they were simply asked to "speak clearly as if you were talking to someone who had difficulty understanding." During the recording session, the talkers were instructed to start and finish each sentence from a closed-mouth position.

The video recordings consisted of the lower half of the talker's face, extending from the bridge of the nose to just below the chin. Lights were used to reduce shadows on the talker's face; however, no special attempt was made to illuminate the inside of the talker's mouth. A lapel microphone was clipped to each talker's shirt at a distance of approximately 15 cm from her mouth.

A Sony 8 mm Editor (EVO-720) was used to edit the recordings from the master tape. The resulting test tape consisted of 204 randomized test items: 17 sentences X 6 talkers X 2 manners of speech (conversational and clear). Each test item consisted of a 3s test-item identification number, a test sentence, and a 9s written message that appeared on a TV monitor and prompted the subjects to provide a response.

Subjects

A total of 56 subjects participated in the investigation. The subjects ranged from approximately 18 to 35 years of age and consisted mostly of students from the Faculty of Applied Health Sciences at the University of Western Ontario. All of the subjects had normal hearing (self-reported) and normal (or corrected normal) binocular vision (20/20) as measured with a Snellen chart.

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Procedure

The subjects were randomly assigned to one of three experimental groups: 24 subjects completed the sentence recognition task in a visual mode; 16 subjects completed the task in an auditory mode; and 16 subjects completed the task in an audiovisual mode. The number of participants assigned to each experimental condition was determined according to power calculations (Browner, Black, Newman, & Hulley, 1988) estimated from the results of a previous investigation (Gagné et al., 1994). For the two conditions in which the auditory signal was provided, a broadband noise was mixed with the audio signal in order to avoid ceiling effects in the speech recognition scores. The sentences were presented at 65 dB SPL (measured 1 m from the loudspeaker). Pilot studies were completed to determine the signal-to-noise ratio (SNR) that would yield overall mean auditory and audiovisual keyword recognition scores of approximately 40%. As a result of those preliminary investigations, the SNR chosen for the auditory and the audiovisual conditions were 0 dB and -7 dB, respectively.

The subjects were tested individually or in groups of two or three. For the auditory and audiovisual conditions, the subjects were seated approximately 1 m in front of a 26-inch color TV monitor (Samsung, model CT-680). The audio signal and noise were mixed and delivered via a loudspeaker (Paradigm Titan) that was placed on top of the TV monitor. For the auditory condition, the cable to the video input of the TV monitor was disconnected. The subjects who completed the task under the auditory-alone condition did not have the benefit of edited video screens that indicated the test item number and response interval. The subjects had to rely on detecting the audio signal and the recurrent time interval between the presentation of the sentences to identify when a test item was presented. In addition, an experimenter was present to ensure that the subjects responded at the appropriate place on the response form.

For the visual condition, the subjects were seated approximately 1 m in front of a 13-inch color monitor (Sony Trinitron, model PVM-1350) at an angle that permitted an undistorted view of the video image (i.e., less than 45° from the center of the screen). Also, the audio signal and the noise source were disconnected from the loudspeaker so that no audio signal was present.

In an attempt to control for learning and fatigue effects, the starting position of the test tape was staggered across the subjects in each sensory modality. Four different starting positions were used (items: 1, 51, 102, 153). At the onset of testing, the subjects were given five practice items (sentences recorded from the pilot investigation and not included as test stimuli). The task consisted of an open-set sentence recognition task. Each subject was provided with a response form and asked to write the test sentence following the presentation of each test item. The subjects were instructed to provide an answer for each test item, and they were encouraged to guess if they were not certain. The subjects were tested in two one-hour sessions.

Scoring

Scoring was based on the number of keywords identified correctly by the subjects. The keywords included one-, two-, and three-syllable words that consisted of nouns, adjectives, verbs, and adverbs. Responses were scored as correct only if an entire keyword was written correctly on the response form. Inserted or deleted morphemes, such as the plural 's', were scored as incorrect. The data were then entered in a database management software program (Quattro Pro, version IV) for further analysis.

