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Context Effects on the Auditory Perception of English by Adults Whose First Language is Korean

by

Marion Levine

A dissertation submitted to the Graduate Faculty in Speech and Hearing Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2000

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This manuscript has been read and accepted for the Graduate Faculty in Speech and Hearing Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

Context Effects on the Auditory Perception of English by Adults Whose First Language is Korean

by

Marion Levine

Advisor: Professor Arthur Boothroyd

The ability to perceive speech, particularly in degraded listening conditions is a function of receiving the sensory signal and the interpretation of that information. While speech perception by native speakers is highly resistant to vagaries of speaking patterns and linguistic information, noise and reverberation, speech perception by non-native speakers is not. Even highly proficient non-native speakers are much more susceptible to interference than are native speakers.

This study focused on linguistic context. The goals of this study were to measure and compare the effect of several linguistic components of context in quiet and noise, on speech perception by native and non-native American-English speakers.

Subjects were eight native American-English speaking college students and eight college students who spoke Korean as their first language. The Korean subjects had learned English between the ages of 0 and 13 years. There was no history of any hearing problems.

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Subjects listened to consonant-vowel-consonant words and nonsense syllables, and three types of sentences: a) high-probability, i.e., semantically and syntactically appropriate sentences, b) low-probability, i.e., semantically anomalous but syntactically appropriate sentences, and c) zero-probability, i.e., semantically and syntactically anomalous sentences (Boothroyd and Nittrouer, 1988). They listened to all stimuli in quiet and at signal-to-noise ratios of 3 and 0 dB. Subjeects repeated what they heard and all responses were recorded.

Three native American-English judges listened to these recordings and scored the words, syllables and phonemes as correct or incorrect.

The findings indicate that overall Korean students performed less well than English students did. The difference in performance increased with the addition of noise. The only exception was phoneme recognition in consonant-vowel-consonant nonsense syllables where there was no significant difference between the two group in quiet and in noise. The difference in performance also increased with increasing contextual information with the Koreans performing more poorly.

Both groups took advantage of context, although the English speakers took more advantage. English speakers took advantage of increased plausibility while the Korean spears did not.

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Both groups took advantage of word meaning to enhance phoneme recognition in consonant-vowel-consonant words, The two groups also took advantage of dependencies among phonemes when recognizing whole consonant-vowel-consonant words, but the English speakers took greater disadvantage.

Both groups took similar advantage of sentence syntax and word meaning to enhance recognition of consonant-vowel-consonant monosyllables.

Finally, the English talkers treated nonsense consonant-vowel-consonant nonsense syllables as three independent phonemes, while the Korean speakers tended to be negatively affected by the nonsense context.

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Context Effects on the Auditory Perception of English by Adults Whose First Language is Korean

Chapter 1

Introduction

All perception involves the acquisition of sensory evidence derived from physical stimuli and the interpretation of the evidence in terms of the objects and events that produced the stimuli. The result of perception is referred to as the percept. The percept is not the object or event being perceived but an internal representation of the object or event that is drawn from the perceiver's model of the world, built over many years as a result of perceptual and cognitive development. In arriving at a percept, the perceiver is heavily influenced by the context in which the stimuli are received. The mixture of direct sensory evidence and indirect contextual evidence applies in all forms of perception - including the perception of speech.

In the case of speech perception, the "event" producing the physical stimuli has many levels. The first level is the intent of the talker. The second level is the message chosen by the talker to satisfy that intent. The third level consists of the language patterns chosen to represent the message. The fourth level consists of the movement patterns used to encode the language patterns in spoken form. Finally, the fifth level consists of the sound patterns resulting from those

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movements. In this study the expression "speech perception" is used to refer to the recognition of speech elements – phonemes and words – presented to the sense of hearing. It is assumed that recognition occurs as a result of inferences based on a combination of:

1) auditory-sensory evidence derived from the speech stimulus,
2) contextual evidence contained within or around the stimulus,
3) the listener's knowledge and processing skill.

It must be stressed that this definition does not extend to the perception of sentence meaning, or of talker intent. It does, however, acknowledge that perception of meaning can influence the perception of the constituent words and phonemes.

