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The benefits of clear speech at normal rates for older adults with normal hearing

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The Benefits of Clear Speech at Normal Rates

for Older Listeners With Normal Hearing

by

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ABSTRACT

Clear speech is a type of speaking style that improves speech intelligibility for many individuals. For example, one study showed a 17 percentage point increase in intelligibility over conversational speech for individuals with sensorineural hearing loss (Picheny et al., 1985). The clear speech benefit also extends to children with learning disabilities (Bradlow et al., 2003), non-native listeners (Bradlow & Bent, 2002), and other populations. Although clear speech is typically slower than conversational speech, it can be produced, naturally, at normal rates with training. For young listeners with normal hearing, clear speech at normal rates (clear/normal) is more intelligible than conversational speech (conv/normal) and is almost as beneficial as clear speech at slow rates (clear/slow) (Krause & Braida, 2002). However, a preliminary study by Krause (2001), found that clear/normal speech may benefit some older listeners with hearing loss but not others, suggesting that age may be a factor in the clear speech benefit at normal rates. It is evident, though, that clear speech at slow rates benefits this population (Picheny et al., 1985; Payton et al., 1994; Schum, 1996; Helfer, 1998). Therefore, the purpose of the study was to examine older listeners with normal hearing to determine how speech intelligibility, measured by % correct keyword scores, varies with speaking mode, speaking rate, talker and listener. Results were then compared to previously collected data from younger listeners with normal hearing (Krause & Braida, 2002) in order to isolate the effect of age on the size of clear speech benefit at slow and normal speaking rates.

Eight adults (ages 55-68) with normal hearing participated in speech intelligibility tests. Each listener was presented with the speech of 4 talkers in 4 speaking styles: conv/normal, clear/normal, conv/slow and clear/slow, drawn from recordings made for an earlier study (Krause & Braida, 2002). Stimuli were nonsense sentences presented monoaurally with speech-shaped noise in the background.

Results showed that clear/slow and conv/slow were the most intelligible speaking conditions. However, clear/normal was also more intelligible than conv/normal, demonstrating that a talker does not need to decrease rate to improve intelligibility for listeners with normal hearing, regardless of age.

More studies are needed to investigate any similarities between conv/slow and clear/slow, since performance by older listeners was highest in these two conditions. Signal-to-noise ratio (SNR) also needs to be controlled in future studies to further characterize the effect of age on clear speech benefits at slow and normal speaking rates.

Chapter 1

Introduction

Clear speech is a type of speaking style used to facilitate conversations in difficult communication settings. It is typically slower than conversational speech and more intelligible. Studies have shown that clear speech is more intelligible than conversational speech for different types of listeners in various listening conditions, such as noise and reverberation. Picheny, Durlach, and Braida (1985) conducted one of the first studies to assess any benefits of clear speech for a group of individuals with sensorineural hearing loss (SNHL). Clear speech had a 17 percentage point increase in intelligibility over conversational speech. Other populations that benefited from clear speech included young listeners with normal hearing (Uchanski, Choi, Braida, Reed, & Durlach, 1996), individuals who were older with hearing loss (Picheny et al., 1985), children with language learning disabilities (LLD) (Bradlow, Kraus, & Hayes, 2003), and non-native listeners (Bradlow & Bent 2002). Although a number of studies have investigated benefits of clear speech use for older listeners with hearing loss and younger listeners with normal hearing in difficult listening situations (e.g., Payton et al., 1994; Krause & Braida, 2002; Ferguson & Port, 2002), few studies have included older listeners with normal hearing (e.g., Helfer, 1998). In addition, very few studies have controlled speaking rate when examining the clear speech effect (e.g., Krause & Braida, 2002). Therefore, the purpose of this study was to determine the benefits of clear speech at normal rates for older adults with normal hearing. In particular, variables such as mode, rate, listener and talker were examined to determine their effect, if any, on speech intelligibility for older adults with normal hearing.

Although it is typically slower, clear speech can be produced at normal rates with training (Krause & Braida, 2002). This form of clear speech is known as clear/normal speech. The investigation of clear/normal speech is important for several reasons. As mentioned, clear/slow speech benefits many populations. Therefore, it is important to determine whether clear/normal speech can be as beneficial to these populations as clear/slow speech. In addition, investigating the acoustic properties of clear speech continues to provide further understanding of the science behind the way speech is produced. For example, it has been shown in conversational speech many sounds are missing or dropped due to assimilation. The sounds in clear speech, on the other hand, are full, accurate and precise in production (Schum, 1996).

Increased understanding of clear speech, particularly clear/normal speech, may also help improve the function of hearing aids. For instance, if conversational speech can be processed by the aid and altered to clear speech, then this could help a person with hearing loss in communication settings. However, if this processing slowed down the speech, the person with hearing loss could fall behind in a conversation. If clear speech could be produced at normal rates by a hearing aid, this problem would be eliminated and the person with hearing loss would benefit.

Furthermore, it is beneficial to use clear speech in a clinical setting with all clients. This will maximize understanding and eliminate unnecessary repetition. If clear speech is not used, some clients may feel awkward in asking for repetition, resulting in poor communication. As mentioned, clear speech is naturally slower. When applying clear speech to a clinical setting, slowing speech rate may also slow down the pace of the session. If clear speech can be produced at normal rates and still be intelligible, then the session's time would not be compromised and the client could benefit from additional time spent on therapy.

Chapter 2

Background

Clear speech has many acoustic properties that differ from conversational speech. For example, Picheny, Durlach, and Braida (1986) noted changes in vowel formants and an increase in voice onset time of unvoiced plosives when clear speech was produced. Although there are many acoustic differences between the two speaking styles, researchers focused more on speech rate, because it was the most observable acoustic difference between conversational and clear speech. When clear speech is produced, the talker naturally slows down his or her rate. The average speaking rate for conversational and clear speech at a normal rate is between 160-200 words per minute (wpm). For clear speech at slow rates, the speaking rate typically decreases by an average of 50-100 wpm (Picheny et al., 1986). Picheny et al. (1986) determined that the rate of clear speech is reduced by inserting and lengthening pauses as well as increasing duration of speech sounds. Although clear speech is typically slower, talkers can produce clear speech at normal rates with training (Krause & Braida, 2002). Whether or not clear speech at normal rates is as beneficial to different populations and environments as clear speech at slow rates should be investigated.

Role of Rate

Artificially Produced Clear Speech at Normal and Fast Rates

Much early work in clear speech focused on whether a slower rate was the main acoustic factor responsible for increasing speech intelligibility. Attempts were made to produce clear speech, artificially, without slowing down the rate. However, these attempts were unsuccessful. In one study, the rate of clear speech was altered to a conversational (i.e. normal) rate and the rate of conversational speech was altered to a clear (i.e. slow) rate, and then back to their original rates (Picheny, Durlach, & Braida, 1989). After processing, intelligibility scores decreased in both cases. After restoring the processed material back to their original rates, the intelligibility scores were not brought back up to their unprocessed levels in either case, but were both within an average of 8 percentage points of the original score. The authors concluded that intelligibility of conversational speech could not be increased simply by uniformly adjusting the duration of speech to achieve a slower speaking rate.

Another study also experimented with speech rate. Speech rates were adjusted by non-uniform time scaling, pauses, and fast clear speech (Uchanski et al., 1996). Time scaling was achieved by measuring the duration of the same phonemes in clear and conversational production of a given sentence. For example, the duration of individual phonemes was measured in both speaking styles. The difference in measurement for each phoneme was then used to decrease the duration of that phoneme in clear speech, resulting in a normal rate production of that phoneme, or to increase the duration of that phoneme in conversational speech, resulting in a slow rate production of that phoneme. Time scaling of all phonemes decreased speech intelligibility scores by 5 percentage points for conversational speech slowed to clear rates and decreased by 24 percentage points for clear speech sped to conversational rates. When keywords were excised from their sentences, scores were slightly lower than when in their sentence contexts (Uchanski et al., 1996). Uchanski et al. (1996) also studied the role of pauses, which are more and longer in clear speech. Pauses were defined as silent intervals longer than 10 ms between words, excluding periods of silence due to plosives (Picheny et al., 1986). Uchanski et al. (1996) found that adding pauses to conversational speech as well as deleting pauses from clear speech decreased speech intelligibility. Clear speech was also attempted naturally at different rates. For example, a professional fast talker was instructed to produce clear speech at rates close to 170, 200 and 400 words per minute (wpm). The goal was to improve or maintain speech intelligibility without altering rate; however, intelligibility scores were negatively correlated with speaking rate. In other words, the higher the speech rate, in clear or conversational modes, the lower the intelligibility scores (Uchanski et al., 1996).