Results

Speech intelligibility was defined as the mean percent correct keyword recognition score obtained by the group of subjects in each sensory modality under investigation. For each talker, a speech intelligibility score was calculated for the tokens of conversational speech and for the tokens of clear speech. As mentioned above, a main purpose of the present investigation was to investigate differences in a talkers' speech intelligibility for conversational and clear speech in each of the three sensory modalities. Thus, the primary variables of interest were: *talker, manner of speech,* and the interaction between those two variables (i.e., *talker x manner of speech*). Recall that, in order to reduce learning effects, the data collected under each experimental condition were obtained from a different group of subjects. Consequently, the results were analyzed separately for the auditory, visual, and audiovisual conditions. However, non-parametric statistics (Spearman rank order correlations: Hays, 1973) were used to provide insights concerning the relationship between the effects of clear speech observed in each of the three sensory modalities.

Auditory speech intelligibility scores. The auditory speech intelligibility scores obtained for the individual talkers are shown in Figure 1. The speech intelligibility scores for the tokens of conversational speech (the hatched bars) ranged from 4% (talker B) to 35% (talker E). The speech intelligibility scores for the tokens of clear speech (the solid bars) ranged from 8.5% (talker B) to 65% (talker E). A 2-way ANOVA for repeated measures revealed that there was a significant effect for *manner of speech* ($F = 148.63$, $df = 1,15$, $p < .05$), a significant *talker* effect ($F = 161.76$, $df = 5,75$, $p < .05$), as well as a significant *talker x manner* interaction ($F = 65.44$, $df = 5,75$, $p < .05$). Paired two-tailed t-tests revealed a significant clear speech advantage for all talkers, with the exception of talker A. Talker A produced a significant *decrease* in auditory speech intelligibility when she produced clear

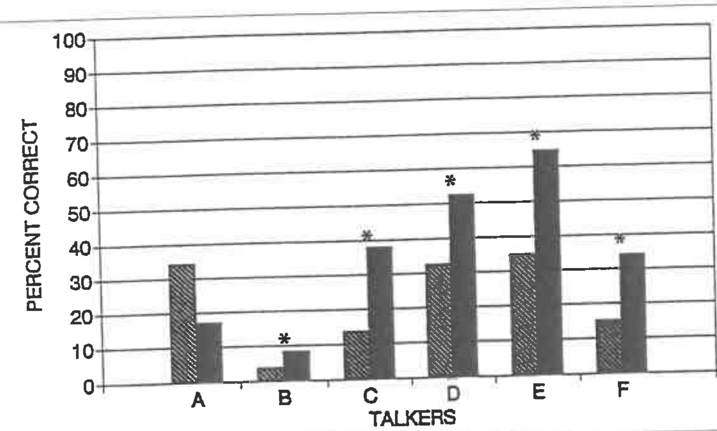

Figure 1. Auditory speech intelligibility scores of individual talkers. The mean percent speech intelligibility score for the tokens of conversational speech (dashed bars) and the tokens of clear speech (solid bars) are shown for each talker. The asterisks indicate those talkers who displayed a significant positive clear speech effect.

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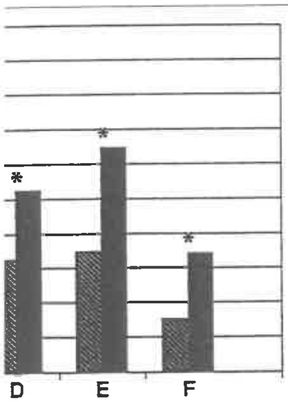

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speech. Overall, the mean auditory clear speech effect (intelligibility for clear speech minus intelligibility for conversational speech) was 13.5%. The largest clear speech effect displayed by an individual talker was 30% (talker E).

Visual speech intelligibility scores. The visual speech intelligibility scores obtained for the individual talkers are shown in Figure 2. The speech intelligibility scores for the tokens of conversational speech (the hatched bars) ranged from 35% (talker A) to 43% (talker E). The speech intelligibility scores for the tokens of clear speech (the solid bars) ranged from 45% (talker B) to 51% (talker F). A 2-way ANOVA for repeated measures revealed that there was a significant effect for *manner* of speech ($F = 60.09, df = 1,23, p < .05$), a significant *talker* effect ($F = 3.96, df = 5,115, p < .05$), as well as a significant *talker x manner* interaction ($F = 5.69, df = 5,115, p < .05$). Paired two-tailed t-tests revealed a significant clear speech advantage for talkers A, C, E, and F. Overall the mean visual clear speech effect was 8.4%. The largest clear speech effect was 14% (talker A).

