Visual Presentation of Connected Speech Test (CST)

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ABSTRACT

The Connected Speech Test (CST) was developed to test hearing aid performance using realistic stimuli (connected speech) presented in a background of noise with a visible speaker. The CST has not been investigated as a measure of speech reading ability using the visual portion of the CST only. Thirty subjects were administered the 48 test lists of the CST using visual presentation mode only. Statistically significant differences were found between the 48 test lists and between the 12 passages of the CST (48 passages divided into 12 groups of 4 lists which were averaged.). No significant differences were found between male and female subjects; however, in all but one case, females scored better than males. No significant differences were found between students in communication disorders and students in other departments. Intra- and inter-subject variability across test lists and passages was high. Suggestions for further research include changing the scoring of the CST to be more contextually based and changing the speaker for the CST.

Keywords: connected speech test, speech reading

1. INTRODUCTION

Studies have shown that speech discrimination scores for traditional speech discrimination stimuli (mainly monosyllabic words) are poor predictors of hearing aid performance (Cox et al., 1987). Traditional monosyllabic word tests use unrealistic stimuli presented in isolation in a sound treated environment away from any visual cues provided by the speaker. Connected speech is a much more realistic test stimulus--taking into account cues which are not present in monosyllabic word tests such as redundancy and coarticulation. Further, tests which involve using a background of multitalker noise with an audiovisual presentation would be much more realistic for testing everyday speech discrimination ability. The Connected Speech Test (CST) was developed to test hearing aid benefit with a more valid stimulus than the traditional monosyllabic word tests (Cox et al., 1987). The CST provides a realistic stimulus (connected speech) with a visual speaker in a background of multitalker

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noise and a large number of equivalent test lists. The CST was designed originally to be used as a criterion measure in investigations of hearing aid benefit (Cox et al., 1987; Cox, et al., 1988; Cox et al., 1989; Cox & Alexander, 1991; Cox et al., 1991, Cox & Alexander, 1992; and Humes et al., 1997). However, its use has been extended to cochlear implantees (Holden et al., 1997). In addition, its use may be expanded as a test of speech discrimination for routine audiometry and as a speech reading test to determine potential for speech reading training and to track the progress of speech reading therapy.

Speech reading is the oldest form of rehabilitation for deaf and hearing impaired people (Newby, 1979). Speech reading involves the use of visual cues (lips, gestures, body language) and contextual cues to aid in the understanding of spoken communication (Newby, 1979). Prior to and during a speech reading training program, it is necessary to assess a student's ability to speech-read in order to determine school placement and progress, study the growth and development of the student, determine the success of different therapy techniques (Utley, 1946), predict speech reading success, and develop better speech reading training programs (DiCarlo & Kataja, 1948). Prior to 1946, speech reading instructors used informal, self-made assessment tools to determine speech reading ability. In 1946, Utley developed a standardized test of speech reading ability which is still used today.

Since 1946, many tests have been developed to assess speech reading ability. Test items consist of single syllables, words, phrases, sentences, and continuous discourse (O'Neill & Stephens, 1959). For example, Utley's speech reading test has three subtests designed to assess sentence, short phrase or word, and continuous discourse ability (O'Neill & Stephens, 1959); the NAL/West Haven speech reading test involves questions related to a specified topic; the CID everyday sentences involves repetition of sentences without a specified topic; the Iowa-Keaster involves written responses to sentence without a specified topic; the Gold Rush Paragraph test involves answering questions based on the topic of a continuous discourse (Spitzer, Leder, Flevaris-Phillips & Giolas, 1987); BKB sentences involve repetition of sentences with no specified topic (Rosen & Corcoran, 1982); and the Manchester Speech Reading Test consisits of a monosyllabic word subtest and a sentence subtest (Elphick, 1984) both presented without a specified topic.

Utley (1946) proposed that many different speech reading tasks (identification of words, isolated phrases, phrases with context, and discourse) are necessary to determine speech reading ability since each situation occurs in daily communication (Utley, 1946). The relationship between speech reading performance for different tasks has been investigated. Risberg and Agelfors (1978) found a poor correlation between speech reading performance on monosyllables and sentences (cited in Rosen & Corcoran, 1982). Utley (1946) found a high correlation between speech reading ability between types of stimuli; however, he suggested each type of stimuli should be administered for diagnostic purposes. The most obvious choice for stimuli for speech reading testing is a realistic stimulus which is reflective of everyday performance (Rosen and Corcoran, 1982). In most instances, speech readers are expected to follow a conversation of a known topic in which several sentences follow the same topic and

then the speaker changes his discourse to follow another topic. Tests of speech reading ability for monosyllabic words do not take into account how contextual or coarticulation cues affect speech reading ability (Benguerel & Pichora-Fuller, 1982). Speech reading tests which involve continuous discourse related to a known topic seem to be a much more valid assessment of speech reading ability than isolated words or monosyllables.