Naturally produced clear speech at normal rates

Because attempts to artificially speed clear speech had failed, Krause and Braida (2002) explored speaking modes that talkers could produce naturally instead of using artificial enhancement. Listeners with normal hearing were used to determine if alternative forms of clear speech exist naturally at normal speaking rates. The talkers in the study underwent intensive training and then were recorded in various modes and rates. Modes used were clear speech or conversational (conv) speech. Rates included slow and normal as well as other rates that will not be discussed here. The modes and rates tested were combined to make the following conditions: clear/slow, clear/normal, conv/slow and conv/normal. Results of the study indicated that after training, perception of clear speech at a normal rate was 14 percentage points higher than perception of conversational speech at normal rate and just 4 percentage points lower than clear/slow speech. This signified that it is possible to produce clear speech without altering speech rate. Krause's other work was also able to replicate (verify) the benefits of naturally produced clear speech at normal rates. For normal hearing listeners, there was a 16 percentage point increase in scores with clear/normal over conv/normal (Krause, 2001).

Acoustic Properties of Clear Speech

It is unclear which acoustic characteristics are responsible for increased speech intelligibility in clear speech, indicating the need for further studies. Acoustic characteristics are not likely to contribute equally to the intelligibility advantage of clear speech (Krause & Braida, 2004). Krause and Braida (2004) noted that it is possible that some characteristics do not contribute at all to increased intelligibility while other important factors may not have been identified based on type of measurements used in each study. Since clear speech is advantageous, it is important to determine what aspects of clear speech make it more intelligible than conversational speech. To begin this process, the acoustic properties of clear and conversational speech must be compared (Picheny et al., 1986).

Properties of clear speech at slow rates

In an investigation of the acoustic differences between conv/normal and clear/slow speech, Picheny et al. (1986) found that clear speech had a greater number and longer duration of pauses, and length of words. There were no differences in long term RMS spectra or formant frequencies. Vowel modification, when vowels become more schwa-like, occurred more in conversational speech than clear speech. Burst elimination, when the stop burst is deleted, occurred mostly in conversational speech. Sound insertion occurred almost always in clear speech. In addition, talkers tended to increase level of consonants when speaking clearly. Although consonant-vowel (CV) ratio, or the ratio of energy in a consonant relative to the neighboring vowel, was not explicitly measured in this study, this change likely resulted in an increased CV ratio for clear speech.

Another property of clear/slow speech relates to the listener's perception that continuous speech is broken up into separate words. Therefore, word boundaries were examined in other investigations of the acoustic characteristics of clear speech. These studies reported that speakers attempt to mark word boundaries in clear speech, but not in conversational speech (Cutler & Butterfield, 1990). For example, the speakers would stress words boundaries before weak syllables, because they are hard to perceive in difficult listening conditions. In another study by these two researchers, it was shown that the duration, fundamental frequency (F0) levels, and intensity of weak syllables were lengthened as well (Cutler & Butterfield, 1991).

Properties of clear speech at normal rates

Further investigation to identify acoustic properties found in clear/normal speech was also made by Krause (2004) who found several differences between clear and conversational speech at normal rates. First, there was an increase in the fundamental frequency (F0) average and range for clear/normal speech. This is relevant because females have higher F0 average and range than males and are generally more intelligible than males, therefore an increase in F0 average and range may play a role in speech intelligibility. Second, more intensity was noted in formant frequencies in clear speech at normal rates, not found in conversational speech. For example, in clear/normal speech there was an increase in level in the second and third formants of vowels. Krause also identified differences in temporal envelope modulations between clear/normal and conv/normal speech that could have possible importance in cueing manner and voicing.

She used signal transformations that altered these three properties (fundamental frequency, formant intensity, and temporal envelope modulations) and created processing schemes in her study, to determine what properties enhance speech intelligibility. In Process A, vowel formant energy was increased by raising formant amplitudes; in Process B, the fundamental frequency (F0) was modified to increase the average and expand the range of F0 values; and in Process C, low frequency modulations of the intensity envelopes were enhanced in several octave bands (Krause, 2001). None of these processing schemes resulted in intelligibility improvements that could account for a substantial portion of the intelligibility benefit observed for clear/normal speech, suggesting that additional properties associated with the increased intelligibility of clear/normal speech have yet to be identified.

Finally, Krause (2001) noted that talkers may have different strategies for producing clear/normal speech because each talker appeared to select only a few characteristics from the many that exist. This may occur because there are many characteristics used to produce clear/slow speech but the talker cannot retain all them at normal speaking rates when producing clear/normal speech. Therefore, variation in speech intelligibility of talkers may be due to the many different characteristics that were chosen.

Clear Speech and its Relevance

Clear speech is relevant for many populations and in various communication settings. When clear, accurate speech is produced, it can benefit a listener, especially with hearing loss, in different communication environments (Schum, 1997). In conversational speech, sounds are mixed together or dropped from the words. These traits of conversational speech may result in a communication breakdown, especially in a difficult environment.

Clear speech and environments

The benefits of clear speech extend to different types of environments. For example, when noise is added, clear speech is more intelligible than conversational speech (Payton, Uchanski, & Braida, 1994). Payton et al. (1994) conducted a study to determine if listeners with normal hearing and listeners with hearing loss would benefit from clear speech in various acoustic environments. These acoustic environments had different levels of noise (signal-to-noise ratios of 0.0 dB, 5.3 dB, and 9.5 dB) and reverberation. For example, the "anechoic" environment (ANEC) had no reverberation. Environments "living room" (LIVR), and "conference room" (CONF) had reverberation times of 0.18s and 0.60s, respectively. Results indicated that clear speech was more intelligible than conversational speech for younger listeners with normal hearing and older listeners with hearing loss in all degraded listening conditions (noise, reverberation and hearing loss).

Clear/slow speech is beneficial in various environments; however, the benefit of clear/normal varies based on talker and type of environment (Krause & Braida, 2003). In Krause and Braida's study (2003), clear/slow was beneficial in all environments (hi/low pass filters, reverberation, and non-native listeners). The benefit of clear/normal varied across the five talkers, labeled T1-T5. For example, T5's clear/normal speech improved speech intelligibility in three of the environments, whereas T4's clear/normal speech improved speech intelligibility in only one environment. The variation across talkers is possibly due to the strategies each talker used to produce clear/normal speech and frequency ranges in the hi/low pass filters.

Populations and clear/slow speech

Those with hearing loss are just one group of individuals that benefit from clear/slow speech. The advantage of clear speech applies to other populations as well. For example, clear speech benefits children with diagnosed learning disabilities (LD), such that performance, measured by key words correct, increases when clear speech is produced (Bradlow et al., 2003). The percent correct scores were converted to rationalized arcsine transformation units (rau) to facilitate statistical analysis (Studebaker, 1985). For children with LD, the clear speech effect was greater when the signal-to-noise ratio (SNR) was lower (10.06 rau) and when a female talker presented the stimuli (11.99 rau). Non-native listeners also benefit from clear speech (Bradlow & Bent, 2002). The mean difference between clear and conversational speech for non-native listeners was 11.11 rau.

Another population that benefits from clear/slow speech is young adults with normal hearing and vision. For example, young listeners with normal hearing benefited from clear speech in every mode in a study that measured speech intelligibility of syllables in auditory only (A), visual only (V), and audiovisual (AV) presentation conditions (Gagne, Rochette, & Charest, 2002). These modes were included in the study because according to Gagne et al. (2002), speech perception is a multimodal phenomenon. Furthermore, listeners with a wide range of hearing loss who have speechreading abilities also benefit from clear speech (Helfer, 1998) such that speech intelligibility scores increased when clear speech was produced. It was also noted that words presented with auditory-visual (AV) cues were easier to understand than those presented in the auditory (A) only mode, which was expected (Helfer, 1998).

Finally, many studies show the benefits of clear speech for those with hearing loss. In an article summarizing such studies, Schum (1997) states that clear speech benefits those with hearing loss, whether they are wearing hearing aids or cochlear implants. Clear speech is a technique that Schum recommends for family and friends of those who can benefit from it.

Populations and clear/normal speech

As mentioned earlier, recent research has focused on whether clear/normal speech has similar benefits as clear/slow speech does for various populations. For example, Krause (2001) investigated if the intelligibility benefit of clear/normal speech reported for young listeners with normal hearing can be extended to populations with hearing loss. She found that young listeners with normal hearing benefited from clear/normal speech, but the older listeners with hearing loss did not. For the young listeners with normal hearing (age range 16-43 years) there was a 16 percentage point increase in scores for clear/normal over conv/normal. The older listeners with hearing loss (age range 40-65 years) had a slight increase in scores but not enough to be statistically significant. The outcome of this study prompted a question of whether age is a factor in the clear speech benefit.