Audiovisual speech intelligibility scores. The audiovisual speech intelligibility scores obtained for the individual talkers are shown in Figure 3. The speech intelligibility scores for the tokens of conversational speech (the hatched bars) ranged from 66% (talker B) to 84% (talker D). The speech intelligibility scores for the tokens of clear speech (the solid bars) ranged from 77% (talker B) to 93% (talker E). A 2-way ANOVA for repeated measures revealed that there was a significant effect for *manner of speech* ($F = 39.91, df = 1,15, p < .05$) and a significant *talker* effect ($F = 26.73, df = 5,75, p < .05$). However, there was not a significant *talker x manner* interaction ($F = 1.85, df = 5,75, p > .05$). Post hoc t-tests revealed a significant clear speech advantage for talkers B, C, D, E, and F. Overall the mean audiovisual clear speech effect was 11.1%. The largest clear speech effect was 16% (talker C).

Comparisons of auditory, visual, and audiovisual clear speech effects. The clear speech effects produced by each talker in each sensory modality are displayed in Figure 4. A clear speech effect was defined as the difference between a talker's

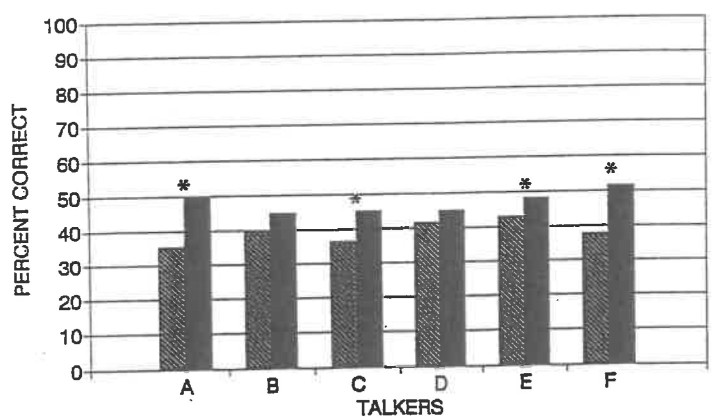

Figure 2. Visual speech intelligibility scores of individual talkers. The mean percent speech intelligibility score for the tokens of conversational speech (dashed bars) and the tokens of clear speech (solid bars) are shown for each talker. The asterisks indicate those talkers who displayed a significant positive clear speech effect.

intelligibility for tokens of clear speech and her intelligibility for her production of conversational speech in a given sensory modality. For each talker, the dark crosshatched bar displays the auditory clear speech effect, the solid bar displays the visual clear speech effect, and the light crosshatched bar displays the audiovisual clear speech effect. Three talkers (talkers C, E, and F) displayed a significant clear speech effect for all three sensory modalities. Five of the six talkers (talkers B, C, D, E, and F) displayed a significant positive audiovisual clear speech effect. All the talkers displayed a positive clear speech effect in at least two sensory modalities. However, in some cases the speech patterns used by a talker to produce clear speech resulted in a significant positive auditory clear speech effect but not a significant visual clear speech effect (e.g., talkers B and D). For one talker (talker A) the production of clear speech resulted in a significant *positive* visual clear speech effect and a significant *negative* auditory clear speech effect.

Spearman rank order correlations were performed in order to get an appreciation of the relationship between the clear speech effects displayed by individual talkers, in each of the three sensory modalities under investigation. The rank order correlation between the auditory and visual clear speech effects yielded a correlation coefficient of -.371; the rank order correlation between the auditory and audiovisual clear speech effects yielded a correlation coefficient of .371; and the rank order correlation between the visual and the audiovisual clear speech effects yielded a correlation coefficient of .029. None of those correlation coefficients was statistically significant (i.e., $p > .05$). Similarly, no statistically significant correlations were observed when the coefficients were recalculated and the data from talker A, who displayed a negative clear speech effect in the auditory condition, were excluded from the analyses. These findings suggest that there is not a direct association between the clear speech effects displayed by a talker across the three sensory modalities investigated.