Just as there are many layers to the speech stimulus, so are there many layers in the context. Individual speech sounds occur in the context of other speech sounds and in the context of words. Similarly, words occur in the context of phrases and sentences. And sentences occur in the context of narrative or conversations, with continuity of topic. Words and sentences must also refer to objects, events, and relationships within the real world to which language refers. The world therefore provides an additional context. Similarly speech perception involves communication among humans and there is, therefore, a social context. The three types of context just defined, linguistic, physical, and social, have both general and specific components. The general components are, respectively, the

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language, the physical world, and the social world shared by talker and listener. Specific contexts are respectively, language, surroundings, and persons (including the roles and purposes of those persons) involved in the immediate communicative exchange.

Native listeners, with normal language knowledge, world knowledge and social cognition have access to enormous amounts of contextual evidence when engaged in speech perception. It is, presumably, this abundance of redundancy that makes speech perception so resistant to the vagaries of pronunciation, accent, noise, reverberation and interference that conspire to reduce the amount and reliability of sensory evidence in the typical listening situation. It is a matter of observation, however, that non-native listeners, even those exhibiting fluency in their second language, are much more susceptible to interference than are native listeners. To the extent that their hearing can be assumed to be normal, it follows that the speech perception difficulties of non-native listeners must be attributed to an inability to take full advantage of the many potential sources of contextual information. Exactly what aspects of the context cause the most difficulty, however, is not clear.

The foregoing considerations provided the motivation for the research to be described. The general purpose of this study was to measure the use of several components of linguistic context by non-native listeners when attempting to perceive speech under difficult listening conditions.

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It was thought that, by measuring phoneme and word recognition with and without various sources of linguistic context, it would be possible to test the hypothesis that the speech perception difficulties of non-native listeners can be ascribed to limited use of context. At the same time, it might be possible to determine which layers of the context present the most serious problems.

The specific goals of this study were:

1) to measure word and phoneme recognition, in groups of native Korean-speaking and native English-speaking subjects, using several types of test material, presented in quiet and in noise,
2) to compare the groups in terms of performance on each measure, and
3) to compare performance for different materials within each group so as to obtain measurements of the use of different kinds of context.

The questions addressed were:

1) How do Korean and English talkers compare in terms of the recognition of words and phonemes, presented with the varying types of linguistic context, in quiet and in noise?
2) How do Korean and English talkers compare in terms of their use of various types of linguistic context to enhance word and phoneme recognition?

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Chapter 2

Review of the Literature

The literature review is in two sections. The first section deals with the effect of context on speech perception by native listeners. The second deals with the perception of a second language by non-native listeners.

Effect of Context on Speech Perception by Native Speakers

Native listeners have access to a great deal of contextual information when engaged in speech perception. There is research that has investigated various linguistic contexts and their influence on native listeners' speech perception. Traditionally, researchers have evaluated the effects of context by measuring performance under difficult listening conditions with and without a particular source of contextual information.

Hirsh, Reynolds and Joseph (1954) investigated nonsense syllables and single words to determine what effect lexical context[1] had on speech perception by

[1] "Lexical context" refers to the word or syllable within which a phoneme occurs. A nonsense syllable provides little or no lexical context. A meaningful word provides considerable lexical context. Even in a meaningful word, there are varying amounts of contextual information-depending on the frequency of occurrence. The amount of contextual evidence may also depend on the size of the "lexical neighborhood"-that is the number of words that sound similar to the target word.

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native listeners. The single words were of varying length to determine if word length was a significant factor in speech perception. They presented monosyllabic words, three types of disyllabic words (iambic, trochaic and spondaic), polysyllabic words and nonsense syllables in four signal-to-noise ratios from -13 to +5 dB. At 5 dB signal-to-noise ratio, subjects scored 100 percent on polysyllablic and disyllablic words but only 60 to 85 percent on monosyllabic words and nonsense syllables. When percent correct was plotted as a function of signal-to-noise ratio, spondaic words had the steepest curve of all the word lists. The fact that the function was steeper for spondees than for polysyllabic words is contrary to what one would expect if increased contextual information affected speech perception positively. Hirsh et al., (1954) attributed this result to the fact that spondees have equal stress on both syllables as opposed to the polysyllabic words where only one syllable is stressed. They argued that the increased decibel level of both stressed syllables in the spondees accounted for the better results of spondees over the polysyllabic words.