Aging and Speech Intelligibility

When studies include participants who are both older and have hearing loss, the question arises of whether age alone is a factor that affects speech intelligibility and the benefits of clear speech, particularly since some aspects of hearing are known to deteriorate with age (Gordon-Salant & Fitzgibbons, 1999). For example, it has been suggested that cognitive factors affect older listeners' speech intelligibility regardless of hearing status. When young and older listeners with normal hearing and young and older listeners with hearing loss were compared on speech intelligibility, the results showed that although listeners with hearing loss performed more poorly than listeners with normal hearing in most conditions (Gordon-Salant & Fitzgibbons, 1997), the listeners who were older, in general, performed poorer than the listeners who were younger, regardless of hearing status. For example, the listeners who were older did poorer on longer test items than shorter ones. This indicates that cognitive factors, such as memory are significant, and may affect the performance of listeners who are older.

In another study, listeners who were older again performed more poorly than the listeners who were younger in all noise conditions (Gordon-Salant & Fitzgibbons, 1999). Listeners with hearing loss performed more poorly than those with normal hearing. Time compressed speech was difficult for older persons to recognize, probably due to deterioration of central timing mechanisms, which may be a possible reason for the decline in speech perception (Gordon-Salant & Fitzgibbons, 1999).

Age and hearing status are significant in word recognition (Dubno, Dirks, & Morgan, 1984). In this study, the speech level required for each listener to attain 50% word recognition in quiet and noisy environments was investigated. Sentences were taken from the Speech Perception in Noise (SPIN) test. Young listeners with normal hearing and hearing loss, and older listeners with normal hearing and hearing loss participated in the study. Hearing level, but not age was significant under quiet conditions. All listeners with hearing loss had higher thresholds (16 dB) than all the listeners with normal hearing in order to attain 50% word recognition. An even higher threshold (22 dB) was needed for keywords in low predictability sentences. In noisy conditions, the main effect of age, as well as the effect of hearing level, was significant. That is, listeners who were older, regardless of hearing status, needed an increase in signal-to-babble ratio in dB (S/B) as the materials increased in difficulty.

Spectral and temporal dips are also important in speech intelligibility when background sounds are present (Peters, Moore, & Baer, 1998). In the background with both dips present, the older listeners, with normal hearing and hearing loss, did worse than the younger listeners. The older listeners with hearing loss needed the speech level 19 dB higher than the younger listeners with hearing loss, indicating a strong correlation between speech recognition thresholds (SRTs) in background sound with spectral and temporal dips and age.

Aging and Clear Speech

Sentence intelligibility in clear/slow speech

As mentioned earlier, it is evident that older listeners, particularly those with hearing impairment, do benefit from clear/slow speech. First, Picheny et al. (1985) found that the benefit of clear/slow speech for older listeners with hearing loss over conversational speech was 17 percentage points. There was also a 26 percentage point increase over conversational speech for older listeners (ages 50-59 years) with hearing loss in Payton et al.'s study (1994).

Since aging affects speech intelligibility, researchers have begun to study the benefits of clear speech and aging. In one study, young and elderly talkers were not much different in producing clear speech (Schum, 1996). Of 60 older listeners with hearing loss in the study, three were randomly assigned to each one of the 20 talkers (10 young, 10 elderly). Both the young and the elderly talkers were intelligible to the older listeners with hearing loss. On average, the older listeners (ages 60-77 years) received a 16.9 rau benefit when the talkers used clear/slow speech compared to conversational speech (Schum, 1996).

Moreover, studies have shown that as a person ages, speech perception decreases, regardless of hearing status, but more so when hearing loss is present (Helfer, 1998; Dubno et al., 1984). Age is significantly and negatively correlated with the perception of conversational speech (Helfer, 1998). In other words, as age increases, conversational speech perception in audio-visual (AV) mode decreases. Yet Helfer also found that as age increases, so does the benefit of clear/slow speech, in the AV mode.

Vowel intelligibility in clear/slow speech

A further study involving age and clear/slow speech investigated differences in vowel intelligibility between young listeners with normal hearing and older listeners with hearing loss (Ferguson & Port, 2002). The results indicated that the young, normal hearing listeners had a 15 percentage point increase in scores with clear speech. There was no significant difference in scores between clear and conversational modes for the older listeners with hearing loss.

Sentence intelligibility in clear/normal speech

As stated previously, clear speech at normal rates is beneficial for listeners with normal hearing (Krause & Braida, 2002). However, older listeners with hearing loss did not benefit significantly in noise when compared to the normal hearing listeners (Krause, 2001). The older listeners' ages ranged from 43-65 years in Krause's study. Possible reasons for the results could be age, configuration of hearing loss, or the limited number of participants in the study.

Summary

In sum, it is evident that clear speech is beneficial for many populations in various environments. Clear speech can also be produced without slowing down speaking rate. However, older listeners with hearing loss may not benefit as much from clear/normal as clear/slow speech. The main question then, is whether hearing status affects speech intelligibility or does age also play a role. Therefore, the purpose of this study was to examine how speech intelligibility, measured by % correct keyword scores for eight listeners (55-68 years of age), varies with:

a) speaking mode: clear or conversational
b) speaking rate: slow or normal
c) talker: four talkers that were pre-recorded to present to each listener
d) listener: individual factors that may influence each older listener's performance

To examine the role of age, the results for older listeners in the present study were then compared to the results for younger listeners in previous studies. Specifically, the data obtained were compared to data obtained with the same stimuli and conditions from eight young listeners (18-29 years of age) by Krause and Braida (2002).

Chapter 3

Methods

Participants

For the purpose of this study, eight normal hearing listeners, ages 55-75, were recruited from the Tampa, Florida area. Each listener was a native English speaker with a high school diploma or its equivalent. In order to be included in this study, the subjects were required to pass audiological and cognitive screenings. First, the audiological screening was administered. Hearing was considered normal if thresholds were 25 dB HL or better at 250, 500, 1000, 2000 and 4000 Hz and 35 dB HL or better at 6000 and 8000 Hz. Normal hearing was required in at least one ear. The mild hearing loss at the higher frequencies was considered acceptable since there is a change in hearing thresholds with age, and these thresholds are typical for persons in this age range (Brant & Fozard, 1990). Next, the Mini Mental State Exam (MMSE) (Folstein, Folstein, & McHugh, 1975) was administered to determine cognitive abilities. A score of 22 or better out of 30 possible points was considered normal.

Twenty interested individuals were screened before the eight participants were acquired. All potential participants passed the MMSE. The most common reason for exclusion was high frequency hearing loss, which is typical in this age group (Brant & Fozard, 1990). The first eight participants to complete and pass the screenings were included in the study. The eight participants included three males and five females and had an age range of 55-68. Detailed demographics and MMSE scores of individual participants can be found in Table A1 in Appendix A. As shown in Table A2 in Appendix A, three of these participants passed the audiological screening with normal hearing in both ears, while five of these participants passed the audiological screening with normal hearing in only one ear. Since stimuli were presented monaurally, normal hearing in one ear was sufficient for the study.

Materials

The Salthouse (1991) materials were used to assess cognitive processing speed of participants. The materials included a letter comparison task and a pattern comparison task. The letter comparison task consisted of 21 pairs, and the pattern comparison task consisted of 30 pairs. In both processing tasks, the participants were to look at a set of patterns or letters and decide if they were the same or different. The participants were to complete as many pairs as possible in 30 seconds, but to also work as accurately as possible. They were scored based on how many of the patterns completed were correct. The resulting scores were used to see if there was any correlation between cognitive processing scores and performance in the study.

Stimuli for the speech intelligibility experiment were drawn from a database collected for an earlier study on clear speech at normal rates (Krause & Braida, 2002). The sentences in the database were nonsense sentences. In other words, the sentences had no semantic meaning; however, they were syntactically correct. An example sentence is “The right cane could guard an edge.” Nonsense sentences were used in order to avoid any guessing by the listeners using semantic context cues. The sentences in the database were produced by five different talkers (T1, T2, T3, T4 and T5). T1, T3, T4 and T5 were selected because they improved speech intelligibility with clear speech without altering speech rate. T2 did not present similar results as the other talkers, and therefore was excluded. A description of the talkers, from Krause and Braida's study (2002) is summarized in Table 1. The talkers were from the Boston area and had experience in public speaking.

Table 1

Description of Talkers

Talker	Sex	Speaking Experience	Years
T1	Female	College television, radio, public speaking	5
T3	Female	Broadcasting student	2
T4	Female	Debate team	6
T5	Male	Debate team	7

As shown in Table 2, eight unique lists of 50 sentences were selected from the database. Each list was recorded twice by one of the talkers, once in conversational mode and once in clear mode at a particular rate. Specifically, each talker recorded one list in both conversational mode and clear mode at normal rates and one list in both conversational mode and clear mode at slow rates. Combining the two rates and two modes resulted in four conditions per talker: conv/normal, conv/slow, clear/normal, and clear/slow, as shown in Table 2. The listeners were then tested on these lists of 50 nonsense sentences. In the end there were four talkers, two lists per talker, and two conditions per list. Each list contained 50 sentences, resulting in 800 stimuli per listener.