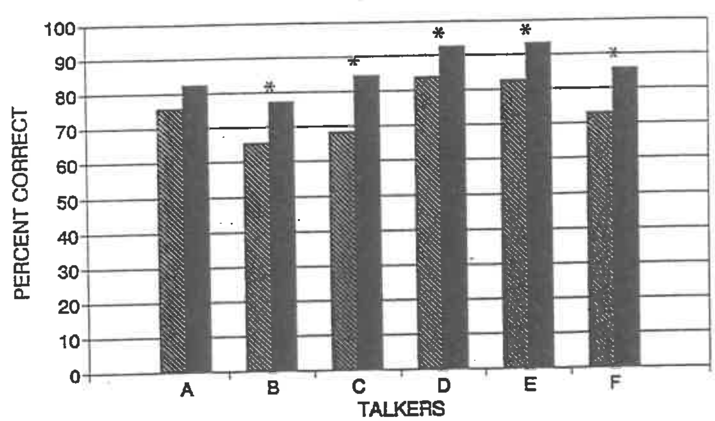

Figure 3. Audiovisual speech intelligibility scores of individual talkers. The mean percent speech intelligibility score for the tokens of conversational speech (dashed bars) and the tokens of clear speech (solid bars) are shown for each talker. The asterisks indicate those talkers who displayed a significant positive clear speech effect.

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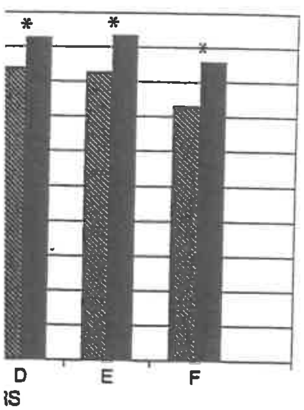

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Discussion

In the present investigation there were substantial differences in speech intelligibility across talkers. These differences were observed in all three sensory modalities. For this group of talkers the range of speech intelligibility scores for the tokens of conversational speech was greatest in the auditory modality (31%), followed by the audiovisual speech intelligibility data (18%), and the visual speech intelligibility data (8%). The present findings are consistent with previous investigations of auditory speech intelligibility (Cox et al., 1987; Picheny et al., 1985), visual speech intelligibility (DeFilippo, 1986; Kricos & Lesner, 1982, 1985; Lesner & Kricos, 1981; Gagné et al., 1994; Grant & Braida, 1991; Stoker & French-St.George, 1987), and audiovisual speech intelligibility (Gagné et al., 1994; Grant & Braida, 1991). The results also showed that there were differences in speech intelligibility across sensory modalities. This finding can be attributed to the signal-to-noise ratio selected for the auditory and the audiovisual speech perception tasks as well as inherent differences in the nature of the perceptual tasks in a given sensory modality (Gagné et al., 1994). Moreover, it is possible that the results could be explained by the fact that the data analyzed in each experimental condition were obtained from a different group of subjects.

The present data support previous reports, which have shown that some talkers are more intelligible than others. This finding has direct clinical implications for rehabilitative audiology. First, the fact that a talker's speech intelligibility will influence speech *perception* scores (because speech intelligibility was operationally defined as "the effects of speech production on speech perception") in a given sensory modality reinforces the need to use recorded (standardized) test stimuli in clinical settings (Palmer, 1955). This is especially true when test scores are used for within-client comparisons (e.g., different amplification systems) or across-client comparisons (e.g., comparing an individual's test score to normative data). Second, some individuals with relatively poor speech intelligibility may benefit from training programs designed to improve their speech intelligibility. Stoker and French-St.

