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# The effects of hearing aid gain on speech perception and the articulation index

Marla Schwartz

# The Effects of Hearing Aid Gain on Speech Perception and the Articulation Index

Independent Study

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## ABSTRACT:

The purpose of this study was to determine if changes in aided Articulation Indices (AI) predict changes in aided speech perception ability. The subjects were 20 children ranging from 6-13 years of age. All of the subjects had a severe to profound sensorineural hearing loss. Each subject had category 3 or 4 speech perception abilities (Moog & Geers 1988). The Early Speech Perception Test (ESP) was administered and sound field thresholds were obtained in two different test conditions. The aided Articulation Index was determined for these two different conditions and compared with the word recognition and pattern perception scores. The first condition is with the child's hearing aid at the recommended gain setting and the second is with the gain reduced 10 dB. The results indicate that there is no correlation between changes in the aided AI and monosyllabic word recognition scores. There was no significant correlation when the changes in the aided AI were compared to changes in pattern perception scores. Although this correlation was insignificant, it was greater than the correlation between the aided AI and word recognition scores.

thresholds and 3) the measurement of real ear gain that is provided by the hearing aid (Popelka and Mason, 1987).

Figure 1 illustrates the unaided Articulation Index for an individual with normal hearing sensitivity. The first curve labeled "TH" represents the individual's thresholds which are better than 20 dB HL for all frequencies. The shaded area is the speech spectrum representing the frequency and intensity range for speech at a normal conversational level. Notice that the entire speech spectrum is audible to this person and therefore, his/her AI is 100%. The "UCL" is the line of uncomfortable loudness levels for this individual.

Figure 2 illustrates an unaided Articulation Index for an individual with a mild to moderate sensorineural hearing loss. The "MCL" is the line of most comfortable loudness levels for this individual. This individual's hearing sensitivity places some of the speech spectrum below threshold making it not completely audible to this individual. His AI is 89%. Figure 3 is an aided Articulation Index for the same individual in Figure 2. Notice the increase in the AI from the unaided Articulation Index in Figure 2 which makes the entire speech spectrum audible to this individual with an aided AI of 100%. The aided Articulation Index can be greatly influenced by small changes in hearing aid gain. Figure 4 illustrates a reduction in hearing aid gain of 5 dB which reduces the aided Articulation Index of 46% shown in panel A, to an aided AI of 35% shown in panel B, for an individual with a severe to profound sensorineural hearing loss.

Individuals with sensorineural hearing loss have increased thresholds and in addition demonstrate a deterioration in suprathreshold sound processing (Pavlovic, Studebaker and Sherbecoe, 1986). Evidence that is both psychophysical and physiological indicates that both frequency resolution and time resolution are affected (Evans, 1975; Florentine et. al. 1980; Tyler et. al., 1980; Patterson et al., 1982; Fitzgibbons and Wightman, 1982; Festen and Plomp, 1983). A deterioration such as this can have adverse effects on suprathreshold speech processing. Previous research suggests that many individuals with sensorineural hearing impairment demonstrate poorer speech processing abilities than expected based on

## INTRODUCTION

The Articulation Index (French and Steinberg 1946) was designed to give a quantitative expression of speech intelligibility based on the fundamental characteristics of speech and the ears' capability of detecting these sounds. A speech spectrum can be divided into weighted parts which depend on their contribution to speech understanding. The AI is the sum of these weighted parts of the speech spectrum which occur above threshold, or the audibility of speech.

The Articulation Index is a numerical value from 0 to 1.0 percent which represents the proportion of the speech spectrum which occurs above threshold. The frequency range of interest is from 200-6000 Hz and the intensity range is 30 dB which represents the intensity fluctuations of speech. The amount of audible speech spectrum for that individual's thresholds is calculated and multiplied by 100 to give a percent score (Popelka 1983). The AI is based on speech at a normal conversational level, which is approximately 67 dB SPL.

There are two types of Articulation Indices that can be determined for an individual: these are the unaided Articulation Index and the aided Articulation Index. The comparison of these two indices will help determine the benefits of the particular hearing aid for that individual. The unaided Articulation Index is determined with the person's thresholds under earphones or in soundfield without the use of amplification. Unaided soundfield thresholds are measured with a soundfield system using a loudspeaker. The thresholds are obtained using a behavioral approach in which the individual raises his/her hand when a sound is detected. The stimuli are narrow-band are frequency-specific. The unaided soundfield thresholds are used with the aided soundfield thresholds to determine the real-ear gain of an individual's hearing aid. The only difference in the measurement of aided soundfield thresholds is that the individual is wearing his/her hearing aid(s). This allows for the measurement of real-ear gain. The determination of speech audibility that is provided by a hearing aid requires three types of measurements, 1) the measurement of speech spectrum, 2) the measurement of auditory their thresholds (Wilber, 1964; Plomp, 1978; Dugal et al., 1978; Tyler et al., 1980; Dreschler, 1983; Hannley and Dorman, 1983; Dubno et al., 1984; Pavlovic, 1984; Milner et al., 1984; Kamm et al., 1985).

Moog and Geers (1988) developed a speech perception test to differentiate the speech perception abilities of profoundly hearing impaired children. The Early Speech Perception Test (ESP) is a test designed to place children in four categories, depending on their speech perception ability.

Category 1: No Pattern Perception
This category includes children who cannot detect amplified speech, and children who can detect speech but have not developed the ability to discriminate speech patterns.

Category 2: Pattern Perception
The abilities in this category include children who can discriminate words or phrases that differ in durational pattern and stress.

Category 3: Some Word Recognition
Children in this category demonstrate the ability to use spectral information in discrimination. These children are able to discriminate among words containing highly differentiable vowel sounds along with stress and durational cues in a closet set of 2-3 choices.

Category 4: Consistent Word Recognition
This category includes the children with the ability to consistently discriminate among words and phrases which contain different vowel sounds. These children can use

spectral information with greater facility than those in Category 3.

The ESP identifies four categories of speech perception ability but it only assesses two. These are: categorical perception and word recognition. The first two categories of the ESP look at a child's ability to use categorical perception and the second two categories identify word recognition abilities. Each subject had word recognition ability. For the study, both word recognition and categorical perception abilities were measured with the ESP.

The direct measurement of speech perception ability is a time consuming process requiring the cooperation and attention of the child. Determination of the Articulation Index uses information about the child's hearing sensitivity and aided thresholds and is thus easier to obtain than direct measures of speech perception. The Articulation Index is designed to predict the amount of speech which is audible and is based on the identification of monosyllables. There have been studies which have compared the unaided Articulation Index with speech perception ability. (Kamm et al., 1985). They have found that the AI is unlikely to provide precise predictions about speech recognition performance among hearing-impaired listeners. The question that is addressed in this study is: do changes in the aided Articulation Index as the result of changes in hearing aid gain predict the concomitant changes in speech perception?

## METHODS

### Purpose

The purpose of this study was to determine if changes in aided Articulation Indices, caused by changes in hearing aid gain, predict changes in word recognition and pattern perception scores as measured by the Early Speech Perception test battery.

### Subjects

There were fourteen males and six females ranging from 6-13 years of age chosen as subjects. All of the subjects were students at Central Institute for the Deaf with with severe to profound sensorineural hearing losses. Each subject had Category 3 or 4 speech perception ability (Moog and Geers 1988).

Materials

The equipment used included the Early Speech Perception Test (ESP) (Moog, Geers 1988) which was administered through a digitized recording of the vocal stimuli on a computer (Macintosh Model SE). This insured that the speech stimuli were consistent throughout the testing. The ESP was administered in sound field. The words were presented through a loudspeaker in soundfield. The child was seated facing the speaker 2.5 feet away. The level of the stimuli was presented at 68 dB SPL. Articulation Indices were determined through the Phase IV program (Popelka 1983).

Conditions

Sound field aided thresholds were obtained from each child in two different conditions. The first condition was with the gain control of the child's hearing aid set to a value recommended by the school audiologist to optimize the child's aided Articulation Index. This was determined during an annual audiological evaluation. The second condition was with the gain of the child's hearing aid reduced 10 dB from the recommended setting. The volume control was turned down until the amount of coupler gain at 1000 Hz was reduced by 10 dB. The frequency response of the subjects' hearing aid affected the gain reduction at other frequencies.