Table 2

Sentence Lists per Talker and Condition

Talker	List	Conditions	
T1	List 1	Conv/normal	Clear/normal
	List 2	Conv /slow	Clear/slow
T3	List 3	Conv /normal	Clear/normal
	List 4	Conv /slow	Clear/slow
T4	List 5	Conv /normal	Clear/normal
	List 6	Conv /slow	Clear/slow
T5	List 7	Conv /normal	Clear/normal
	List 8	Conv /slow	Clear/slow

Speech shaped noise (noise with same long-term frequency characteristics as typical speech) was added to the background. The signal-to-noise ratio (SNR) was 0dB, meaning there was an equal balance in level between noise and signal output.

Procedures

First, cognitive processing speed of participants was assessed by administering the two Salthouse tasks, letter comparison and pattern comparison. Each participant was instructed to look at pairs of letter strings or patterns and determine if the items in the pair were the same or different. Before each task, the participant was given three trials as practice. After the practice trials, the participant was given 30 seconds to complete the given task. The participant was timed with a stopwatch and after 30 seconds the participant was instructed to stop. The participants were scored based on what percent of the pairs completed were correct. The results were used later in the study to examine the relationship between cognitive processing speed and performance on the speech intelligibility tasks.

Each listener then participated in the speech intelligibility experiment for a minimum of four sessions for 2-3 hours each session. Listeners were tested individually and attended sessions no more than once a week. Some participants attended weekly sessions while other participants required longer breaks between sessions due to vacation plans or other scheduled events. When half the lists had been presented to a listener, he or she was given an additional weeklong break. The purpose of the break was to allow time to rest as well as avoid improved performance due to sentence repetition. In other words, since each talker recorded each list in two conditions, the break would allow time to reduce the chances of the listener remembering words from the nonsense sentences. Table 3 shows how and when the stimuli were presented. For example, the conditions per list that listeners 1-4 heard in weeks 1 and 2 were not heard by listeners 5-8 until weeks 4 and 5. The conditions per list that listeners 5-8 heard in weeks 1 and 2 were not heard by listeners 1-4 until weeks 4 and 5. The purpose of counterbalancing the stimuli in this manner was to average out variance in listener performance due to any potential learning effects that might have remained even after the weeklong break.

Table 3

Presentation Order of Stimuli for Listeners

WEEK	LISTENERS 1-4	LISTENERS 5-8
1	T1 List 1-conv/normal T1 List 2-clear/slow T4 List 5-clear/normal T4 List 6-conv/slow	T1 List 1-clear/normal T1 List 2-conv/slow T4 List 5-conv/normal T4 List 6-clear/slow
2	T3 List 3-clear/normal T3 List 4-conv/slow T5 List 7-conv/normal T5 List 8-clear-slow	T3 List 3-conv/normal T3 List 4-clear/slow T5 List 7-clear/normal T5 List 8-conv/slow
3	BREAK	BREAK
4	T1 List 1-clear/normal T1 List 2-conv/slow T4 List 5-conv/normal T4 List 6-clear/slow	T1 List 1-conv/normal T1 List 2-clear/slow T4 List 5-clear/normal T4 List 6-conv/slow
5	T3 List 3-conv/normal T3 List 4-clear/slow T5 List 7-clear/normal T5 List 8-conv/slow	T3 List 3-clear/normal T3 List 4-conv/slow T5 List 7-conv/normal T5 List 8-clear-slow

The sentences for the speech intelligibility experiment were presented monaurally over headphones connected to a computer and played from software called Matlab. The participants who passed the screening in only one ear were restricted to that ear throughout the experiment. The participants with bilateral normal hearing were permitted to alternate ears but only between sentence lists.

Prior to the start of data collection, the listener was familiarized with the computer equipment that was used in the study. On the first day, participants were given a practice list of 50 different sentences than those used for data collection to accommodate to the SNR. They were instructed to do as many practice sentences as necessary before beginning the real sentence lists. On the participants' first days, the range of practice materials used was 10-30 sentences. For subsequent sessions, continuing with the remaining practice materials was an option. Two listeners, L6 and L8, did not utilize the practice sentence list again after the first session. The remainder of the listeners practiced at least one more time in subsequent sessions. For example, L1-L5 completed between 5 and 10 practice items in their second sessions and then did not request the practice list again. L7 used the practice list the most. She completed all 50 practice items in the first three sessions.

The Matlab software provided the listener with control over the presentation of the stimuli. For instance, when ready to hear a sentence, the listener clicked on the "play" button using the mouse. Sentences could not be repeated; however, the listener did not listen to the next sentence until ready. Listeners were encouraged to take breaks as often as needed. The listeners usually took short, stretching breaks between sentence lists and a longer break during the midpoint of the session. The stimuli were presented over headphones at a sound level of approximately 82 dB SPL. None of the participants complained of the sound level, indicating that it was within a comfortable range.

The listener listened to sentences played from the Matlab software and responded by writing the sentence that he or she perceived on the answer sheet provided. Responses were scored based on the percentage of key words correctly identified by each listener and followed the same scoring system as Picheny et al. (1985). Keywords correct included nouns, verbs and adjectives. Errors such as inserting, omitting, or misidentifying a single phoneme in the word, were counted as incorrect. Errors such as inserting or omitting a plural or past tense suffix were counted correct.

Chapter 4

Results

The purpose of this study was to investigate how speech intelligibility, measured by percent key words correct varied with speaking mode, speaking rate, talker and listener for older listeners with normal hearing. This study is considered a parametric experiment consisting of ratio data. In a parametric experiment, independent variables (mode, rate, talker and listener) can be simultaneously examined for main effect and interactions with the dependent variable (% keywords correct). Results were analyzed in three ways. First, key word scores for each condition were tabulated in an Excel Spreadsheet. Second, data were graphed for visual analysis. Finally, a four-way analysis of variance (ANOVA) was used to test significance of the results. Inferential statistics were used because conclusions were drawn from the results obtained.

Key word scores for each listener are listed in Appendix B. These results are summarized in Table 4 which shows results for each talker, averaged across the listeners. For example, the average listener performance, in percent key words correct, for T1, in the conv/normal condition is 43%. The average listener performance for all talkers in the conv/normal condition is 45%. Standard deviations and standard errors for each condition are also included.

Table 4

Average Speech Intelligibility per Talker in Each Condition

Talker	conv/normal	conv/slow	clear/normal	clear/slow
T1	43%	72%	52%	71%
T3	28%	66%	51%	45%
T4	49%	58%	55%	74%
T5	61%	69%	77%	84%
AVG	45%	66%	59%	68%
SD	13.5%	6.2%	12.5%	16.6%
STD ERR	5%	2%	4%	6%

In analyzing the results, conv/normal should be viewed as the baseline condition. When comparing the other three conditions to conv/normal, it can be seen that clear/slow and conv/slow provided the most intelligibility benefit overall. In the clear/slow condition, the average key words correct was 68%, a 23 percentage point increase over conv/normal. The conv/slow condition was also more intelligible than conv/normal by 21 percentage points, with an average of 66% correct key words. Clear/normal speech also provided a benefit; the average percent key words correct across listeners and talkers was 59% for clear/normal, a 14 percentage point increase over conv/normal. These results suggest that the talker does not have to decrease rate in order to increase speech intelligibility.

A four-way repeated measures analysis of variance (ANOVA), with three within-subjects factors (rate, mode and talker) and one between-subjects factor (listener) was performed on key-word scores, after an arcsine transformation ($\sqrt{I_j}/100$) to equalize the variances. F-ratios and significance levels for those effects and interactions that are significant ($p<0.01$) are listed in Table 5. A complete listing of these values for all effects and interactions, including those that were not significant, can be found in Table C1 in Appendix C. As shown in Table 5, all main effects and several interactions were significant at $p<0.01$.

Table 5

Significant Effects and Interactions at the 0.01 level

Effect	F	Hypothesis df	Error df	Sig.	Eta-Squared
mode	202.101	1	32	.000	5.11
rate	826.128	1	32	.000	17.78
talker	218.390	3	30	.000	24.36
listener	54.667	7	32	.000	13.29
rate x mode	61.931	1	32	.000	2.24
rate x talker	20.905	3	30	.000	2.32
mode x talker	57.464	3	30	.000	3.07
rate x mode x talker	64.698	3	30	.000	7.83
rate x mode x talker x listener	2.770	21	96	.000	2.49

In addition, post-hoc t-tests were performed to determine significant differences for all pairwise comparisons of conditions (modes and rates). A Bonferroni adjustment for multiple comparisons was implemented in the t-test results. Results are listed in

Table 6. Differences between each pair of conditions were statistically significant except for the difference between conv/slow and clear/slow.