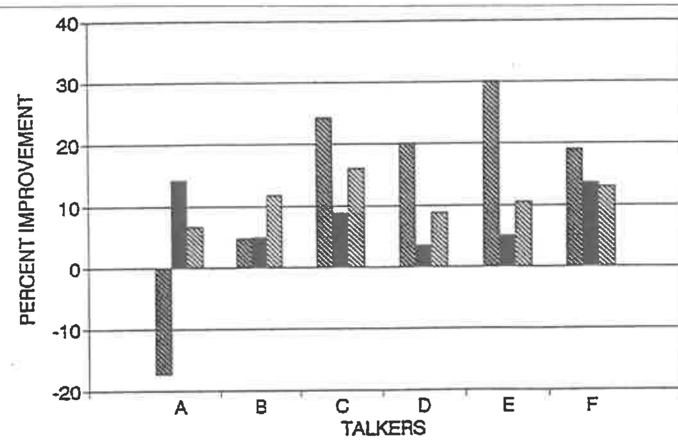

Figure 4. Percent clear speech effects (intelligibility for clear speech minus intelligibility for conversational speech) displayed by individual talkers. The auditory (dark dashed bars to left of filled bars), visual (filled bars), and the audiovisual (light dashed bars to right of filled bars) clear speech effects are shown for each talker.

George (1987) have shown that the visual speech intelligibility of some talkers improved significantly after they completed a training program designed to ameliorate their communication efficacy with individuals with hearing impairments. The results of the present investigation do not provide guidelines concerning the type of training program that could improve speech intelligibility. Additional research is required before the type, content, and extent of those training programs can be developed. Third, the findings of the present investigation suggest that it may be beneficial to develop a clinical procedure for assessing the speech intelligibility of persons who frequently communicate with individuals who have hearing impairments. Such a test would make it possible to identify individuals who could benefit from training on how to produce clear speech (Gagné et al., 1994).

A major objective of the present investigation was to determine if the use of clear speech would improve the speech intelligibility of individual talkers. The group results indicated that the use of clear speech significantly improved speech intelligibility in all three sensory modalities. The mean clear speech effects observed in all three sensory modalities were not trivial (13.5% for the auditory condition; 11.1% for the audiovisual condition; and 8.4% for the visual condition). Moreover, in some cases even greater clear speech effects were displayed by individual talkers (e.g., 20%, 24%, and 30%, for talkers D, C, and E in the auditory condition; 12% and 16% for talkers B and C in the audiovisual condition; 12% and 13% for talkers F and A in the visual condition). Improvements of this magnitude are not negligible and could potentially contribute to improvements in the speech perception performances of individuals with hearing impairments.

An important finding of the present investigation was the fact that, in two of the sensory modalities (auditory and visual), there was a significant interaction between the variables *manner of speech* and *talker.* Some talkers failed to display significant positive auditory and visual clear speech effects (e.g., talkers A, B, and D). This finding indicates that not all talkers were able to modify intuitively their speech patterns in a manner that improved their speech intelligibility in all three sensory modalities. In fact, talker A's attempt to produce clear speech resulted in a reduction in her auditory speech intelligibility scores. An examination of the videotape revealed one possible explanation for this finding. Talker A reduced the overall level of her voice when she produced clear speech. Consequently, aspects of her speech became inaudible to the subjects when the audio signal was mixed with the broadband noise in the perceptual task used to ascertain her auditory and audiovisual speech intelligibility. The present findings further substantiate the claim that some persons could benefit from a training program designed to teach talkers how to produce clear speech in all sensory modalities.

A comparison of the auditory, visual, and audiovisual speech intelligibility scores is tenuous because the data were obtained from different subjects in each sensory modality. Also, data were available only for a relatively small number of talkers. Nonetheless, the present results do provide some preliminary insights concerning the relationship of a talker's speech intelligibility to the three sensory modalities under investigation. All the talkers produced either a positive auditory or visual clear speech effect. Five of the talkers produced significant positive audiovisual clear speech effects. These findings indicate that, in general, the beneficial effects of clear speech produced in one of the primary sensory modalities (auditory or visual) are also available when the stimuli are presented audiovisually.

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sensory modality were not correlated to the clear speech effect observed in the other sensory modalities. For five of the talkers, the use of clear speech produced a significant improvement in auditory speech intelligibility. However, only three of those talkers (talkers C, E, and F) produced both a significant positive auditory and visual clear speech effect. For one talker (talker A) the use of clear speech resulted in a negative auditory clear speech effect, a positive visual clear speech effect, and no significant changes in speech intelligibility in the audiovisual mode. The data reported by Gagné et al. (1994) for words spoken in isolation also suggest that speech patterns that produce improved speech intelligibility in one sensory modality may not necessarily produce significant clear speech effects in both primary sensory modalities. However, O'Neill (1951) reported that talkers who displayed high auditory speech intelligibility also displayed high visual speech intelligibility. Additional studies are required to further explore the relationship between the effects of clear speech on auditory, visual, and audiovisual speech intelligibility. This information would be pertinent, especially for individuals with hearing impairments who rely on both auditory and visual cues for speech perception.