There are two versions to the ESP, the Low-Verbal Version and the Standard Version. The Low-Verbal Version was created for young children with a very limited vocabulary. The Standard Version was administered for this study because all of the subjects had a sufficient vocabulary. The ESP consists of a Pattern Perception Test and two word identification subtests. The scores obtained from the ESP are in percent correct and give a pattern perception score and a word recognition score for spondees and monosyllables.

The Pattern Perception Test has been adapted from Glendonald Auditory Speech Perception Test (GASP, Erber 1981) and is designed to measure the child's ability to recognize temporal patterns in speech. Twelve words are presented in four different durational or stress patterns. There are 3 words each of monosyllables, trochees, spondees and three-syllable words for a total of 12 words. There are 24 possible points to each subtest because each word is presented twice. The child is presented the stimulus and must respond by pointing to a picture on a grid in front of him/her. A correct response on this subtest is obtained by identifying the correct category. A child scoring 17 out of 24 on the Pattern Perception Test has the ability to discriminate speech patterns and therefore has Category 2 speech perception ability.

The second part of the test is the Spondee Identification Test. This subtest evaluates the child's ability to perceive durational patterns in words. The Spondee Identification subtest can be used to determine if a child can perform in Speech Perception Category 3. Twelve spondees with widely differing vowels and consonants make up the stimuli. A correct response on this subtest is correct identification of the word that was presented. A child scoring 8 out of 24 on this subtest is considered to have sufficient word recognition skills to be placed in speech perception category 3 and the third subtest should be administered.

The third part of the test is the Monosyllable Identification Test. This subtest consists of twelve quite similar words and the discrimination of the words is based on finer vowel discrimination abilities than was required for the spondees. All of the words begin with /b/ and most end with a plosive. A child correctly identifying at least 13 out of 24 words on this subtest demonstrates the ability to be in speech perception category 4.

The ESP was administered to each child with the child's hearing aid set at the reduced volume setting. The scores for the ESP at the recommended volume setting were obtained through their annual audiological evaluation. The stimuli were presented at 68 dB SPL.

<u>Comparison of Data</u>

Each subject's aided Articulation Index was determined at the two gain control settings through the Phase IV program. The information needed for the Phase IV program was the following;

1. Thresholds under earphones for the individual
2. Unaided sound field thresholds for the individual
3. Aided sound field thresholds for the individual
4. Coupler-gain
5. Coupler-Maximum Power Output (MPO)

The aided Articulation Indices at the recommended and reduced gain control setting were compared to the speech perception scores at the same two settings. There was also a comparison in the amount of change in the aided AI and speech perception scores when the hearing aid gain was reduced.

Although the Articulation Index is based on word recognition, the child's performance on both the monosyllable subtest and the pattern perception subtest were compared to the aided AI. This was done to determine if the aided AI predicts pattern perception abilities in this sample.

RESULTS

Figure 5 illustrates the aided monosyllabic word recognition score (%) as a function of the aided Articulation Index (%). These data are obtained at the recommended gain control setting for each child. There was no correlation between the child's speech perception score and the aided AI.

Figure 6 illustrates the monosyllabic word recognition score (%) as a function of the aided Articulation Index (%) at the reduced gain control setting. This illustrates that there is no relationship between the aided AI and speech perception scores in this condition either.

Because there appeared to be no relationship between the actual aided AI and word recognition scores, the difference between the two measure was looked at more closely. The word recognition score from the second test condition was subtracted from the score in the first condition for each subject. The same equation was used for the aided AI. Figure 7 illustrates the difference in word recognition scores (%) as a function of the difference in the aided Articulation Index (%).

Figure 8 shows the relationship between the ratio of the two aided Articulation Indices measured and the ratio of the two speech perception scores measured. An example is a subject whose aided AI at the recommended setting is 70% and reduced aided AI is 35%. The reduced aided AI is divided by the recommended aided AI along the horizontal axis and the reduced speech perception score is divided by the recommended speech perception score along the vertical axis. The correlation between the AI and speech perception ratios, r= 0.41, was statistically significant.

Although the Articulation Index is based on monosyllable words, the relationship between the aided Articulation Indices and the pattern perception scores, obtained from the ESP, have a stronger relationship. There is a correlation of 0.49. Figure 9 illustrates this correlation as the two different test conditions are overlaid in this graph. The pattern perception scores (%) as a function of the Articulation Indices (%) for the individual subjects.

## DISCUSSION

The results indicate that AI changes as a result of hearing aid gain changes don't predict word recognition abilities in this sample. One would expect to see Articulation Index decreases with hearing aid gain reduction and similar decreases in speech recognition scores. These were not the results obtained in this study. There were large discrepancies between the AI decrease and speech perception score decrease. Subjectively, most of the children complained when the hearing aid gain was reduced. They were either unable to compensate for this gain change and did poorly on the speech perception test or the gain change did not make a significant change on the word recognition scores. There was no consistent performance among the subjects. This shows that word recognition scores as measured by the ESP shouldn't be the main determinant when deciding on recommended hearing aid gain control setting for a child.

There was no correlation between the Articulation Index and speech perception scores in this population. These results agree with a study by Kamm, Dirks and Bell (1985) in which they concluded the AI was a valid predictor for hearing impaired listeners with a mild to moderate sensorineural hearing loss and normal or near normal speech recognition scores. However, the AI was a poor predictor for a hearing impaired listener with low recognition scores. A reason for this may be due to the deteoration of suprathreshold sound processing found in individuals with sensorineural hearing loss (Pavlovic, Studebaker and Sherbecoe 1986).

The comparison of pattern perception scores to the Articulation Index for the different gain control settings did not show significant correlation (0.49). However, this was a stronger relationship than the aided AI compared to the monosyllabic word recognition scores. This indicates that it may be more effective to compare the aided AI to pattern perception scores than monosyllable identification for this sample.

Pavlovic (1983) found that the AI was not a good predictor for hearing impaired subjects. The subjects with the greater hearing impairment scored consistently lower, and exhibited a disproportionate loss in speech discrimination over and above that predicted on the basis of the AI procedure. Therefore, Pavlovic concluded that the AI does not predict speech discrimination scores of hearing-impaired individuals in its present form. Modifications of the AI are necessary to account for suprathreshold speech distortion. It appeared that the discrepancy from the performance predicted by the AI is directly related to the magnitude of hearing loss.

In conclusion, as there are varied speech perception abilities in severe to profound hearing impaired children, there are also varied performances when the hearing aid gain is reduced. Some of the subjects were able to compensate for the reduction in hearing aid gain and others were not. The Articulation Index is not an accurate predictor of these changes since its formula is consistent regardless of the population.

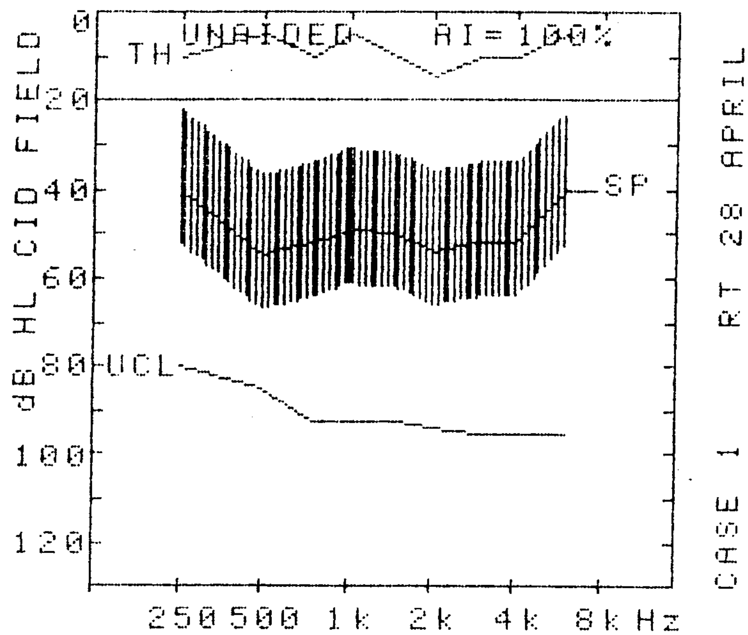



FIG. 1: The Articulation Index (AI) for an individual with normal hearing sensitivity. The shaded area is the speech spectrum and is completely audible to this individual which makes his AI100%