In a related experiment presented in the same paper, Hirsh et al., (1954) required subjects to listen to the same word lists used in the signal-to-noise experiment using high-and low-pass filtering. Speech perception was not seriously impaired until the high-pass filters eliminated frequencies below 3200 Hz and the low pass filters eliminated frequencies above 800 Hz. In this case, when percent correct was plotted as a function of cut-off frequency, the polysyllabic words had the steepest function and spondees had the second steepest. Hirsh et al. argued

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that the level of the signal was of greater importance in the masking experiment than in the filtering experiment.

Hirsh et al., (1954) also created sentences from the word lists used in the above two experiments. They had too few sentences presented too often to yield valid results. However, they reported the measurements made of the first few presentations of the sentences at several signal-to-noise ratios. They found that the sentences had a steeper function (percent correct as a function of signal-to-noise ratio) than any of the types of words presented in isolation. The difference between recognition of the different word types was reduced and sentential context had the greatest effect on the recognition of monosyllable words.

Rosenzweig and Postman (1957) evaluated the effect of the frequency of occurrence of words on word recognition. They had subjects listen to lists of monosyllabic words at four ranges of frequency of occurrence: one to three occurrences, 10 to 33 occurrences, 100 to 330 occurrences and 1000 to 3300 occurrences in 4.5 million words. These lists were presented in order of ascending signal-to-noise ratios, in four dB steps, from -12 to +8 dB and then in quiet. Thresholds (lowest level at which correct word recognition first occurred) for the least frequently used words (one to three occurrences in 4.5 million) were 12 dB higher than thresholds for the most frequently occurring words (1000 to 3300 per 4.5 million). In the same paper, the authors reported a similar study in French with native French speakers with similar results. As the frequency of word

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occurrence increased, the subjects were able to respond correctly in more noise. Thus, the probability of a word occurring can be perceived as contextual information and as such influences speech perception.

Howes (1957) examined the effects of frequency of occurrence and word length on recognition. In this study, word length was determined orthographically by the number of letters in the words, from one to 21 letters. To ascertain the validity of using orthography to choose stimuli to be presented orally, Howes ran correlations between number of letters and number of phonemes (r=+0.972) and number of letters and number of syllables (r=+0.923). He presented words of different frequencies of occurrence and different lengths at seven signal-to-noise levels from -9 to +20 dB. Responses were written. Results showed an inverse relationship between frequency of word occurrence and signal-to-noise ratio for a given percent correct score. Howe's study and those of Rosenzweig and Postman (1957) both demonstrate that the accuracy of perception of words in noise increases with increasing frequency of occurrence.

Giolas and Epstein (1963) compared the recognition of words in continuous discourse with the recognition of single words in isolation. They used the Harvard PB-50 Word Lists, the Central Institute for the Deaf (W-22) Monosyllabic Word Lists, and continuous discourse and presented them in quiet and six low-pass filtering conditions, from 540-2000 Hz. In the unfiltered condition, scores for all the speech stimuli were 100 percent. When filtering was added, loss of

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intelligibility for continuous discourse did not occur until the 1200 Hz low-pass filtering condition was reached. After that there was a gradual loss of intelligibility to 75 percent in the 540 low-pass filtering condition. Loss of word intelligibility for monosyllables dropped from 100 percent with no filtering to 75 percent with a 2000 Hz low-pass filter. As the filtering was increased, the slope of intelligibility loss was much steeper for the monosyllable words than for continuous discourse. Thus, continuous discourse appears to be more resistant to the effect of filtering than are single words. One can assume that this difference can be attributed to the contextual information found in continuous discourse.

Miller, Heise and Lichten (1951) used two subjects to explore context effects in terms of set size. They also examined the effect of sentence context and repetition on open set recognition. They varied set size from two to 256 words. Results showed that as set size increased, the signal-to-noise ratio required to obtain a given percentage score also increased. Thus, set size was a significant context variable in speech perception when using a forced-choice task. Of particular relevance to the present study was the work Miller et al. did in comparing the intelligibility of words in isolation and in sentences. They presented stimuli in signal-to-noise ratios from -12 to +18 dB. The scores for the words presented without sentence context were as much as 30 percentage points lower than the same words presented in sentences. When the words were presented in isolation, subjects needed 6 dB more signal-to-noise ratio to obtain 50 percent correct recognition than when the words were presented in

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sentences.