Speech reading tests many be presented through two modes; live or recorded (Elphick, 1984). Live administration is predominant in diagnostic settings today (Spitzer, et al., 1987). Live administration is less expensive, generally shorter to administer and includes a 3-dimensional image; however, live administration usually involves changes in rate and facial expression, over exaggeration of lip movement, and variations in production (Elphick, 1984). Recorded administration can exactly replicate the visual image of the speaker, the lighting in the room, the image size, angle, and rate of presentation (Spitzer et al., 1987) for each subject; however, some of the speech reading cues are lost with a 2-dimensional image (Elphick, 1984). Several studies have compared scores on live and recorded presentations; however, in most cases, the differences in means were not statistically significant (Elphick, 1984). Further, in practice, the examiner presenting a test live would not be as strictly monitored as the examiner in these experiments (Elphick, 1984).

The CST-3 is a speech recognition test consisting of 48 paragraphs relating to specific topics. Each paragraph consists of 10 sentences. The topic is given prior to each passage. This format seems to more closely follow every-day communication requirements than many of the traditional isolated word and sentence tests. Further, the test is recorded on a laser disk for consistent presentation to the listener. The audio portion of the test can be disconnected to provide an ideal speech reading task. The CST has been found to have equivalent passages for audio and audio-visual presentation for normal hearing and hearing impaired listeners. This test has not been assessed for equivalency of passages for visual presentation only.

The original CST was developed by Cox, Alexander, and Gilmore in 1987. The first version of the CST, the CST-1 contained 48 passages of 7 to 10 sentences each. The test lists were found to be equivalent for normal subjects. In 1988, Cox et al. found the passages of the CST-1 were not equivalent for hearing impaired listeners. As such, they developed the CST-2 which contained 48 passages, each containing 10 sentences. The CST-2 was found to be equivalent for both normal and hearing impaired subjects. They further found that the SBR (signal to babble ratio) for the CST-2 with hearing impaired listeners was 2 dB S/N which indicates that it is a sensitive predictor of speech discrimination. In 1989, Cox et al. found that the within subject variability of the CST-2 was higher for auditory-visual presentation than it was for auditory presentation. They developed the CST-3 which has 48 passages: 12 sets of 4 passages to be averaged. The CST-3 was found to have similar variability for auditory and auditory-visual presentation. The CST-3 has not been investigated using three separate presentation modes: visual only, auditory only and auditory-visual. This test may offer a standardizable test for speech reading ability as well

as a discrimination tool.

In order for a test to be standardized, it needs to be consistently administered with a large number of equivalent test items (Rosen & Corcoran, 1982). The purpose of this study is to investigate the performance of normal hearing subjects on the CST-3 using visual presentation mode only with an aim towards standardizing the CST as a speech reading test; specifically, to determine if the 48 test lists or 12 passages of the CST are equivalent, and if so, what the range of normal performance is across test lists.

2. METHOD

2.1 Subjects

Data was obtained for 30 subjects between 21 and 44 years old having a mean age of 25 years. Twenty-three subjects were female and seven subjects were male. Nineteen subjects were students from the Communication Disorders Department (CMDIS) and eleven subjects from other departments (NON-CMDIS).

2.2 Instrumentation

Each subject was seated in a double walled audiometric sound booth (Suttle, SE-B1) conforming to the ANSI S3.1-1990 standard for maximum permissible ambient noise levels (MPANLs) for sound field testing. The Connected Speech Test (CST) was presented visually via a 3M 12" laser disk using a Pioneer LD-870 laser disk player. The CST consists of 48 passages--each related to a specific content word. Each passage is composed of 10 sentences. The laser disk recording of the CST was produced by Cox et al. (1989) using a female speaker who was subjectively judged to have average intelligibility, rate, and generation of speech reading cues. The auditory output from the laser disk player was disconnected from the subject portion of the sound booth so that only the examiner could hear the speaker. The subject was isolated from the examiner by a double walled sound booth and the auditory signal could not be heard by the subject. The visual output from the laser disk player was directed to a BMC (model BMAU9191U) video monitor. Each subject was seated directly in front of the video monitor at a comfortable distance.