Table 6

Pairwise Comparisons of Modes and Rates

(I) cond	(J) cond	Mean Diff. (I-J)	Std. Error	Sig.[a]	99% Confidence Interval Lower Bound Difference	99% Confidence Interval Upper Bound Difference
conv/slow	clear/slow	-.030	.010	.027	-.064	.004
	conv/normal	.225*	.010	.000	.190	.260
	clear/normal	.077*	.009	.000	.047	.107
clear/slow	conv/slow	.030	.010	.027	-.004	.064
	conv/normal	.255*	.008	.000	.227	.284
	clear/normal	.107*	.009	.000	.078	.137
conv/normal	conv/slow	-.225*	.010	.000	-.260	-.190
	clear/slow	-.255*	.008	.000	-.284	-.227
	clear/normal	-.148*	.010	.000	-.181	-.115
clear/normal	conv/slow	-.077*	.009	.000	-.107	-.047
	clear/slow	-.107*	.009	.000	-.137	-.078
	conv/normal	.148*	.010	.000	.115	.181

* = significant at the 0.01 level

Effect of Mode

The ANOVA indicated that the main effect of mode was statistically significant. In other words, clear speech was more intelligible overall than conversational speech. On average, key word scores for clear speech were 64% and key word scores for conversational speech were 56%.

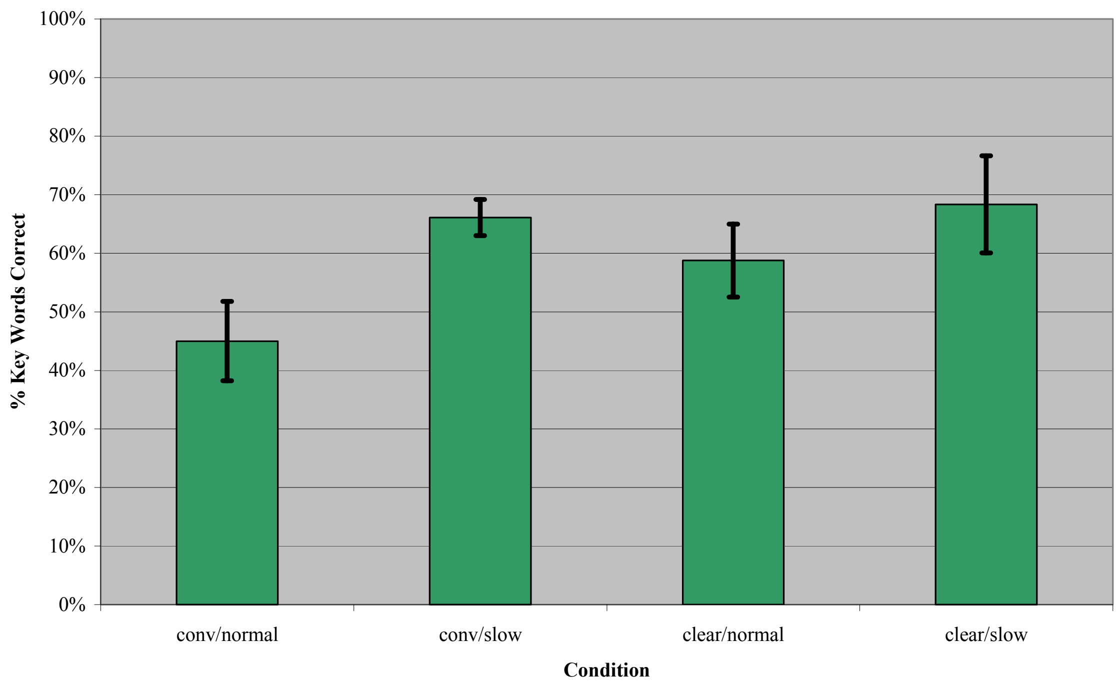
To examine the effect of the mode x rate interaction, which was also statistically significant, the overall average across talker and listener for each condition is presented in Figure 1. This figure allows comparisons of the effect of mode within rates. At normal rates, conv/normal can be viewed as the baseline condition. The average percent key words correct across listeners and talkers was 45% for conv/normal. In the clear/normal condition, average percent key words correct across listeners and talkers was 59%, a 14 percentage point increase over conv/normal. The post-hoc pairwise comparison, listed in Table 6, verifies that the difference between these conditions was significant ($p<0.01$). In other words, clear/normal speech provided a statistically significant benefit over conv/normal speech. This significance verifies that the talker does not have to decrease rate in order to increase speech intelligibility.

As mentioned earlier, clear/slow and conv/slow were the most intelligible speaking conditions overall. To examine the effect of mode at slow rates, conv/slow can be viewed as the baseline condition. Average speech intelligibility, based on key words correct, for conv/slow was 66%. In the clear/slow condition, speech intelligibility increased by only 2 percentage points. Pairwise comparison indicated no significant difference between these two conditions, as seen in Table 6. Taken together, the effect of mode at slow rates and normal rates explains why the mode x rate interaction was found to be significant in the ANOVA. In other words, at normal rates, mode made a difference in speech intelligibility; however, at slow rates there was no significant difference, indicating that the size of clear speech benefit varies at different speaking rates.

In the present study, the average performance in the conv/slow condition proved to be higher than expected for the older normal hearing listeners. Surprisingly, conv/slow was just as intelligible as clear/slow, which is different than previous research findings for younger normal hearing listeners: Krause and Braida (2002) found a 12 percentage point benefit for clear/slow relative to conv/slow for such listeners. Although this difference with previous studies for the conv/slow condition is not yet fully understood, it should be noted that the average benefit of the clear/slow condition was consistent with Krause and Braida (2002) and other previous studies. The benefit of clear/slow compared to conv/normal in this study, which provided a 23 point statistically significant ($p < 0.01$, see Table 6) improvement in intelligibility, was similar to the benefit reported in previous studies where rate was not a controlled factor (e.g., Picheny et al., 1985).

Figure 1

Average intelligibility, in percent key words correct, for each condition. Performance averaged across talker and listener (Grand Average). Error bars indicate +/- 1 standard error above and below the mean.



Effect of Rate

The ANOVA indicated that the main effect of rate was statistically significant. This means that speech produced at slow rates was more intelligible overall than speech produced at normal rates. Clear/slow and conv/slow speech was more intelligible than clear/normal and conv/normal speech, respectively. On average key word scores for speech produced at slow rates were 67% and key word scores for speech produced at normal rates were 52%.

To re-examine the statistically significant mode x rate interaction, the effect of rate within mode can also be examined. From Figure 1, it can be seen that conv/slow condition was more intelligible than conv/normal by 21 percentage points, with an average of 66% correct key words. Similarly, in the clear/slow condition, the average key words correct was 68%, a 9 percentage point increase over clear/normal. Again, both post-hoc pairwise comparisons, listed in Table 6, verify that these differences were significant ($p<0.01$). To summarize, either speaking mode (conversational or clear) produced at a slow rate was more intelligible than that speaking mode produced at a normal rate. However, the size of the benefit that results from a slower speaking rate is larger for conversational speech (21 points) than for clear speech (9 points), which again explains why the mode x rate interaction was statistically significant.

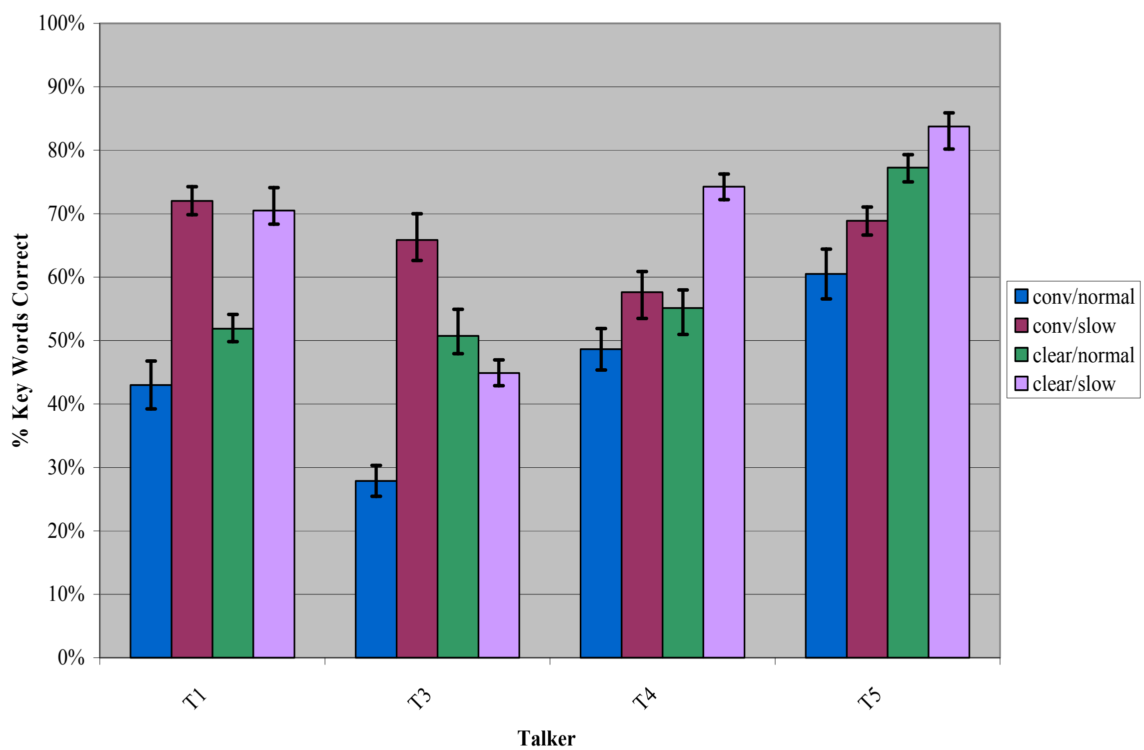
Effect of Talker

The main effect of talker was also statistically significant according to the ANOVA. In other words, some talkers were more intelligible than others. For example, T5 was the most intelligible and T3 was the least intelligible. Average percent key word scores in the four conditions ranged from 61-84% correct for T5 and 28-66% correct for T3.