Kalikow, Stevens and Elliott (1977) developed the Speech in Noise (SPIN) test to evaluate the effect of high and low word predictability on word recognition in sentence context. There are 50 sentences in each of eight lists of the test. The sentences were balanced for acoustic-phonetic components with the last word of each sentence having either high or low-predictability based on the context of the sentence. "Harry sleeps on the folding cot" is an example of a sentence that ends in a high predictability word, one that makes sense and would come to mind readily if the final word were left blank. "I want to speak about the crash." is an example of a sentence ending with a low-predictability word, that is, one of a large body of words that makes sense in that sentence.

Kalikow et al., (1977) established norms for two subject groups. Ten young subjects from 18 to 25 years and ten older subjects from 60 to 75 listened to test lists in four signal-to-noise ratios (-5 to 10 dB) and repeated the last word of each sentence. Scores were generated for high- and low- predictability words. Results showed greater percent correct recognition scores for high-predictability words in all signal-to-noise ratios. As signal-to-noise ratios deteriorated, high predictability functions fell much more rapidly than did the low- predictability functions. Scores for older subjects were slightly below those of the younger subjects. The arithmetic differences between the high- and low- predictability scores were examined as a function of the low-predictability scores. The

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maximum difference between the two was 40 or 50 percentage points for both age groups. This difference was used as a measure of context effect.

Elliott (1979) administered the Speech in Noise Test to children 17, 15, 13, 11 and 9 years old at -5, 0 and 5 dB signal-to-babble ratio. The 15 and 17 year old subjects performed comparably to Kalikow et al.'s (1977) population. The 13 and 11 year olds performed less well on the high-predictability sentences. The 9 year olds did the poorest of all the age groups on both the high- and low-predictability sentences. These findings indicate that the 11 years olds in this study were not as adept or capable of using linguistic context (High-Predictabiliity=75% in signal-to- babble=0 dB) as 15 and 17 year olds (High-Predictability=90% in signal-to-babble=0 dB) and adults.

Boothroyd and Nittrouer (1988) compared the effects of several different types of linguistic context on speech perception. First, they examined the effect of word context on phoneme recognition. They presented lists of consonant-vowel-consonant words and lists of consonant-vowel-consonant nonsense syllables in noise, and found that the probability of phoneme recognition in words is about 10 percentage points higher than it is in nonsense syllables and the probability of recognition of the whole syllable is 20 to 30 percentage points higher for words than for nonsense syllables. These findings are in keeping with those of Hirsh et al., (1954) reported earlier.

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Boothroyd and Nittrouer (1988) then measured context effects in sentences and went one step further than Kalikow et al., (1977) and Elliott (1979). They developed materials to assess separately the effects of semantic and syntactic aspects of sentence context. They created three types of four-word sentences. One type was sententially correct, labeled high-probability. An example of a high-probability sentence would be "Birds like long worms." A second type of sentence was semantically anomalous and syntactically correct (low-probability) for example, "Cups kill fat leaves." The third type of sentence was semantically and syntactically anomalous (zero probability) for example, "Sing his get throw." They used these materials to measure and compare the effects of semantic and syntactic context on the recognition of words in noise. They found that the probability of word recognition in high-probability sentences was 20 to 35 percentage points higher than in low-probability sentences. Recognition of whole sentences in high-probability sentences was as much as 60 percentage points higher than in the zero probability sentences. The authors quantified context effects in terms of a k factor.[2] Using this measure, semantic context had the greatest context effect. It was two and a half times greater than that of the syntactic context. Their findings demonstrated that, in addition to lexical and semantic context, syntactic context affects speech recognition.

In summary, the literature shows that speech perception by native speakers is affected by context. These context effects were investigated by measuring the

[2] The k factor is derived from measurements of recognition probabilities for units presented with and without context. K is the ratio of the logarithm of the two error probabilities.

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perception of stimuli with and without varying degrees of contextual information under difficult listening conditions. The results showed that speech perception was affected to varying degrees by different types of linguistic contexts and as contextual information increases, phoneme and word recognition also increase.

Speech Perception by Non-native Speakers

Fluent non-native speakers may perceive their second language just as well as native speakers of that language do when the listening environment is quiet. However, non-native speakers - even fluent non-native speakers – have greater difficulty perceiving the second language than native speakers do when interference is present.