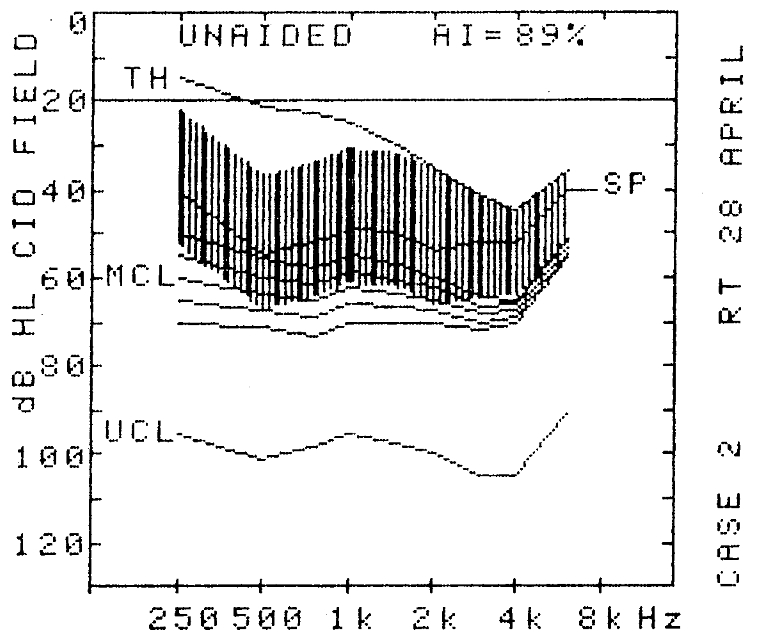



FIG. 2: The Articulation Index for an individual with a mild to moderate sensorineural hearing loss. The speech spectrum is not completely audible to this individual and his AI is 89%.

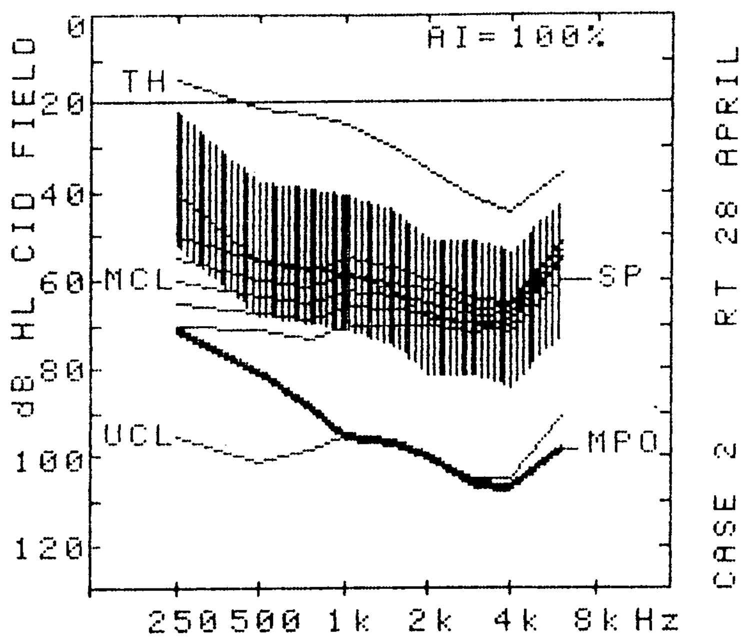
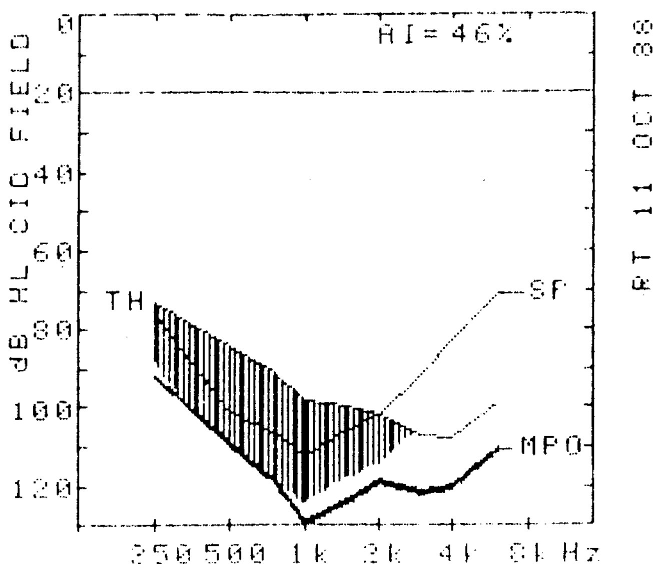



FIG. 3: An aided Articulation Index for the same individual in figure 2. This hearing aid improves this individual's AI bringing it up to 100%, making the entire speech spectrum audible.

FIGURE 4:

**GRAPH-A**




**GRAPH-B**

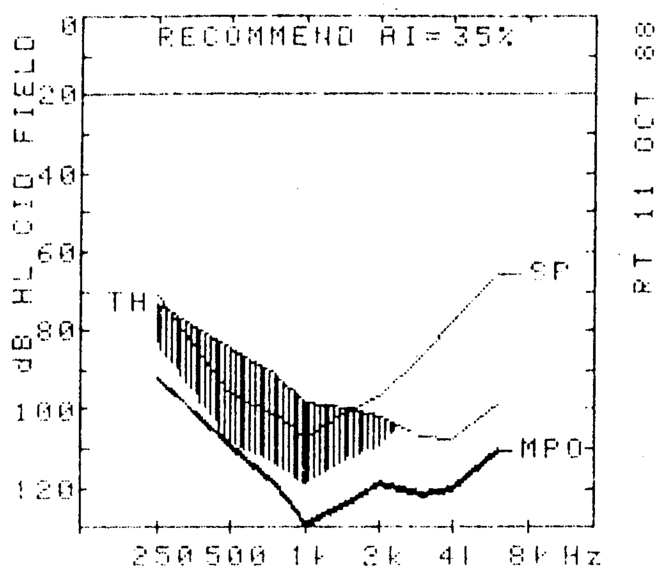



FIG. 4: This is illustrates a reduction gain of 5 dB and changes in the Articulation Index of 11% shown in graph A & B.

## FIGURE 5

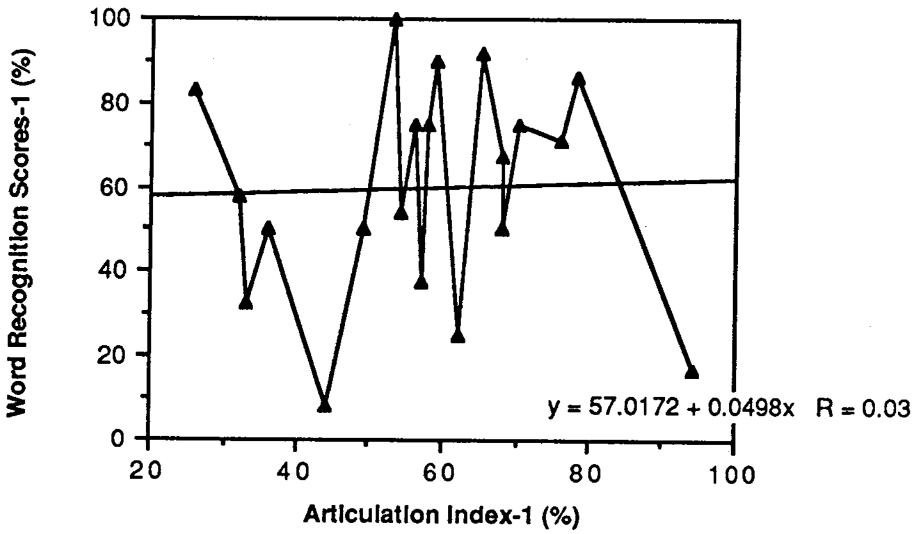



FIG. 5: The monosyllabic word recognition scores (%) as a function of the aided Articulation Index (%). These data were obtained at the recommended volume setting. The line is fitted by a linear regression line. The correlation is 0.03