Of the interactions with talker, three were statistically significant according to the ANOVA: mode x talker, rate x talker, mode x rate x talker. To examine these interactions in more detail, average speech intelligibility for each talker is shown in Figure 2. Despite these interactions and individual talker differences, Figure 2 shows that relative benefits of each condition are observed across all talkers. For example, if conv/normal is again viewed as the baseline condition, the benefits of clear/normal speech compared to conv/normal can be noted for all talkers, as seen in Figure 2. Speech intelligibility for T1 increased 9 percentage points. T3 and T5 had a 23 and 16 percentage point increase, respectively. T4 had the smallest benefit, a 6 percentage point increase in speech intelligibility.

Figure 2

Average speech intelligibility, in percent key words correct for each talker in each condition. Performance averaged across listener. Error bars indicate +/- 1 standard error above and below the mean.



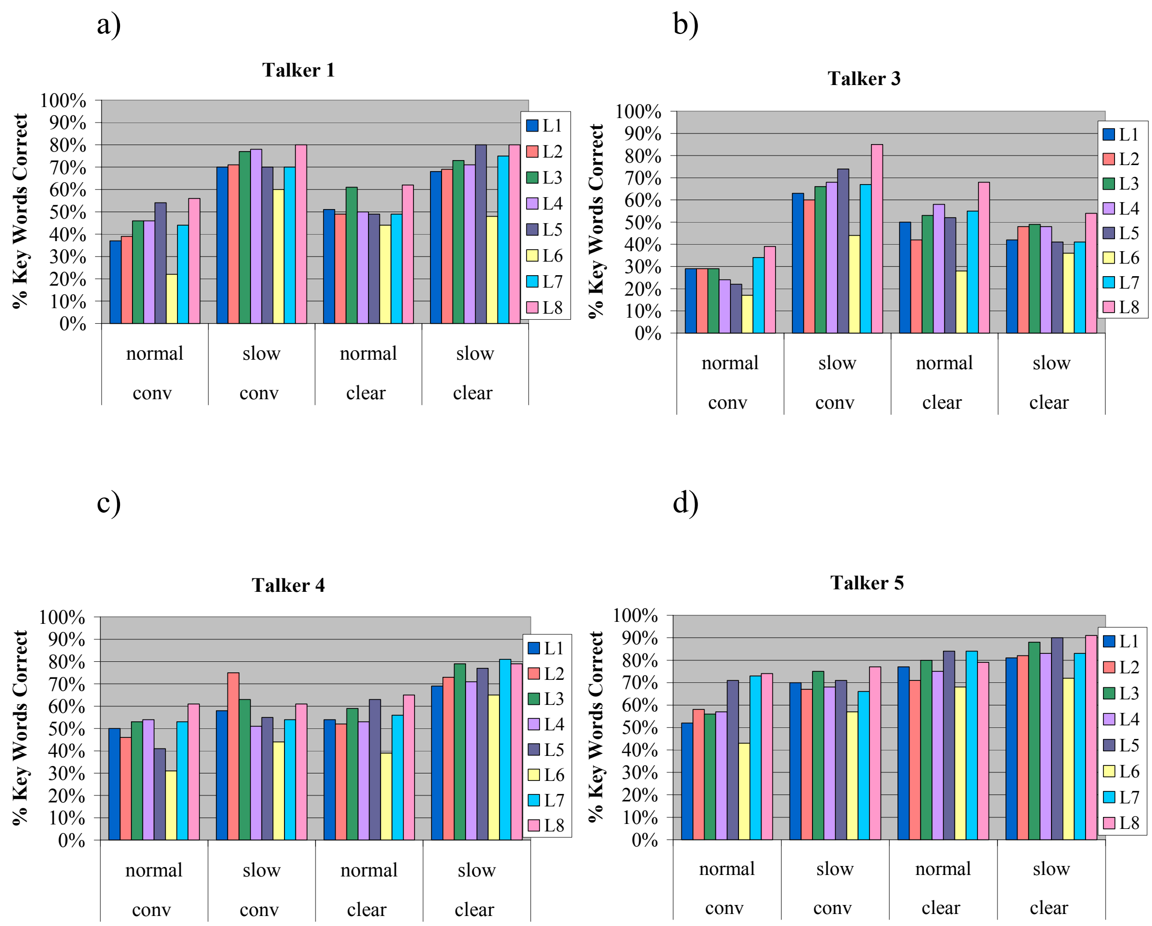
Effect of Listener

Figures 3a through 3d display each listener's performance for each talker and condition. From these figures, the listener effect can be derived. The main effect of listener was also statistically significant according to the ANOVA. This means that some listeners performed better than others. For example, L6 tended to perform the poorest of all the listeners, with key word scores ranging from 17-72%, and L8 had the highest scores in all conditions, with key word scores ranging from 39-91%. L6 later disclosed that he suffered from two traumatic brain injuries (TBI) in his past; however, he scored within normal limits on the MMSE.

Of the interactions with listener, only rate x mode x talker x listener was statistically significant. Despite this interaction and individual listener differences, Figure 3 shows that relative benefits of each condition are observed across all listeners. For example, although L6 has a history of TBI and overall poor performance, it can be seen that he still follows the same general pattern seen from all listeners. Conv/slow and clear/slow are the most intelligible conditions. Also, clear/normal is more intelligible than conv/normal.

Figure 3

Average performances, in percent key words correct, of every listener, for each talker in the four conditions.



The Role of Cognitive Processing Speed

Lastly, the results of the Salthouse tasks were used to assess cognitive processing speed and to explore whether a relationship might exist between such skills and either overall speech intelligibility or amount of benefit obtained from clear speech. There were two tasks administered, letter comparison and pattern comparison. The participants had

30 seconds to complete each of the tasks and were then scored on accuracy. Table 7 lists the scores of the processing tasks as well as overall intelligibility performance and clear speech benefit for each listener in the study. Overall intelligibility performance was defined as the average performance of each listener across all talkers and conditions, and clear speech benefit was defined as the difference between each listener's clear/normal and conv/normal scores, averaged across listener. The data were then graphed as a scatter plot, and linear regression equations were calculated as can be seen in Figure 4.

Table 7

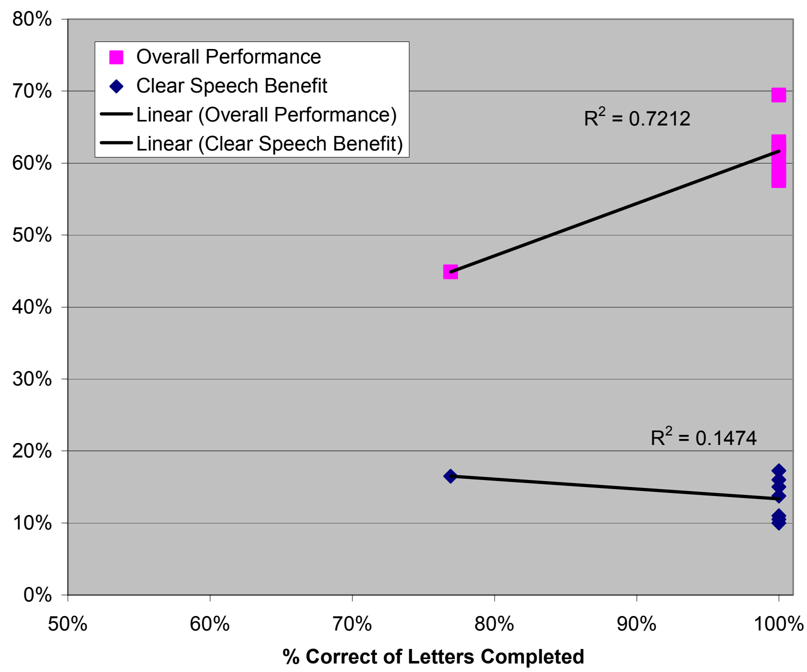
Summary of Performance on Salthouse Tasks, Overall Performance in the Study, and Clear Speech Benefit