Rosenzweig and Postman, in their 1957 study, mentioned earlier, investigated the effect frequency of word occurrence had on speech perception. Their study included 87 American-English speakers (reported earlier), and 10 bilingual students (those who had English and another language as their first language) and 12 foreign students (those who had a language other than English as their first language). They presented words in various signal-to-noise ratios. The frequency of occurrence of these words varied between 1 and 200,000 occurrences per 4.5 million words. In all three groups, as the frequency of word occurrence increased the signal-to-noise ratio at which words were perceived with a given accuracy decreased. The English speakers' thresholds (lowest level at which correct word recognition first occurred) were the lowest and the foreign

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speakers' the highest. There was no statistically significant difference between the English and the bilingual groups, but there was a significant difference between these two groups and the foreign group. While the thresholds differed among groups, the inverse relationship between frequency of occurrence and threshold was similar for all three groups. As stated earlier, the probability of a word occurring can be seen as a form of contextual information and can, therefore, influence speech perception -- the greater the frequency of occurrence the more likely it will be perceived correctly. The non-native speakers, however, were handicapped by noise even though the frequency of occurrence still had an effect.

Gat and Keith (1978) investigated the ability of non-native speakers from various linguistic backgrounds and native American-English speakers to recognize CID W22 words in isolation. They had three groups: 6 non-native speakers with one year's experience using English in the United States, 6 non-native speakers with three to four years' experience using English in the United States and 6 native American-English speakers. They were presented with the word lists in quiet and in signal-to-noise ratios of 12, 6 and 0 dB. All groups did relatively well in quiet. Non-native speakers' mean percent correct scores dropped about 20 percentage points from quiet to 12 dB signal-to-noise ratio and then another 20 percentage point drop from 6 dB signal-to-noise ratio to 0 dB signal-to-noise ratio with the least experienced group doing less well than the more experienced non-native speakers. Between 12 and 6 dB signal-to-noise ratios there was a drop of five

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percentage points or less.

The English speakers' scores dropped only about 10 percentage points at the signal-to-noise ratio of 12 dB and another 10 percentage points at the signal-to-noise ratio of 0 dB. The percentage points scores at 12 dB and 6 dB signal-to-noise ratio were also less than five percentage points. This study indicates that non-native speakers even with up to three years experience speaking the language are less able than are native speakers to recognize words in noise.

Takata and Nabelek (1990) compared the effects of noise and reverberation on speech perception by subjects whose primary language was English or Japanese and whose ages ranged from their early 20's to their early 40's. The non-native speakers had studied English for at least six years starting at the ages of 12 or 13 years. The Modified Rhyme Test (Kreul, Nixon, Kryter, Bell, Lang and Schubert 1968) was presented in a signal-to-noise ratio of -3 dB, a reverberation of 1.2 seconds and in quiet (absence of noise and reverberation). Both groups scored 95% or higher on the Modified Rhyme Test presented in quiet. The Japanese subjects performed significantly less well (8 percentage points) in noise and reverberation than did the Americans.

Nabelek and Donahue (1984) compared native American-English speakers to non-native speakers in their perception of consonants in reverberation. Each group had ten people who met the following criteria: young or middle aged adults

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with normal hearing and scores of at least 94% on the Modified Rhyme Test. All of the non-native subjects had learned English as teenagers. The recordings of the Modified Rhyme Test were presented with reverberation times of t= 0.4, 0.8 and 1.2 seconds. Native and non-native speakers' scores were compared. In quiet, mean scores for both groups were 98%. In t=0.4 s non-native speakers' scores were 6 percentage points lower, and in t= 0.8 and 1.2 s non-native speakers' scores were 10 percentage points lower, than the native speakers' scores. Thus, as reverberation time increased, the perception by non-native speakers deteriorated relative to that of native speakers. Nabelek and Nabelek (1985) found that a 1.2 seconds reverberation rate was generally considered acceptable for normal hearing native listeners in an auditorium. Thus, it appears that the speech perception of non-native listeners suffered not only in obviously difficult listening situations but also in environments that native speakers find acoustically acceptable.