2.3 Procedure

Each subject was administered the 48 test lists of the CST in a random order. The display was paused between each sentence to allow the subject to verbally respond. The subject was asked to repeat any words, phrases or sentences he/she saw and was encouraged to guess. This occurred because the CST is scored via specific words in each sentence. If the subject did not repeat the sentence correctly or completely, he was given credit for any of the scoring words he repeated. For example, in such target sentence as "Windows provide light and air to rooms.", the maximum possible socre was 3. If the subject responded "Windows are found in rooms.", he/she obtained 1 point; but "Windows give air to

places." obtained 0 point. The topic of each passage was presented on the monitor prior to the presentation of the passage. Each subject was given a 5 minute break half way through the testing. The test procedure took approximately 60 minutes to complete.

3. RESULTS

A three-way multivariate analysis of variance (MANOVA) was used to analyze the data from the 48 test lists. In a prior study, Cox et al. (1989) suggested averaging the test lists having higher audio-visual scores with lists having lower audiovisual scores. The 48 test lists were divided into 12 passage in which lists 1, 2, 3, 4 constituted passage 1, lists 5, 6, 7, 8, constituted passage 2, and so on. A three-way MANOVA was used to analyze the data from the 12 passage. Three factors were investigated: test lists (separately and combined into passages), gender, and major (CMDIS vs NON-CMDIS).

The results showed a significant main effect for the 48 lists and 12 passages (Table 1). That is, the lists and passages were not equivalent but significantly different in the visual presentation mode. A prior study showed that the 12 grouped passages were equivalent in audio and audio-visual presentation modes (Cox et al., 1989) although the 48 individual lists were not equivalent in audio and audio-visual presentation modes. No significant 2-way or 3-way interactions were found.

Table 1. Three-way MANOVA showing significant main effects of test lists and passages.

Source	DF	F-Value	P-Value
List (48)	1,222.47	3.11	< 0.01
Passage (12)	209.11	2.87	< 0.05

Figure 1 illustrates the mean score per list and one standard deviation above and below the mean. The block in the center of each line represents the mean for the individual lists and the upper and lower horizontal bars represent one standard deviation above and below the mean. Therefore, each line captures approximately 68% of the distribution for each list. Most scores ranged from 0 to 8 out of a possible maximum score of 25. All the mean scores are connected and illustrate the unstable variation from passage to passage.

Figure 2 represents the mean and standard deviation results from the 12 passages in which the maximum possible score was 100. These scores appear to be less variable than the individual test list scores; however, statistically significant differences were found between the passages.

Figure 1. Average number correct per list. The maximum possible score was 25.

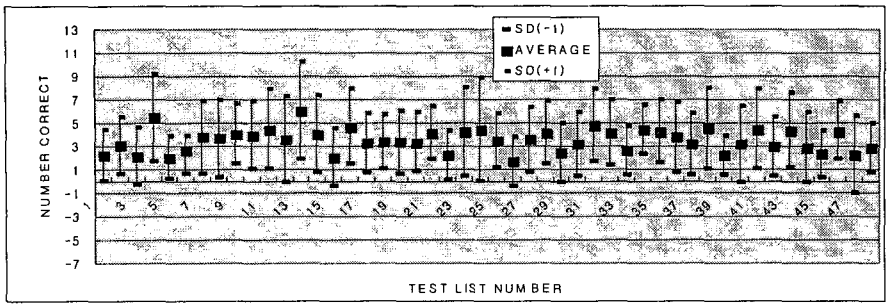


Figure 2. Average number correct per passage. The maximum possible socore was 100.