Listener	Letter Comparison (%)	Pattern Comparison (%)	Overall Performance (%)	Clear Speech Benefit (%)
L1	100	83	58	16
L2	100	88	58	11
L3	100	100	63	17
L4	100	100	60	14
L5	100	100	62	15
L6	77	63	45	17
L7	100	100	62	10
L8	100	100	69	11

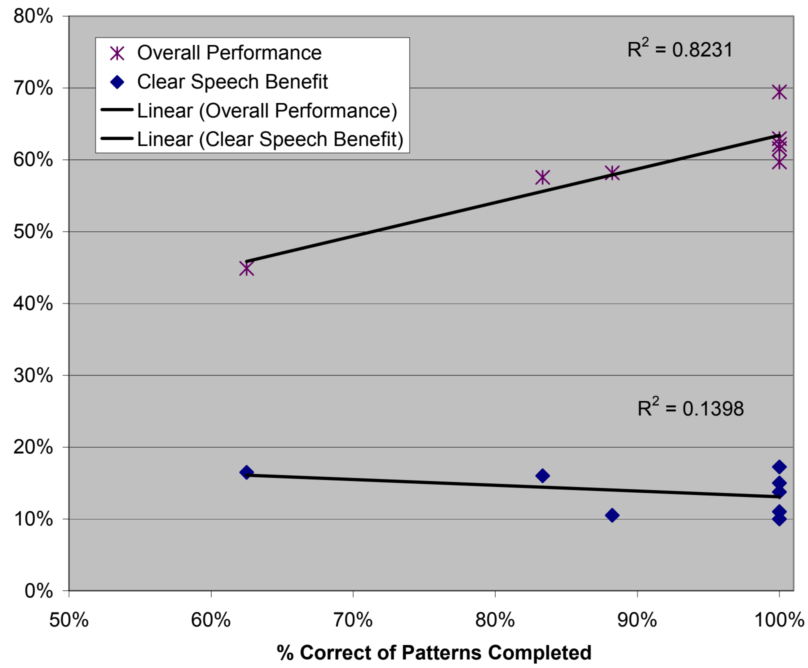
Figure 4

Data were graphed and regression lines were calculated. In each figure, y-axis represents 1) average % key words correct (averaged across talker and condition) for overall performance data and 2) difference in % correct scores between clear/normal and conv/normal (averaged across talker) for clear speech benefit data. Figure a) represents Letter comparison task. Figure b) represents Pattern comparison task. Significant correlation found between accuracy on Pattern task and overall performance in the study.

a)



b)



Spearman's rho (ρ) correlation coefficients were used to assess the relationship between cognitive processing speed, as measured by accuracy on each of the Salthouse tasks, and overall performance on the intelligibility tasks in the study. These results are summarized in Table 8. The moderate correlation between letter comparison accuracy and overall performance, ρ=.577, was not statistically significant. However, a strong positive correlation, ρ=.873, was found between pattern comparison accuracy and overall performance. This correlation was statistically significant at $p<0.01$ and indicates that the more accurate the participant was in the pattern comparison task, the better he or she did on the speech intelligibility tasks.

Table 8

Spearman's Rho (ρ) Correlation Coefficients

	Spearman Rho (ρ)
Letter Comparison and overall average performance	.577
Letter Comparison and clear speech benefit	-.412
Pattern Comparison and overall average performance	.873*
Pattern Comparison and clear speech benefit	-.300

* = significant at the 0.01 level

As seen in Table 8, correlation was also examined between cognitive processing scores and average clear speech benefit per listener. Weak negative correlations were found for letter and pattern comparison and clear speech benefit. However, these correlations were not statistically significant.

Chapter 5

Discussion and Future Research

From this study it can be concluded that for older listeners with normal hearing, clear speech at normal rates is more intelligible than conversational speech at normal rates. Although clear/normal is not as intelligible as clear/slow and conv/slow for the older listeners with normal hearing, it still has a 14 percentage point increase over conv/normal, indicating that rate does not have to decrease to improve speech intelligibility. Also, the same size benefit from clear/normal speech was seen in the younger listeners with normal hearing in Krause and Braida's study (2002).

To analyze the age factor, the results of this study were compared to Krause and Braida's study (2002), which included young listeners with normal hearing. It is important to note the differences in SNRs in the two studies. Krause and Braida (2002) used a SNR of -2 dB with the younger listeners. In both studies, the purpose of the SNR was to avoid ceiling or floor effects. In particular, 0 dB SNR was employed in the present study in order to avoid floor effects. In other words, since it is known that listeners who are older, in general, perform poorer than listeners who are younger (Gordon-Salant & Fitzgibbons, 1997), an easier SNR was used to prevent the older listeners in this study from scoring too low.

Table 9 shows the comparison of percent key words correct between the present study and the previous study. Again, the average percentages for conv/normal should be viewed as a baseline for comparison to the other conditions. In parentheses is the increase in percentage points of each condition compared to conv/normal.

Table 9

Average Listener Performance Across Studies

	Current study: older listeners with normal hearing SNR = 0 dB	Krause and Braida's study (2002): younger listeners with normal hearing SNR = -2 dB
Conv/normal	45%	45%
Conv/slow	66% (+21)	51% (+6)
Clear/normal	59% (+14)	59% (+14)
Clear/slow	68% (+23)	63% (+18)

For the normal rate conditions, the older listeners performed more poorly overall than the younger listeners. Despite the SNR difference, both populations had an average of 45% key words correct in conv/normal, and both populations had an average of 59% key words correct in clear/normal. Even though the scores for these conditions were the same for both groups, this level of performance for older listeners is actually worse because of the easier SNR presented to them compared to younger listeners. If the SNR for the younger listeners was 0 dB, they would have scored higher in conv/normal and clear/normal compared to the older listeners. In addition, it is important to note that there is a 14 percentage point increase when clear speech at normal rate was obtained for both populations regardless of SNR, indicating that age is not a factor in the clear speech benefit at normal rates.

For the slow rate conditions, the older listeners seem to have outperformed the younger listeners in reception of both conversational and clear speech. The older listeners had average scores of 66% and 68% in conv/slow and clear/slow, respectively. The younger listeners had average scores 51% and 63% in conv/slow and clear/slow, respectively. However, the difference in SNR could account for why it may seem that the older listeners outperformed the younger listeners in the clear/slow condition. If the SNR was the same in both studies, both populations may have performed similarly at the slow rates. In other words, if the younger listeners were presented the stimuli at 0 dB SNR, their scores would increase, possibly to the levels obtained by the older listeners. However, it is unclear what the size of increase in scores would be, and the size of increase in conv/slow would also not necessarily be the same as the size of increase in clear/slow. Therefore, additional testing of both groups at each SNR is needed in order to determine the relative performance of the older and younger listeners for each of the conditions at slow rates.

One unexpected finding at slow rates was that clear speech (68%) did not provide a benefit over conv/slow (66%) for older listeners with normal hearing. In Krause and Braida's previous study (2002), the younger listeners received a 12 point benefit from clear/slow relative to conv/slow speech whereas, the older listeners in the present study performed about the same in both slow conditions. Since both groups experienced a benefit from clear speech at normal rates but only younger listeners experienced a benefit at slow rates, an age by rate interaction may be present. To investigate this possibility, further testing of both groups and SNRs is warranted. Other possible explanations of the results are also discussed below.

One possible explanation is the different SNRs. The results may have been different if the SNRs were the same. For example, the size of the clear speech benefit is typically larger in more difficult listening environments (e.g., Payton et al., 1994; Helfer, 1998; Bradlow & Bent, 2002; Bradlow et al., 2003). Consequently, it is possible that if the older listeners were tested at SNR = -2 dB, they might have experienced a larger clear speech benefit, perhaps more comparable to the younger listeners at slow rates.

Another possible explanation is that these results may reflect a difference between the two groups in noise. Perhaps the lack of benefit of clear/slow relative to conv/slow for older listeners represents a ceiling effect for that group in noise. In other words, the older listeners attained their highest possible performance levels in noise for conv/slow speech and could not achieve higher speech intelligibility for clear/slow speech.

Finally, a third explanation could be that, for older adults with normal hearing, conv/slow functions as a type of clear speech for them. In such a case, it could then be expected that for older listeners, conv/slow would provide a comparable intelligibility benefit (relative to conv/normal) as clear/slow at a variety of signal to noise ratios, even though no such benefit is apparent for younger listeners. Furthermore, such a finding would suggest that conv/slow speech has acoustic properties different from conv/normal speech that benefit older listeners. If this is the case, then an acoustical analysis of the two speaking conditions would be needed. For example, the acoustical research could then clarify why conv/slow and clear/slow are intelligible for older adults and only clear/slow is intelligible for younger adults. Also, the analysis could determine the acoustical differences between conv/normal and conv/slow. In sum, further testing of both groups at the same SNR is needed. Future research should control for the SNR as well as age to answer these questions.