## Figure 6

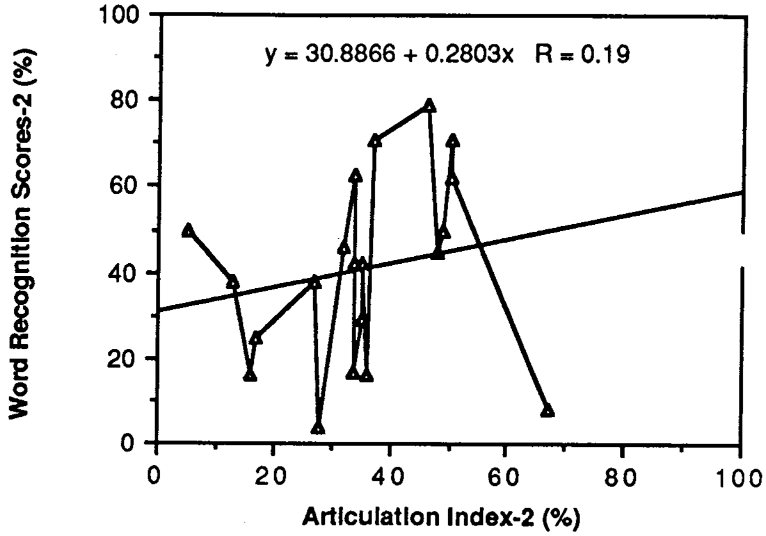



FIG 6: The monosyllabic word recognition scores (%) as a function of the aided Articulation Index (%). These data were obtained at the reduced volume setting. The line is fitted by a linear regression line. The correlation is 0.19.

## FIGURE 7

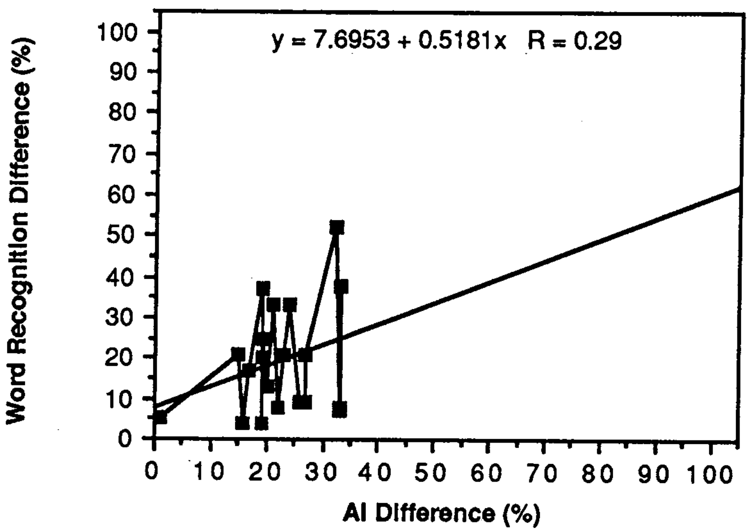



FIG 7: The difference in word recognition scores (%) as a function of the difference in the aided AI (%). The line is fitted by a linear regression line. The correlaton is 0.29.

## FIGURE 8

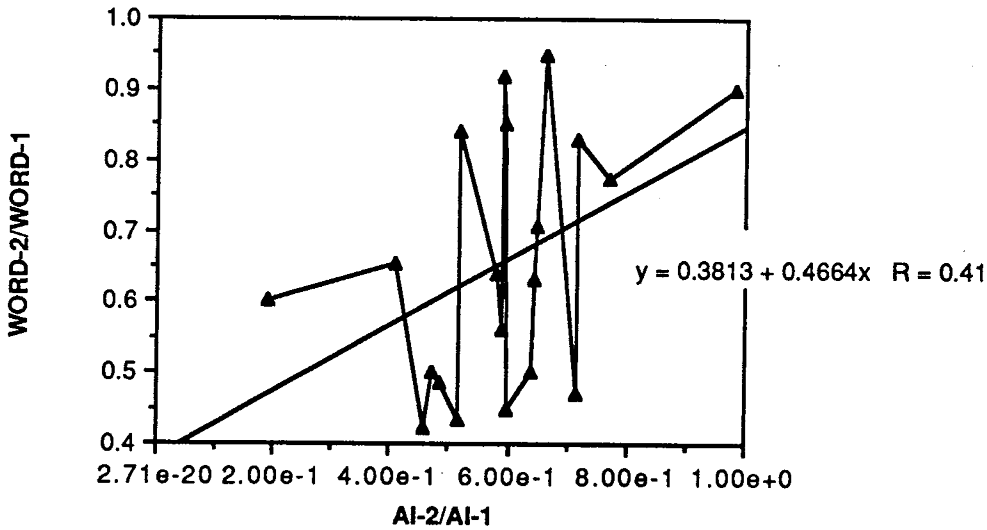



FIG. 8: A proportionate comparison of the two aided Articulation Indices and the two speech perception scores. The AI proportion is plotted along the vertical axis and the proportionate speech perception scores are plotted along the horizontal axis. The line is fitted by a linear regression line. The correlation is 0.41.

## FIGURE 9

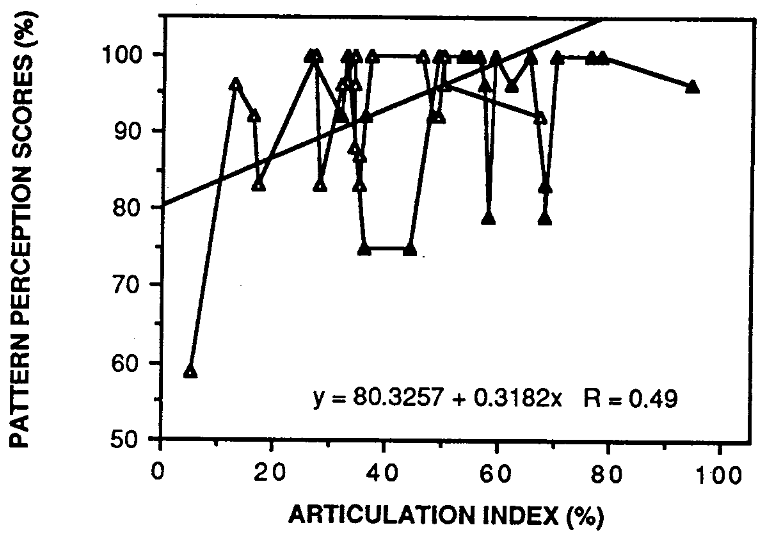



FIG. 9: The pattern perception scores (%) as a function of the aided AI (%). The closed triangle graphs the first test condition data and the open triangle graphs the second test condition data. The line is fitted by a linear regression line. The correlation is 0.49.