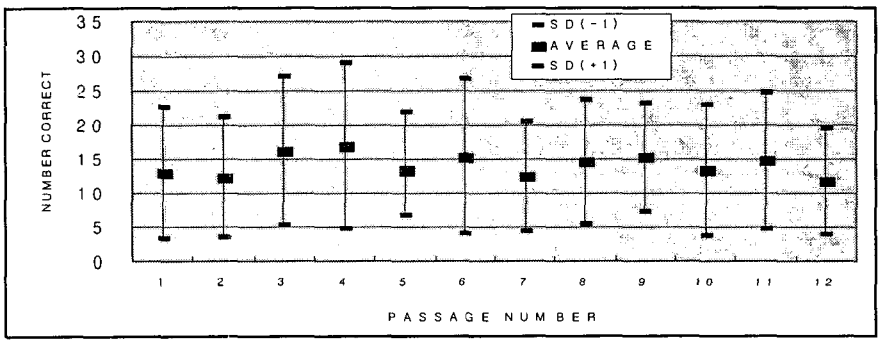


Figure 3 illustrates an overall frequency distribution of the data regardless of specific list or passage number. The distribution is seriously positively skewed indicating that the task was very difficult. Except for several outliers, the majority of the data points were concentrated between 0 and 5 items correct.

Figure 4 illustrates inter-subject variability. The data from three subjects are represented: one subject scored well above average for each list; another subject scored approximately average for each list; and the other scored below average for each list. Observation of this Figure reveals the wide range of possible scores for subjects with no prior history of speech reading training. Kricos and Lesner (1982) pointed out that there is a considerable variability in the generation of speech reading cues across talkers (from their study it would appear that a talker of average visual intelligibility probably generates about six separate viseme categories). Figure 4 illustrates that some individuals may be very well equipped for speech reading even without having any training and other individuals are not as perceptive of speech reading cues.

Figure 3. Overall frequency distribution of data points. The maximum possible score was 25.

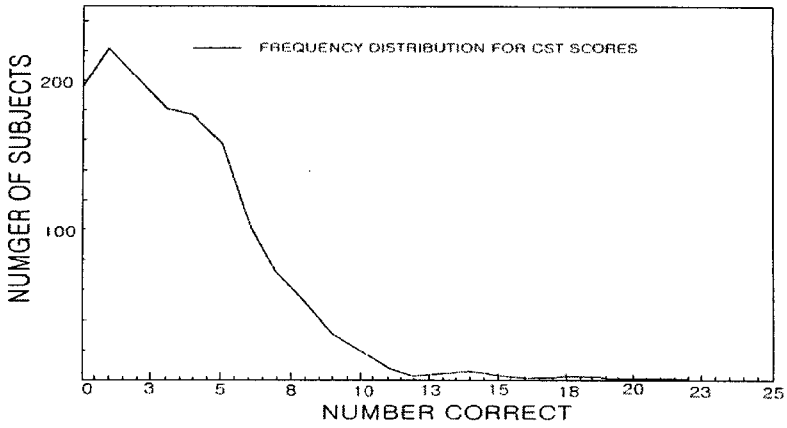
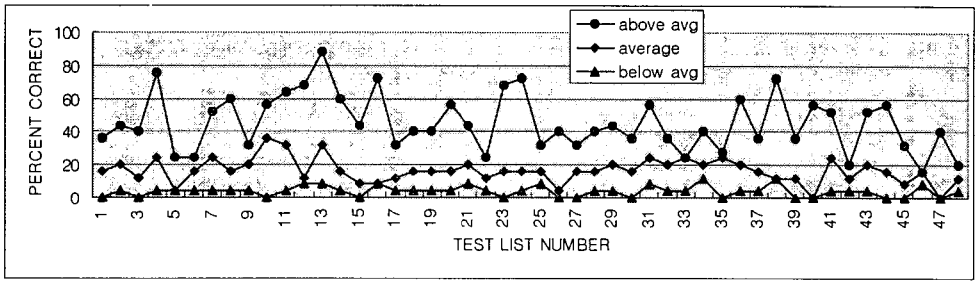


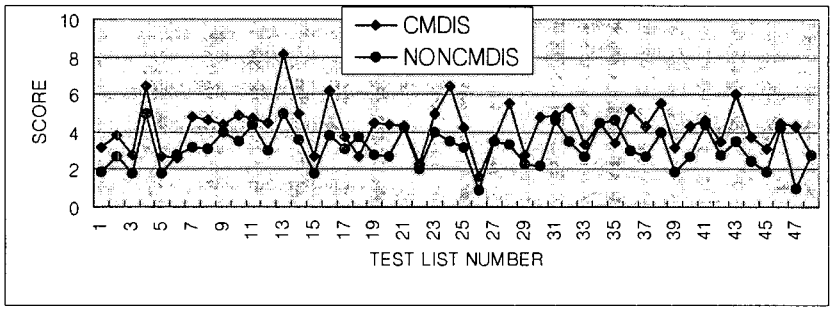
Figure 4. Percentage correct per list for 3 subjects.