Mayo, Florentine and Buus (1997) administered the Speech in Noise (SPIN) test (Kalikow et. al. 1977) to four groups of children: (1) those who learned their second language in infancy, (2) those who learned their second language as toddlers, (3) those who learned their second language post puberty and (4) monolinguals. First, all four groups were tested in quiet. Subjects who scored 96 percent or better were then tested at various noise levels to determine their Noise Tolerance Level, the level where they scored 50 percent correct. The Noise Tolerance Level for high-predictability sentences for those who learned

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their second language post puberty was 5 to 6 dB lower than the monolinguals or bilinguals who learned their second language before they were six years old. For the low-predictability sentences, the post-puberty learners scored 4 to 6 dB lower than the other groups.

The researchers then plotted the groups' percentage correct responses at each of several noise levels (50-75 dB SPL). The average slopes for high- and low-predictability sentences were highest for the monolinguals, that is, their percentage correct scores improved the most as the noise was decreased. The subjects who were bilingual since infancy and those bilingual since being toddlers had slopes that were lower than that of the monolinguals. The post-puberty learners had the least steep slope. In the first three groups there was a marked difference within each group between high- and low-predictability scores, but in the post-puberty group the scores were almost the same and comparable to the low-predictability scores of the subjects who were bilingual since six years old or before. Thus, it seems that those learning a language before six years make better use of semantic information than those who learn a language post puberty. It should also be noted that while the early bilinguals made better use of contextual information than did the post puberty group, they did not use it as well as the monolinguals.

Crandell and Smaldino (1996) studied the effect of noise on speech perception by non-native speakers. They administered the Bamford Kowal Bench Standard

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Sentence (BKB) Test at five signal-to-noise ratios ranging between 6 and -6 dB. Their subjects were 40 children (20 native English listeners and 20 non-native listeners) from eight to ten years old. All the non-native listeners began to speak English by the age of two years, and they spoke it at least 50% of the time at home. In quiet, both groups performed well. Scores were 99.9 percent for native speakers and 98.9 percent for bilingual speakers. In noise, however, the non-native speakers' scores were poorer, and, as the signal-to-noise ratio decreased, the non-native scores decreased significantly more than did the native speakers' scores. The difference was 4 percentage points at a 6 dB signal-to-noise ratio and nearly 25 percentage points at a signal-to-noise ratio of -6 dB. These results are different from those of Gat and Keith (1978), who found that while the non-native listeners did less well in noise than the natives, they tended to parallel the native speakers' slope in different signal-to-noise levels. A possible explanation for this discrepancy might be found in Elliot's (1979) research. She found that children below the age of 11 do not perform as well in their native language on the SPIN test as 15 - 17 year olds and adults. In fact, the youngest children in Elliot's study, those between eight and ten years old performed least well of all her groups. She concluded that these children were not adept at using semantic information in degraded listening conditions. Crandall and Smaldino's population was nine year old children. It is possible that nine year old bilinguals would be less able than monolinguals to use linguistic information, in either their native or non-native language, as the interference increased.

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Buus, Florentine, Scharf and Canevet (1986) investigated English speech perception by four native American-English speakers and 14 native French speakers with minimal, moderate and extensive experience in English. Those subjects with minimal experience in English had 1.5 to 4 years' English language instruction and had visited an English speaking country briefly. The moderately experienced group had more than four years of English language instruction and had lived in the United Kingdom or the United States for one to two years. The most experienced group had extensive language instruction and had been living in the United States over four years and had been speaking English daily. The subjects listened to sentences that were chosen to be representative of everyday language. All native French and English speakers scored 100% in quiet. Buus et al. presented the stimuli at 70 dB SPL in different noise levels to determine the subjects' Noise Tolerance Level, the point where the subjects perceived 50% of the sentences correctly. Native English speakers had an average Noise Tolerance Level of about 71 dB SPL (s/n=−1 dB); non-native speakers with the most experience with English, 68 dB SPL (s/n=2 dB); moderately experienced listeners, 63 dB SPL (s/n=7 dB); and the least experienced group, 59 dB SPL (s/n=11 dB). The difference of Noise Tolerance Levels between the native speakers and the least experienced non-native speakers was 12 dB. These results using sentence material are in agreement with Gat and Keith's (1978) findings using monosyllabic words, that is, more experienced non-native listeners of English can perceive speech in noise interference better than less experienced listeners, but not as well as native listeners.