The results of the present investigation were most likely influenced by some (in some cases unsurmountable) limitations in the experimental design. First, as mentioned above, only six talkers took part in the present investigation. It is likely that the range of speech intelligibility scores and the extent of the clear speech effects observed might have been different if more talkers, or a different group of talkers, were selected for the investigation. As mentioned in the methods section, the two secretaries who took part in the study did not have any knowledge concerning the characteristics of clear speech. Also, their positions at the university did not require them to interact regularly with individuals who have communication disorders. The other four talkers had completed the first year of a three-year audiology graduate program. Although they had completed some course work indirectly related to the present investigation (e.g., phonetics, speech sciences) none of them reported having any knowledge of the characteristics of clear speech. Also, none of the student talkers reported that she interacted on a regular basis with individuals who had communication disorders. It is possible that the findings of the present investigation could have been different if the talkers had knowledge of the characteristics of clear speech or if they had the opportunity to frequently interact with individuals who displayed receptive communication disorders.

Second, the talkers were not given any specific instructions or training on how to produce clear speech. They were simply instructed to "speak clearly as if you were talking to someone who had difficulty understanding." This was done because one of the objectives of the present investigation was to determine whether *untrained* talkers would inherently produce clear speech tokens that improved their speech intelligibility. As with the companion study (Gagné et al., 1994), the results of the present investigation revealed that a request to produce clear speech does not necessarily result in more intelligible speech. These findings are different from most previous investigations of clear speech (e.g., Moon & Lindblom, 1989; Picheny et al., 1985; Uchanski, 1988). In those studies, the speech intelligibility scores for the production of clear speech always showed more intelligibility than the scores obtained for tokens of conversational speech (e.g., Moon & Lindblom, 1989; Picheny et al., 1985; Uchanski, 1988). The incongruence between the present findings and the results of previous investigations is likely attributable to the differences in the criteria used to select the talkers or to the instructions and training given to the talkers who took part in the various investigations. The findings of the present investigation suggest that variables, such as knowledge of the characteristics of clear speech, instructions to talkers, or experience and training on the production of clear speech, should be given careful consideration when the results of clear speech experiments are compared across studies. More research is needed to define more precisely the effects of those variables on the production of clear speech.

Third, although the talkers were not informed of the specific objectives of the experiment, they were aware that they were being videotaped and that the purpose of the experiment was to investigate aspects of their speech production. Thus, it is possible that, even though they were instructed to speak normally, their production of conversational speech was superior to their speech production performances during everyday conversations. The presence of the camera during the recordings of the clear speech tokens would be less deleterious on the outcome of the investigation because, by definition, clear speech is speech that is produced with a conscious attempt to optimize one's speech intelligibility. Hence, the results of the present investigation most likely underestimated the beneficial effects of using clear speech.

Fourth, the number of sentences that were used to measure speech intelligibility was limited. Moreover, the same set of 17 sentences was presented to each subject on 12 different occasions, albeit they were spoken by different talkers who used one of two different manners of speech. Although some steps were taken to minimize the effects of having to present the same set of sentences on several occasions (i.e., the randomization of the test items; the use of a staggered starting positions on the test tape; and the use of different subjects for each sensory modality investigated), it is likely that some learning effects did occur. Thus, the recognition of keywords became easier as the subjects were exposed to the same sentence several times (regardless of who produced the sentence and whether the sentence was produced using conversational or clear speech). The learning effects that occurred in the present investigation provided data that overestimated the talkers' intelligibility for conversational speech and thus under estimated the magnitude of the clear speech effects observed among individual talkers. This limitation in the experimental design severely limited the ability to reveal differences between conversational and clear speech. It is likely that, during everyday conversations, the beneficial effects of clear speech would be even more substantial than those reported in the present investigation.