In the comparison between male and female average scores for the 48 lists and 12 passages, although differences in scores did not reach statistical significance, females performed superiorly to males for all but one test list (list 34). However, the standard deviations were fairly large. With a large sample size, gender may have been a significant main effect in favor of females.

Figure 5 illustrates the performance of CMDIS students compared with NON-CMDIS students. In most cases the students studying CMDIS scored higher than students outside of the CMDIS department; however, differences were not statistically significant.

Figure 5. Average number correct per list for CMDIS vs NONCMDIS majors.



4. DISCUSSION

4.1 Scoring

The results of the analysis of variance indicated that the 48 test lists and the 12 passage divisions of the CST were not equivalent. As such, the CST can not be standardized as a speech reading test in its present form. However, it is possible that a change in scoring technique could improve the variability between the test lists. The current scoring procedure involves giving the viewer points for repeating key words in each sentence. In many cases, the subject was able to score points for key words even though the context of the sentence was incorrect. For instance, in sentence "Cabbage can live through several freezes.", the maximum possible score was 3. The response "Cabbage come in many psychedelic colors." obtained 1 point. Conversely, subjects were frequently not given points for repeated sentences with correct context if they did not repeat the key scoring words. For example, in the target sentence "The camel is a very ugly animal.", "The camel is a very strange looking animal." obtained 0 point. This appears to be a major flaw in the CST when used as a visual test. Although repetition of exact words may be appropriate for evaluation of hearing aid performance, speech reading ability may be better estimated with a contextually based scoring system. In reality, if a deaf person were able to pick out a few key words, yet completely miss the context of the sentences, he would be at disadvantage to a deaf person who missed a few of the words but was able to follow the context of the sentence. Several researchers have investigated the use of word vs context scoring. Rosen and Corcoran (1982) compared the use of key word scoring, whole sentence scoring, and contextual scoring. For the contextual scoring, they had three judges (one speech-language pathologist, one audiologist, and one non-speech-language-hearing person) rate the context of a repeated message in comparison with the stimulus on a numerical scale. For whole sentence scoring, the entire sentence had to be repeated in order for the response to be correct. For key word scoring, the experimenters designated 50 words per list as key words. The results of this study indicated that the key word scoring and contextual scoring were highly correlated; however, the whole sentence scoring was poorly correlated with the order two measures. Rosen and Corcoran (1982) suggested that the key word scoring approach would be the most logical considering its validity and the improvement in time of administration. Utley (1949) found a high correlation (r=.98) between scoring using the context and the number of words correct; however, each correct word was tallied instead of just key words. It is possible that results from Rosen and Corcoran (1982) and Utley (1946) would not be applicable to the present test. Rosen and Corcoran used isolated sentences made up of common British English statements and Utley used each word in the sentence as a scoring word. Investigation of the correlation between key word scoring, contextual scoring, and some other speech ability rating scale should be investigated to determine if alternate scoring methods would improve the list equivalence and validity of the CST as a speech reading tool.

4.2 Administration

Cox, Alexander, and Gilmore (1987) described the speaker from the laser disk recording of the CST as an "average talker" who lacked a pronounced regional accent and was able to read prepared material in a manner similar to her spontaneous speech. They also pointed out that her articulation rate of 4.8 syllables was within the range of 4.4 to 5.9 syllables/sec reported by Goldman-Eisler for spontaneous utterances. Many of the subjects from the current study, however, complained that this "average talker" was extremely distracting. Her eyes were convergent and obviously fixated on the material she was reading and her rate appeared to be abnormally fast. The screen was blank during pauses and the speaker did not pause between sentences long enough for the viewer to fixate on the mouth following a pause. In a study by Elphick (1984), a light was flashed by the speaker's face prior to a speech signal to alert the viewer of a speech message. A study by Rosen and Corcoran (1982) had the speaker pause for a few seconds before each speech signal in order for the viewer to fixate on the speaker's mouth. Both of these procedures may improve the CST visual presentation. Further, if the speaker were to memorize the speech material prior to each utterance, it would cause fewer distractions from the eyes. The rate may have seemed subjectively fast since the task was quite difficult; however, in order for the test to be a valid instrument, a normal speaking rate should be maintained. Investigation into changes in the speaker's eye movement and pause rate may improve visual CST scores.