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So far, the papers reviewed support the assumption that non-native listeners, who have excellent speech perception of English in quiet conditions, have greater difficulty in perceiving in degraded listening situations. Some of the research reviewed indicated that increased experience in the second language reduces the problem of speech perception in noise. However, there is additional research that shows the effects of speaking a second language can persist for many decades.

In examining the effects of aging on speech perception, Bergman (1980) discovered a group of non-native speakers whose scores were significantly different from those of the rest of the population tested. He found that the non-native English speakers who were 60-69 years old perceived speech less well in degraded listening conditions than did the same aged native English speakers. This was so even though the subjects had been speaking English for an average of 50 years

A second study by Bergman (1980) in Israel examined the effects of aging and second language perception. The subjects were divided into four groups: native Hebrew speakers aged 20-29 year; native Hebrew speakers aged 50-77 years; and two groups of non-native Hebrew speakers, similar to the native speakers in age. The non-native speakers had been speaking Hebrew for at least 13 years but had spoken another language at least until the age of seven years. The

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subjects listened to undistorted everyday Hebrew sentences in quiet and in noise with a signal-to-noise ratio of 3 dB. There was a significant decrement in speech perception in quiet only for non-native Hebrew speakers over 60 years old. The speech in noise test results showed a significant decrement in speech perception of 13 percentage points for non-native speakers in the younger age group, as compared to native speakers. The older age group was divided into two groups: 50-60 and 61-70 years old. The older groups performed less well in the noise than the younger group; the older non-native speakers performed approximately 15 percent less well than the older native speakers. So it seems that the problems of speech perception in a second language in noise do not go away with time and use, even with 50 years of use. Further, this last study indicates that the effect of aging combined with second language has an adverse effect on speech perception in quiet.

The research reviewed to this point has measured non-native listener's speech perception using different types of noise and/or reverberation rates. However, in everyday listening situations the noise frequently encountered is other speech and it often acts as interference. The next two studies examine the speech perception of non-native listeners when the intervening noise is spoken language.

Keith, Katbamna, Tawfik, and Smolak (1987) investigated the effect of linguistic background on two tests of dichotic listening taken from a central auditory test

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battery and presented in English. Their subjects were 10 native American-English speakers, 10 native Hindi speakers, and 20 native Arabic speakers. The non-native American speakers had Test Of English as a Foreign Language (TOEFL) scores of 450 or better, had been exposed to American-English from two months to 10 years of age, and reported no difficulty in understanding everyday spoken English. The Staggered Spondaic Word (SSW) test was presented to all subjects; the dichotic listening Consonant Vowel (CV) Test was presented to all native American and Hindi speakers and to ten of the native Arabic speakers. Scores for the SSW were reported in percent of errors made in the four conditions. The native American speakers had no errors in all four conditions. Both non-English speaking groups performed less well than the native English speakers, with a score of approximately 20 percentage points less in the competing conditions and three to six percentage points less in the noncompeting conditions. Results of the CV test were reported as percentage correct responses. In the CV Test, the native Hindi speakers performed similarly to the native American-English speakers. The native Arabic speakers, however, performed much less well. Native American speakers and Hindi speakers had a right ear advantage of 24 percent when they were directed to attend to stimuli in the right ear. The Arabic speakers had a right ear advantage of eight percent. When directed to attend to the left ear, the native English speakers scored 27 percent better in the left ear, the Hindi speakers scored nine percent better and the Arabic speakers showed no difference in the percent correct in the two ears. In the free recall section, the Arabic subjects performed less well than the Hindis

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and Americans. The uneven results between the two non-native groups may be attributed to the fact that of the six consonant vowel stimuli (/ba, pa, ta, da, ka/ and /ga/) used in the testing, the /ba/ and /pa/ are not differentiated in Arabic as they are in English and Hindi. Thus, even when using simple CV syllables, one cannot rule out phonological context effects..

Lew and Jerger (1991) tested 24 bilingual subjects, 12 with English and 12 with Spanish as their native language, using the Synthetic Sentence Inventory (SSI), in four conditions: target and competition sentences in English, target and competition sentences in Spanish, target sentences in English with competition sentences in Spanish, and target sentences in Spanish with competition sentences in English. Lew and Jerger used a two-tailed Student's t test and found that the effects of ear preference, gender and native language were not statistically significant. They, therefore, collapsed the data to analyze the difference between inter and intralanguage interference. They found that interlanguage interference was significantly less than intralanguage interference.