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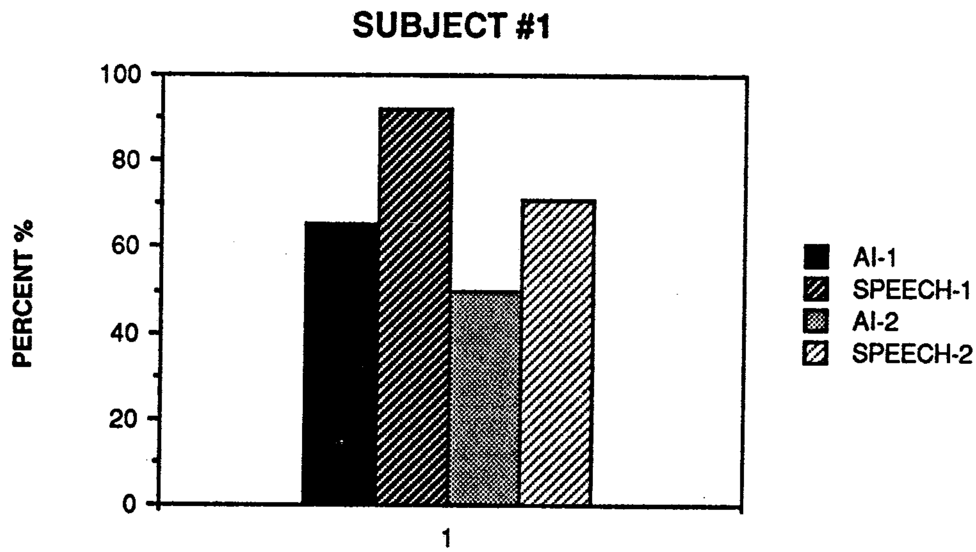
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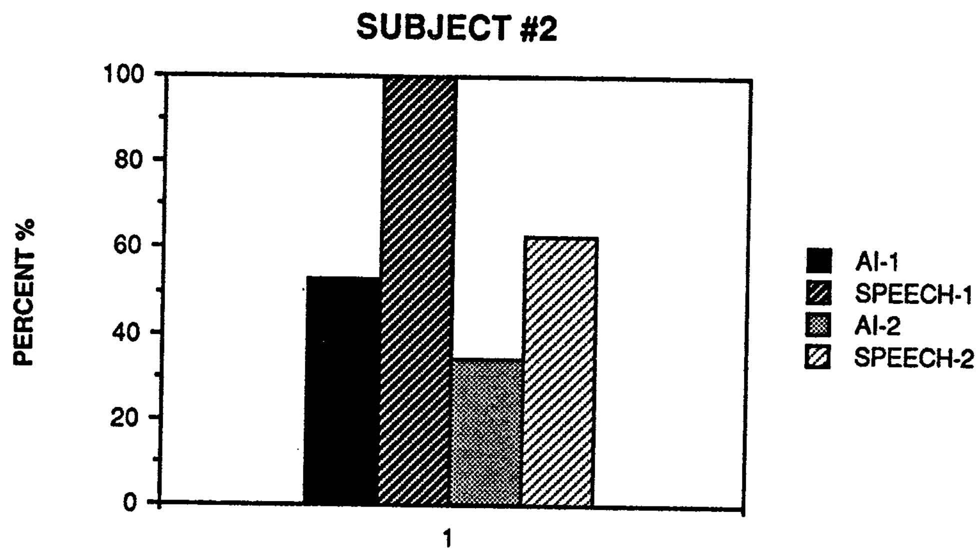
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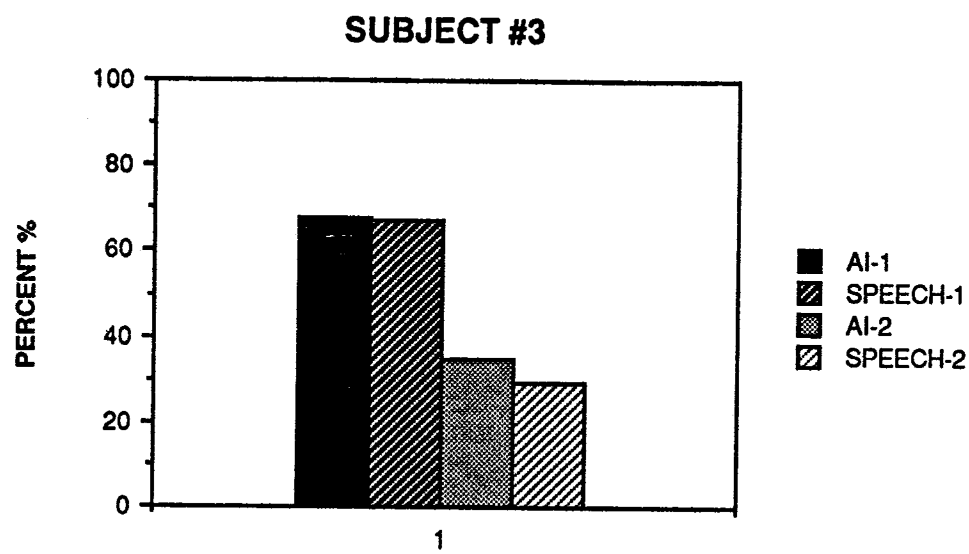
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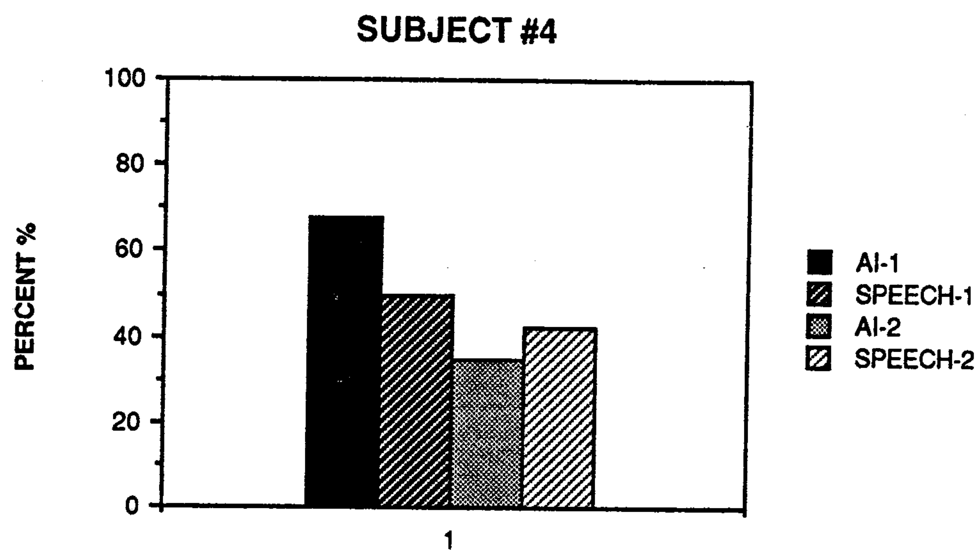
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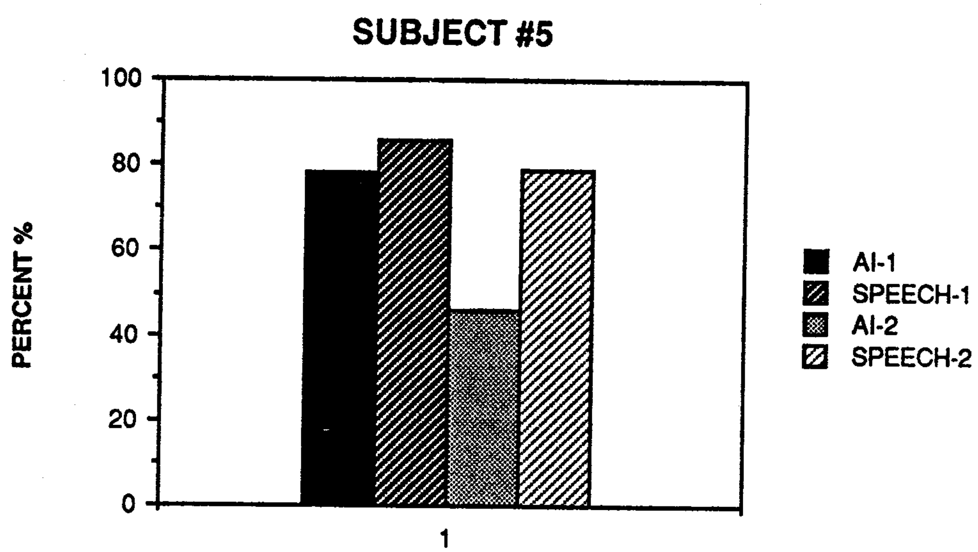