Chapter 6

Clinical Implications

In summary, older listeners experience a large intelligibility benefit from clear/normal speech (14 point benefit relative to conversational speech). Although, clear/slow (23 point benefit) and conv/slow (21 point benefit) were the most intelligible conditions, the benefit of clear/normal is most notable because speaking rate does not have to decrease to improve speech intelligibility for listeners who are older. Furthermore, the amount of benefit from clear speech at normal rates is roughly the same (14 percentage points) for these listeners as for younger listeners. Therefore, hearing aid technology, based on clear speech, should provide comparable benefit to listeners of any age. The hearing aid can process conversational speech into clear speech without slowing down rate and as a result, the listener will not fall behind in the conversation.

In addition, there is a better understanding of the relative intelligibility of conversational and clear speech at normal and slow rates. The present study provides more information regarding the effect of mode and rate of speech production on speech intelligibility. The study also brings up new questions, such as why do older adults benefit from conv/slow as much as they do from clear/slow.

Finally, knowing that rate does not have to decrease in order to improve speech intelligibility, productivity in therapy sessions may increase, regardless of the client's age. Using clear speech at a normal rate will increase the efficiency of the session and reduce communication breakdowns.

Because of theses benefits, clinicians, especially those working with children and older adults, should be trained for clinical application of clear speech. From the present and previous studies, it has been shown that adults with normal hearing, young and old, benefit from clear/normal speech. Therefore, training should not only include clinicians working with hearing loss populations, or children with learning disabilities. The benefit of clear speech should be brought to the attention of all clinicians in fields such as audiology, speech-language pathology and education, just to name a few.

Presently, few sources can be found for training clear speech. Tips for producing clear speech can be found in Don Schum's Oticon pamphlet (1996) or from Krause and Braida's study (2002) which described formal training procedures for eliciting clear speech. Krause and Braida's study (2002) trained professional speakers to produce clear speech at a normal rate. In their study, the talkers underwent roughly six hours of intense training. Rate was regulated using metronome clicks and speech intelligibility was achieved by using young listeners with normal hearing to recognize all key words.

However, neither of these sources is ideal for training clinicians to produce clear speech at normal rates. Schum's information (1996) does not regulate for rate. It is aimed at producing clear speech that is naturally slower. Krause and Braida's study (2002) for clear speech at normal rates involved intense training in a laboratory setting, which is not feasible for clinicians and communication partners.

Because the benefits of clear/normal speech are evident, it would be useful to develop more practical means of training. For example, training clear speech could be completed in workshop type settings as a weekend course or part of a curriculum. This workshop may be ideal for the university setting where students are educated. A workshop for the public could also be offered for family, friends and other professionals to learn about clear/normal speech and its benefits. The workshops should be led by professionals or clinicians who have researched clear speech at different rates.

It is important to note that it may not be possible for all talkers to achieve immediate results when learning to produce clear speech at normal rates. For example, Krause and Braida (2002) selected talkers who showed potential for producing clear speech without altering rate, but T2 did not fully accomplish the goal in the time frame provided. This will not be uncommon because all talkers are different and will use different characteristics to achieve clear/normal speech. For example, some talkers may modify the production of vowels and others may make stops more evident by including the bursts. Because there are many characteristics for clear/normal that can be used, not all talkers will use the same characteristics; hence, every talker will be different, and some will require more time than others to learn to produce clear speech at normal rates.

In the meantime, tips and exercises for learning to produce clear speech at slow rates, such as those in Schum's Oticon packet (1996) are useful, because studies have shown that most talkers can learn to produce clear speech at slow rates within 15 minutes, which includes instruction and practice (e.g., Schum, 1997). The Oticon packet instructs talkers to use pauses, intonation, stress, and to produce accurately, fully formed sounds. Also, it is important to not forget other good communication habits such as reducing background noise, face to face communication and appropriate lighting (Schum, 1996).

In conclusion, clear speech is a type of speaking style that benefits many populations, from children to adults, in difficult communication settings. Better yet, clear speech does need a slower rate to be intelligible. Clear/normal speech is fairly new research and still needs to be investigated to further explore the relationship between rate, speaking style and speech intelligibility.

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Appendices

Appendix A: Screening Results

Table A1

Listener Demographics and MMSE Scores

Listener	Age	Sex	MMSE Score
L1	55	F	28
L2	58	F	30
L3	68	M	29
L4	67	F	30
L5	60	M	30
L6	62	M	29
L7	59	F	30
L8	61	F	30

Table A2

Results of Hearing Screening

	Ear Tested	250 kHz (in dB)	500 kHz (in dB)	1 kHz (in dB)	2 kHz (in dB)	4 kHz (in dB)	6 kHz (in dB)	8 kHz (in dB)
L1	Right*	20	20	10	5	10	15	15
	Left*	10	5	15	15	0	10	5
L2	Right*	25	20	0	5	5	10	15
	Left	30	30	15	5	15	15	25
L3	Right	30	25	15	5	15	25	30
	Left*	20	10	10	10	20	25	25
L4	Right*	10	5	10	5	20	30	30
	Left*	10	5	0	20	15	35	25
L5	Right*	25	15	0	10	25	15	20
	Left	25	20	10	10	35	20	20
L6	Right*	15	15	10	5	10	30	30
	Left	10	20	20	35	55	65	65
L7	Right*	15	20	15	10	20	25	15
	Left*	15	20	10	15	20	25	20
L8	Right*	25	10	20	10	20	35	30
	Left	30	15	15	10	10	35	40

* = ear used in study. If both ears are marked, participant allowed to alternate ears between lists, if desired. All other participants were restricted to the ear that passed.

Appendix B: Listener Data

Talker	Mode/Rate	L1	L2	L3	L4	L5	L6	L7	L8	Avg
T1	conv/normal	0.37	0.39	0.46	0.46	0.54	0.22	0.44	0.56	43.0%
T1	conv/slow	0.70	0.71	0.77	0.78	0.70	0.60	0.70	0.80	72.0%
T1	clear/normal	0.51	0.49	0.61	0.50	0.49	0.44	0.49	0.62	51.9%
T1	clear/slow	0.68	0.69	0.73	0.71	0.80	0.48	0.75	0.80	70.5%
T3	conv/normal	0.29	0.29	0.29	0.24	0.22	0.17	0.34	0.39	27.9%
T3	conv/slow	0.63	0.60	0.66	0.68	0.74	0.44	0.67	0.85	65.9%
T3	clear/normal	0.50	0.42	0.53	0.58	0.52	0.28	0.55	0.68	50.8%
T3	clear/slow	0.42	0.48	0.49	0.48	0.41	0.36	0.41	0.54	44.9%
T4	conv/normal	0.50	0.46	0.53	0.54	0.41	0.31	0.53	0.61	48.6%
T4	conv/slow	0.58	0.75	0.63	0.51	0.55	0.44	0.54	0.61	57.6%
T4	clear/normal	0.54	0.52	0.59	0.53	0.63	0.39	0.56	0.65	55.1%
T4	clear/slow	0.69	0.73	0.79	0.71	0.77	0.65	0.81	0.79	74.3%
T5	conv/normal	0.52	0.58	0.56	0.57	0.71	0.43	0.73	0.74	60.5%
T5	conv/slow	0.70	0.67	0.75	0.68	0.71	0.57	0.66	0.77	68.9%
T5	clear/normal	0.77	0.71	0.80	0.75	0.84	0.68	0.84	0.79	77.3%
T5	clear/slow	0.81	0.82	0.88	0.83	0.90	0.72	0.83	0.91	83.8%

Appendix C: ANOVA Statistics

Table C1

Within-subjects Effects and Interactions

Effect	F	Hypothesis df	Error df	Sig.	Eta-Squared
*rate	826.128	1	32	.000	17.78
rate x listener	2.733	7	32	.024	0.41
*mode	202.101	1	32	.000	5.11
mode x listener	1.489	7	32	.206	0.26
*talker	218.390	3	30	.000	24.36
talker x listener	1.159	21	96	.305	1.18
*rate x mode	61.931	1	32	.000	2.24
rate x mode x listener	.908	7	32	.513	0.23
*rate x talker	20.905	3	30	.000	2.32
rate x talker x listener	1.500	21	96	.096	1.00
*mode x talker	57.464	3	30	.000	3.07
mode x talker x listener	.970	21	96	.506	0.64
*rate x mode x talker	64.698	3	30	.000	7.83
*rate x mode x talker x listener	2.770	21	96	.000	2.49

* = significant at the 0.01 level

Table C2

Between-subjects Effects

Effect	Type III Sum of Squares	Mean Square	F	Hypothesis df	Error df	Sig.	Eta-Squared
*listener	3.306	.472	57.444	7	32	.000	13.29

* = significant at the 0.01 level