4.3 Gender Difference

Although the analysis of variance for gender did not reveal any statistically significant differences, in all but one case the average score per list and per passage as shown on Table 2 was higher for females than for males. A previous investigation by Spitzer, et al. (1987) compared average scores for 4 different recorded speech reading tests and found female average scores were significantly higher than male average scores for 3 of the 4 speech reading tasks he administered. The differences between male and female scores were not statistically significant for the fourth task. The average score for the present study could have occurred as a result of the differences in subject sample size in each group (female=23 and male=7). It is possible the male subject group included only those male subjects at the bottom of population distribution. It is also possible that our results were not significant because of the large variation usually associated with a small sample size. Further male subjects should be sampled before conclusions can be made regarding gender differences for this speech reading task.

4.4 Normative Data

The average score for all subjects across all test lists ranged from about 12 to 20 %. The variations were too great between lists to use the current scoring for standardization; however, these scores are comparable to a previous study which used continuous discourse as a test stimulus. Spitzer, et al. (1987) used the Gold Rush Passage test and found an

overall average score of 19 % correct. Speech reading tests which use isolated sentences and words have been found to have much higher average scores. Utley's speech reading test has a rating scale for scores in which under 40% is considered poor. Other speech reading tests using isolated sentences as stimuli have resulted in average of 38.05 % (Elphick, 1984), 30 % (Rosen & Corcoran, 1982), 63.82 %, 29.12 % and 54 % (Spitzer, et al., 1987) correct. In each of these cases, the scores were much higher for isolated sentences than for the CST scores. Considering the CST is presented in sentence format (pausing between sentences) with a known context, this finding is unusual. It is possible that the previously discussed administrative and scoring procedures are affecting the performance on this task. Further research should be aimed at understanding why subjects score poorly on the CST compared with other speech reading tests involving sentences.

4.5 Inter and Intra Subject Variability

Figure 4 illustrates the percentage correct for each of the 48 test lists for three subjects. One subject performed poorly, another performed at an average level, and the other subject performed extremely well. The difference between the three subjects can be seen in both mean score and in variability. The subject who performed poorly, was consistently poor across test lists. The subject who performed very well, was more variable in her responses across test lists. Elphick (1984) advocated that "good speech readers" achieved good results irrespective of video or live modes and "poor speech readers" were consistently poor. Ultey (1946) observed that speech reading ability was not predicted by reading level, achievement in school, chronological age, age of onset of deafness or grade level. Tiffany and Kates (1962) observed that difficulty in ability to learn speech reading was unrelated to the ability to learn other subjects or in residual hearing. It seems that some people are better speech readers than others irrespective of many other factors. This seems to be the case for the subjects in the current study. No one list was particularly difficult or easy for subjects overall. Although the variability for each subject was large, a general trend of "good" vs "poor" speech readers can be seen. Although none of the subjects whose scores are illustrated in figure 5 have had prior speech reading training, and none were familiar with the test before its administration, one person scored far better than the other two. Tiffany and Kates (1962) found a high correlation between speech reading and the ability to form non-verbal concepts and organize parts into wholes. An area for further research may be to include a correlation between a subject's opinion of his primary mode of reception on a continuous scale from primarily visual to primarily auditory with his score on this test. An assessment of a person's ability to learn through auditory vs visual modes may also be a good comparison study to the CST as a speech reading test.

5. SUMMARY AND CONCLUSIONS

In summary, the 48 test lists of the Connected Speech Test (CST) were administered to

30 subjects in a random order. The subjects responded to the visual display from the recorded test and were scored using the key word scoring system currently used for the audio and audio-visual presentation of the CST as suggested by the creators of the test (Cox, et al., 1989). Within the confines of this study, the authors found:

1. The 48 test lists were not equivalent when presented visually and scored using key words as designated by Cox et al. (1989).
2. The 12 passages were not equivalent when presented visually and scored as designated by Cox et al. (1989)
3. Inter and intra subject variability was high.
4. No statistically significant differences existed between gender or major area of study (CMDIS vs NON-CMDIS).
5. The CST can not be standardized as a speech reading test using the current administration and scoring procedures.

The investigators suggest changes in the administration and scoring of the CST specific to visual presentation only. Further testing of the CST including these changes is necessary to determine if changing the test will facilitate its standardization as a speech reading test.

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