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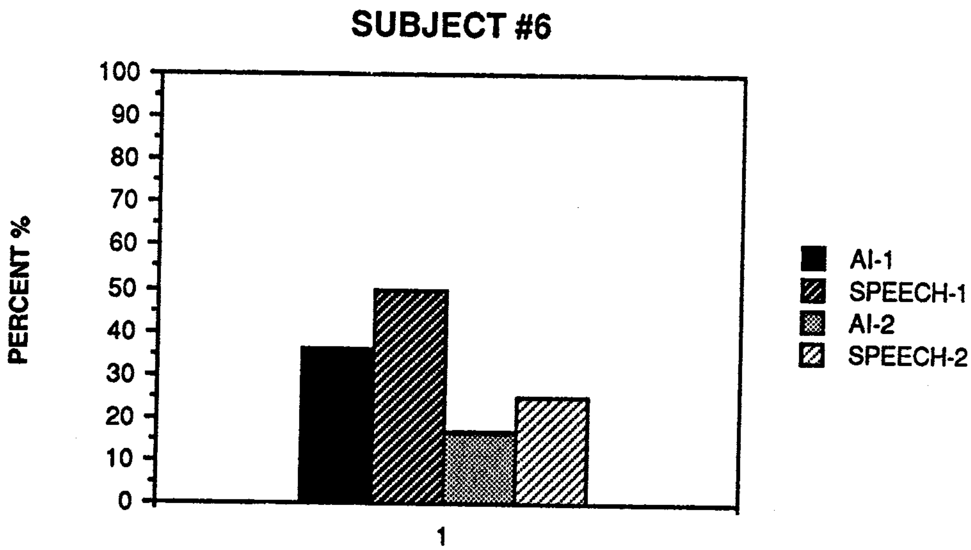
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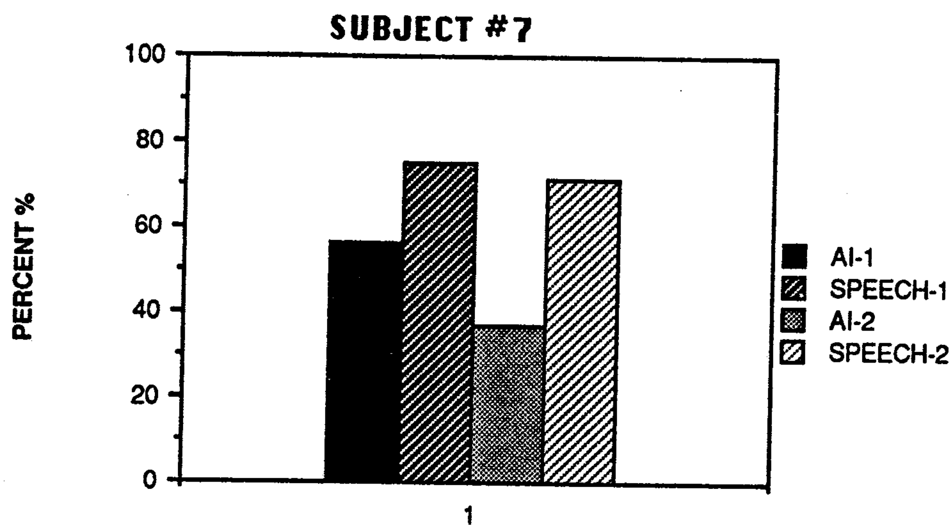
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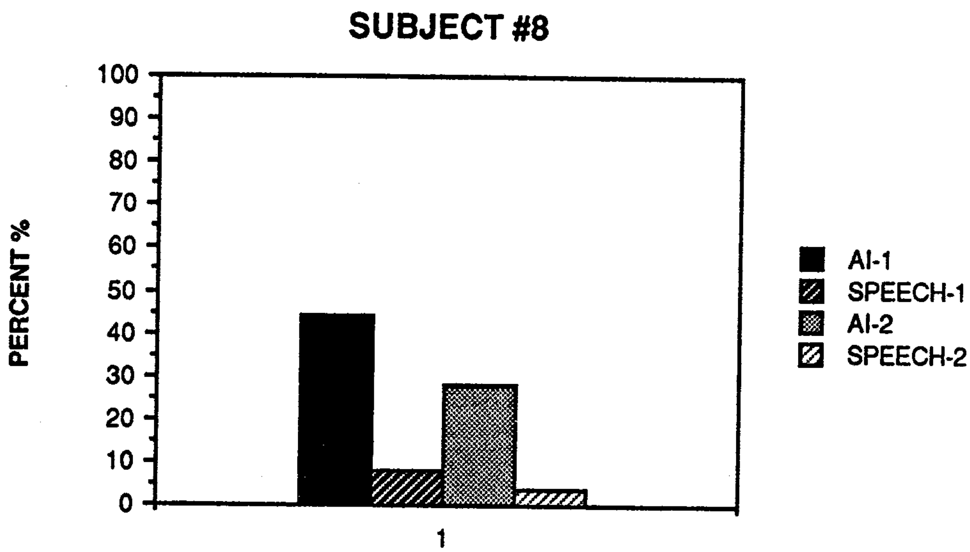
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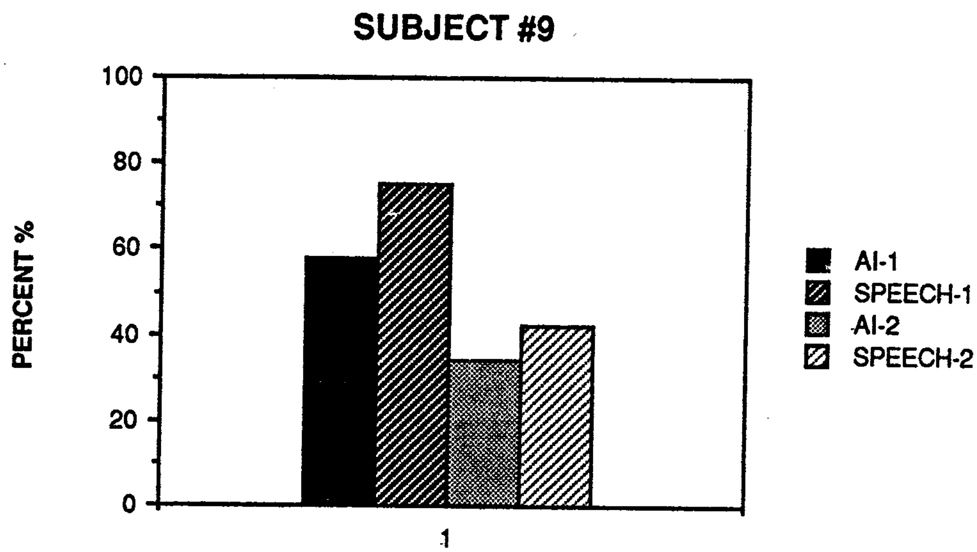
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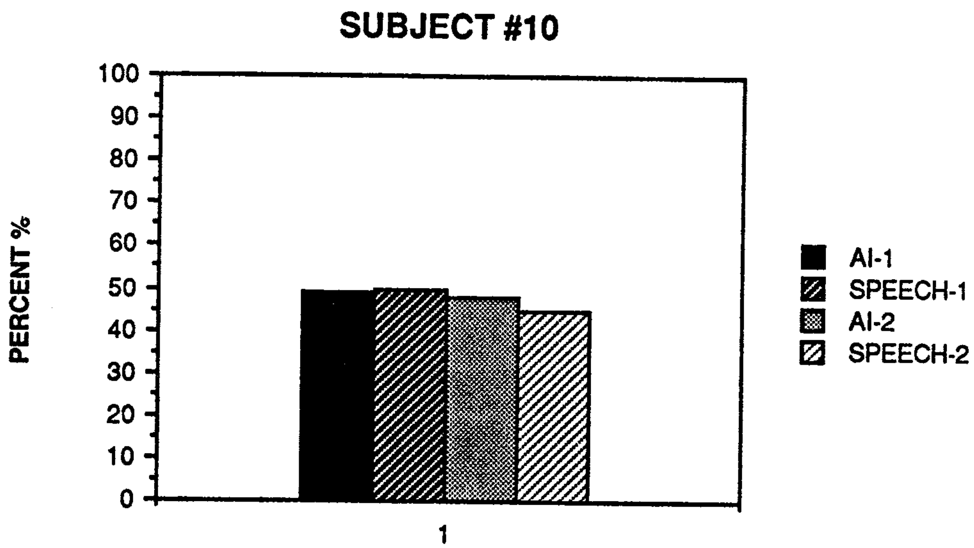