Finally, all the speech intelligibility data reported in the present investigation were based on speech perception scores obtained from subjects who had normal hearing sensitivity and normal, or corrected normal, visual acuity. The use of subjects with normal hearing sensitivity does not invalidate the present findings as they relate to the clear speech effects displayed by individual talkers per se. However, the present results do not make it possible to conclude unequivocally that the use of clear speech would have beneficial effects on the speech perception performances of individuals who have hearing impairments. Previous studies have shown that subjects with normal hearing who complete auditory speech perception tasks in noise obtain results that are similar to those obtained from subjects with sensorineural hearing losses (e.g., Wang & Bilger, 1973; Zurek & Delhorne, 1987). Also, investigators have reported that there is not a significant difference in the visual speech perception performance between subjects who have normal hearing ıus investigations. The findings of the ;uch as knowledge of the characteris- , or experience and training on the :areful consideration when the results ross studies. More research is needed variables on the production of clear

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sensitivity and those who have sensorineural hearing impairments (e.g., Gagné, 1994; Hanin, 1988). However, it is possible that the acoustic and kinematic cues that render clear speech more intelligible than conversational speech are not available to (or are not used in the same fashion by) individuals with normal hearing and those with hearing impairments. Uchanski (1988) reported that the beneficial effects of auditory clear speech were the same for individuals with hearing losses and for a group of subjects with normal hearing who performed the listening task in noise. Nevertheless, more investigations are required to assess more directly the effects of auditory, visual, and audiovisual clear speech on the speech perception performances of individuals who have hearing impairments.

Summary and Conclusions

In the present investigation, sentence-length stimuli were used to investigate differences in speech intelligibility between conversational and clear speech. The investigation was conducted in three different sensory modalities: Auditory, visual, and audiovisual. The results may be summarized as follows:

- In all three sensory modalities there were considerable amounts of variability in speech intelligibility for the tokens of conversational and clear speech produced by the talkers.
- Overall, the use of clear speech improved speech intelligibility. The positive effects of clear speech were observed in all three sensory modalities.
- For five of the six talkers, the use of clear speech yielded a significant positive audiovisual clear speech effect. For some talkers, the use of clear speech resulted in a significant improvement only in one of the primary sensory modalities (auditory or visual). For one talker, attempts to produce clear speech actually resulted in a decrease in her speech intelligibility (talker A in the auditory condition).

The results of this investigation revealed that the use of clear speech generally improves speech intelligibility in at least one of the primary sensory modalities for speech. This finding suggests that individuals who interact with persons who have hearing impairments could facilitate communication by speaking more clearly. However, the present results indicate that not all talkers have an inherent knowledge of how to produce speech in a way that will make them more intelligible. It is possible that some frequent communication partners might benefit from training programs designed to teach individuals how to produce clear speech. Finally, the results of the present investigation suggest that the use of clear speech does not necessarily produce the same beneficial effects in all sensory modalities. There is a need for additional research to assess more directly the effects and characteristics of auditory, visual, and audiovisual clear speech.

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APPENDIX A

Test sentences with keywords underlined.

1. **MOVE** THE **COUCH** TO THE **WALL** FACING THE **WINDOW**.
2. **TAKE** THE **DOG** FOR A **WALK**.
3. DOES YOUR **BROTHER** STILL **LIVE** AT **HOME**?
4. **FEED** THE **ANIMALS**.
5. I AM **SMOKING** THE **PIPE**.
6. **TAKE** YOUR **BASEBALL GLOVE** TO THE **GAME**.
7. **CLEAN** THE **GUEST BEDROOM** BEFORE NEXT **WEEKEND**.
8. HE IS A **COWBOY**.
9. THE **BOY** IS **GREEK**.
10. WOULD YOU **LIKE** A **GREEN SALAD**?
11. BE **CAREFUL DRIVING** ON THE **BRIDGE**.
12. SHE **PLAYS SOFTBALL** WITH HER **FRIENDS** ON **SUNDAYS**.
13. WHAT DO YOU **WANT** FOR **LUNCH**?
14. THE **BOOK** IS **OVER THERE**.
15. THE **COWBOY** IS ON HIS **HORSE**.
16. **TELL** ME A **TRUE STORY**.
17. MY **SISTER** HAS A **NEW BOYFRIEND**.