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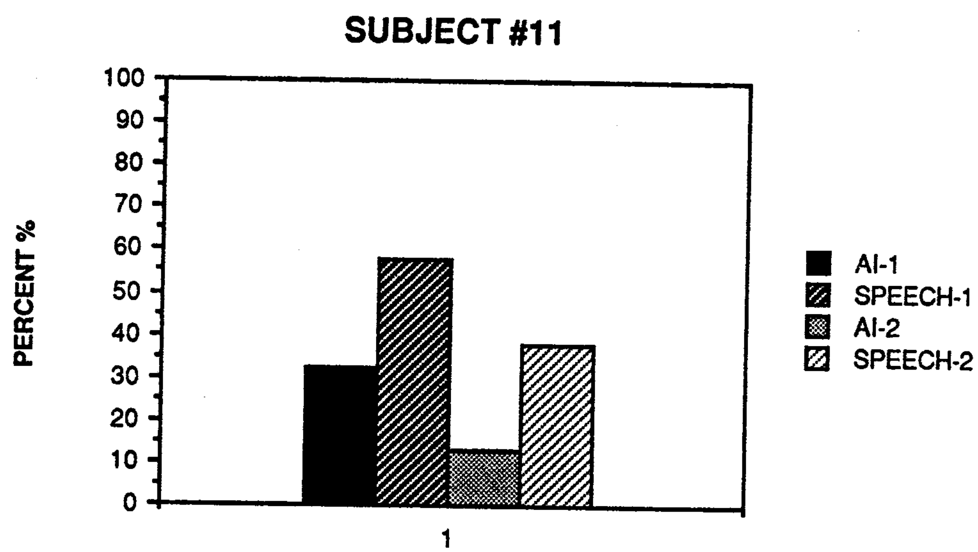
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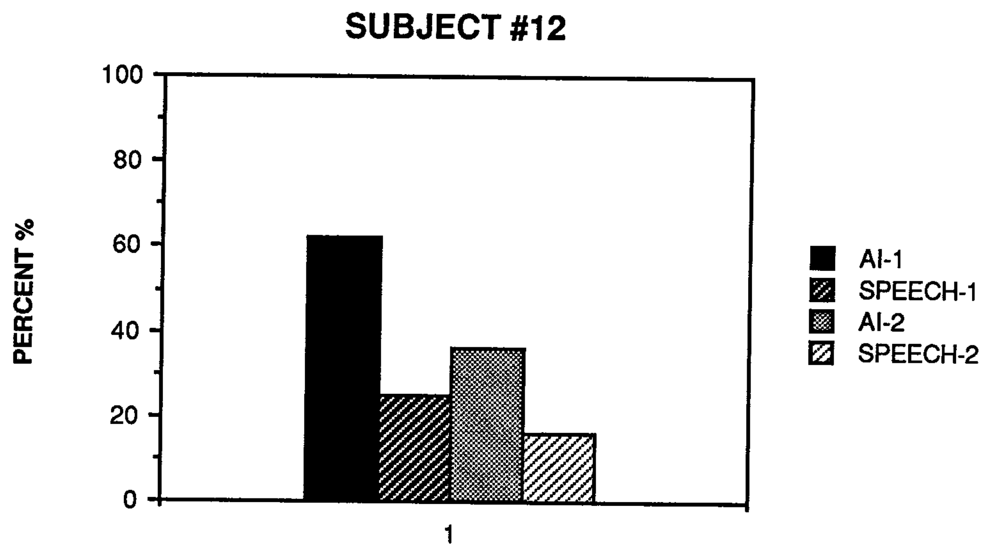
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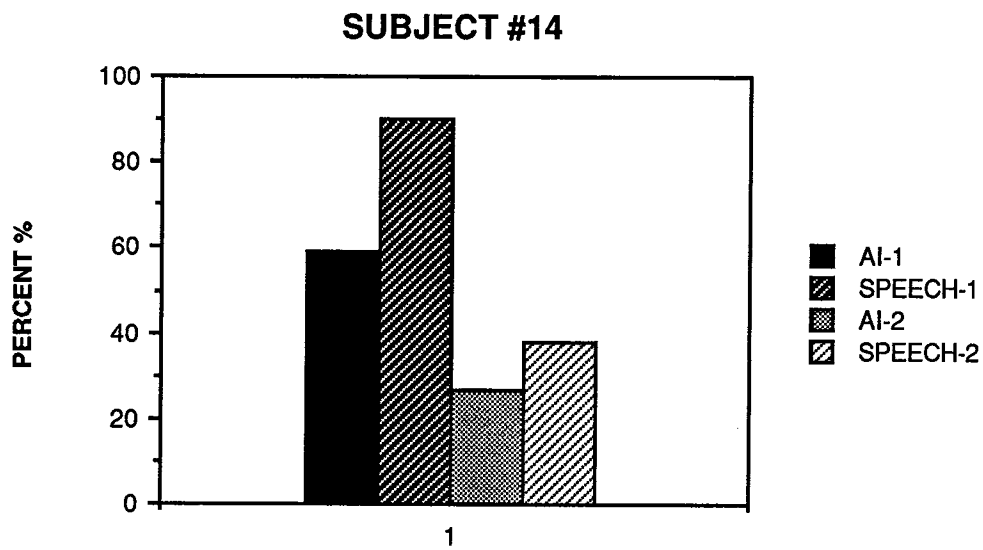
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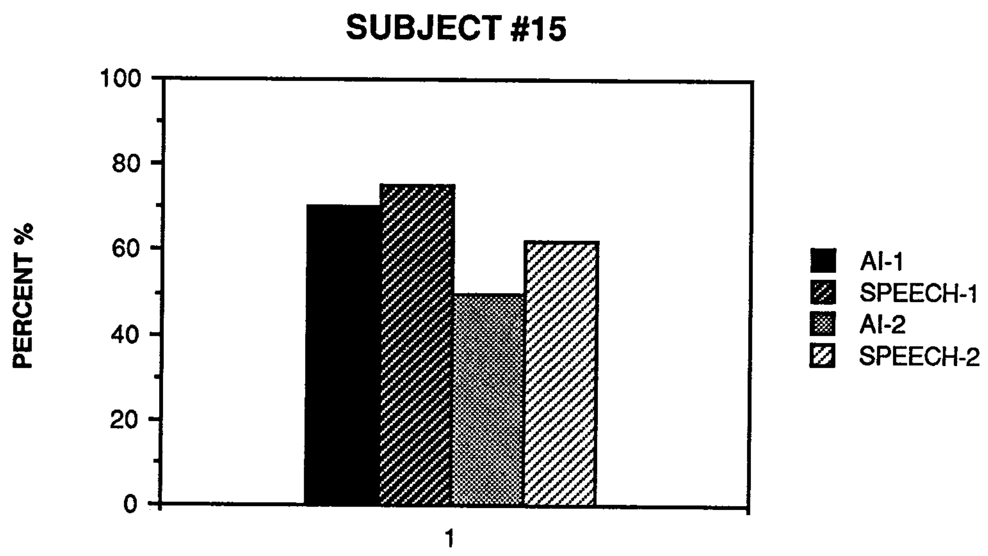
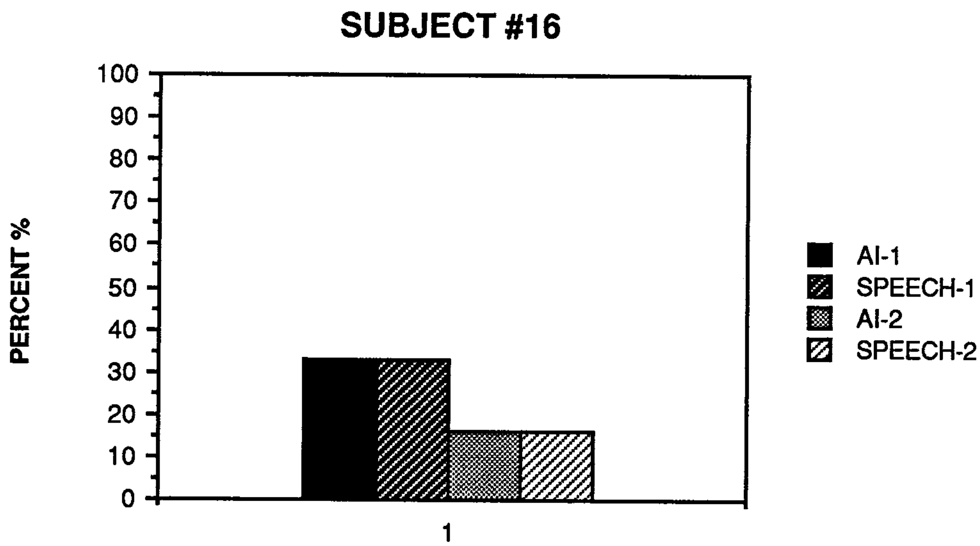
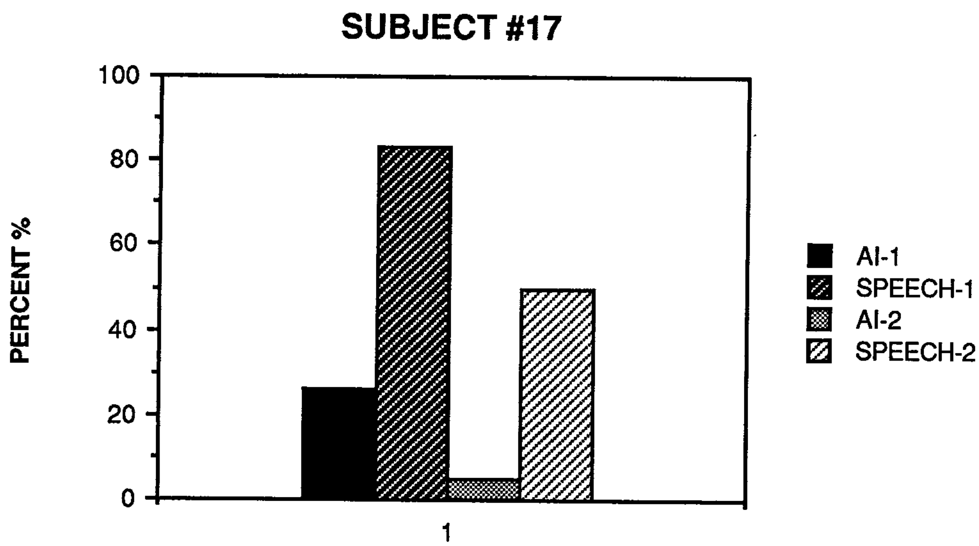
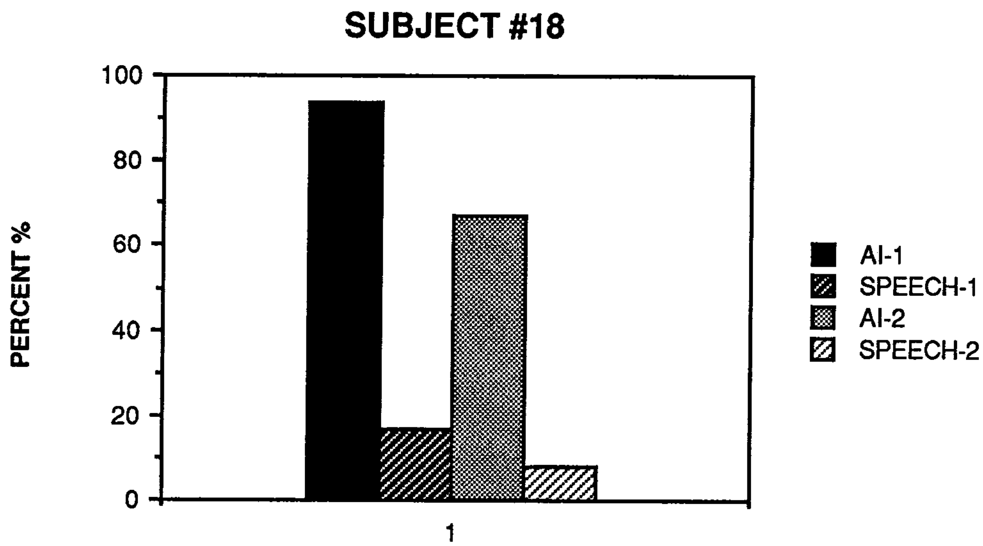
SPEECH-2


SUBJECT #15
100
80
60
40
20
0
PERCENT %
1
AI-1
SPEECH-1
AI-2
SPEECH-2


SUBJECT #16
PERCENT %
100
90
80
70
60
50
40
30
20
10
0
1
AI-1
SPEECH-1
AI-2
SPEECH-2


SUBJECT #17
100
80
60
40
20
0
PERCENT %
1
AI-1
SPEECH-1
AI-2
SPEECH-2


SUBJECT #18
PERCENT %
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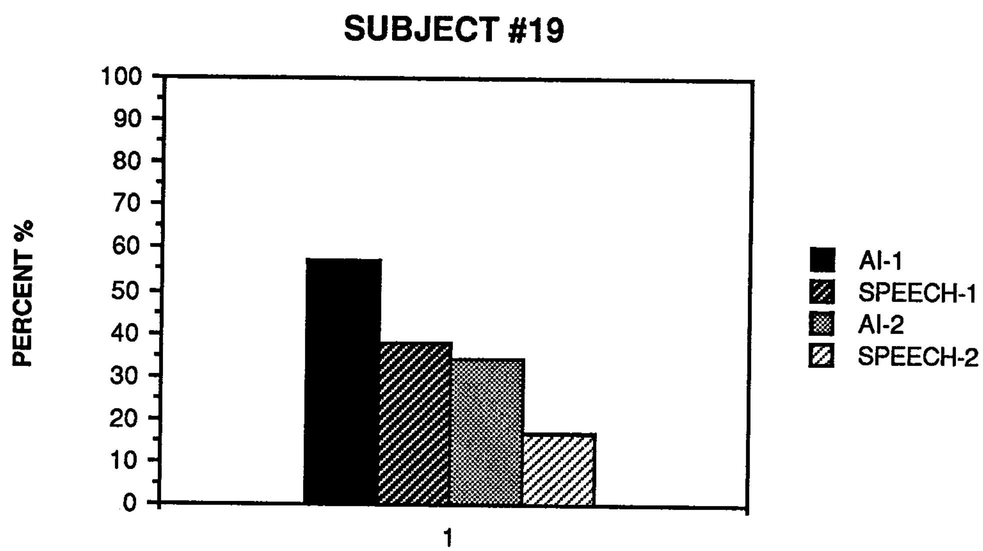
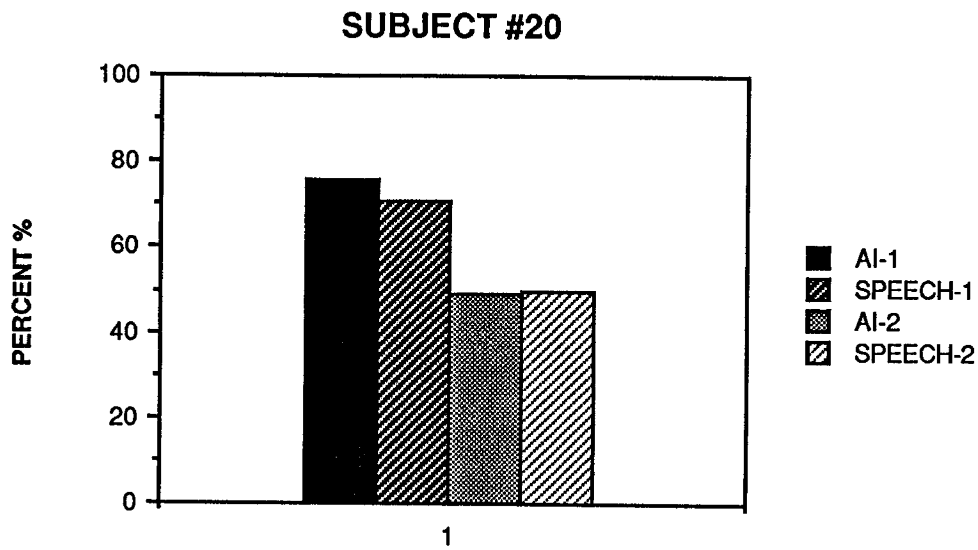
60
40
20
0
1
AI-1
SPEECH-1
AI-2
SPEECH-2


SUBJECT #19
PERCENT %
100
90
80
70
60
50
40
30
20
10
0
1
AI-1
SPEECH-1
AI-2
SPEECH-2


SUBJECT #20
PERCENT %
100
80
60
40
20
0
1
AI-1
SPEECH-1
AI-2
SPEECH-2