In summary, the literature shows that in quiet, speech perception by non-native speakers can be comparable to that of native speakers. However, in degraded listening conditions such as noise, reverberation and competing messages, the non-native speakers sustain a significant decrement in perception of phonemes, simple words and sentences relative to native speakers. These difficulties persist over many decades and begin to affect speech perception even in quiet in

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older non-native speakers.

Rationale for the present study

The first section of this literature review showed that native listeners make use of various types of linguistic context when engaged in speech perception in difficult listening situations. The second section of the literature indicated that the speech perception by non-native listeners is significantly reduced compared to the native speakers in these difficult situations. With the exception of Rosenzweig and Postman (1957), there is no literature that evaluates the effects of linguistic context on the speech perception by non-native listeners. With the exception of one article, Mayo et al. (1997), there is no information about what limitations the non-native listener encounters in accessing and using contextual information, nor how these limitations may contribute to their perceptual difficulties. In particular, there is no research about how well non-native speakers make use of contextual information at the phonological, lexical, semantic or syntactic level or if their perceptual difficulties arise from a combination of these factors. Thus, the following questions were addressed in the present study,

1. What is the effect of sentence context on word recognition in sentences by native and non-native speakers?
2. What is the effect of sentence meaning on word recognition in sentences by native and non-native speakers?
3. What is the effect of syntactic context on word recognition in sentences by native and non-native speakers?

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4. What is the effect of placing words in a word string on word recognition by native and non-native speakers?
5. What is the effect of lexical context on the recognition of isolated words by native and non-native speakers?
6. What is the effect of lexical context on phoneme recognition by native and non-native speakers?

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Chapter 3

Method

Subjects

There were two subject groups. The first group consisted of eight native American-English-speaking college students, five males and three females from three colleges. Subjects were between 18 and 23 years old and had no reported hearing loss. Table 3.1 shows background information on this subject group.

The second subject group consisted of eight female Fashion Institute of Technology college students who speak Korean as their first language. These subjects answered a questionnaire investigating their linguistic backgrounds. (A copy of the questionnaire can be found in Appendix A.) The Korean subjects had learned English between the ages of 9 and 13 years. Three of them used English at school only, while three spoke English at school and with friends. Only one of the Korean subjects used English at school, at home, at work, with friends and with family. These subjects had no reported hearing problems. Data on the Korean subjects can be found in Table 3.2.

Subjects in both groups participated willingly and gave informed consent. Approval by the City University of New York's Human Subjects Committee, including a copy of the consent form, can be found in Appendix B.

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Table 3.1 Background Information for Five Male and Three Female Native Speakers of American-English

Subject:	Age in Years	College
1	20	OWU
2	20	Col
3	20	OWU
4	20	MSU
5	20	Ken
6	18	FIT
7	23	FIT
8	18	FIT
Mean	19.88	
SD	1.55	
Range	18 – 23	

Col=Colgate

MSU=Montclair State University

OWU=Ohio Wesleyan University

Ken=Kenyan College

FIT=Fashion Institute of Technology

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Table 3.2 Background Information for Korean Speakers of American-English

Subject	Age in Years	Age L2 Acquired in Years
1	24	15
2	26	13
3	30	11
4	24	13
5	24	9
6	28	13
7	25	14
8	28	14
Mean	26.13	12.75
SD	2.30	1.91
Range	24 – 30	9 - 15

All Korean speakers were female students at the Fashion Institute of Technology Of the State University of New York

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Test Materials

In order to examine the role of context on speech perception by non-native speakers, several stimuli were used, ranging from nonsense syllables to meaningful sentences. The speech stimuli were developed by Boothroyd and Nittrouer (1988). They consist of 12 lists of ten CVC nonsense syllables, 12 lists of ten CVC words and 80 four-word sentences. The sentences fall into three categories: those that are semantically and syntactically appropriate (high-probability); those that are semantically anomalous but syntactically appropriate (low-probability); and those that are semantically and syntactically anomalous (zero-probability). The lists of stimuli can be found in Appendix C. A more detailed explanation follows.

The nonsense syllables consisted of consonant-vowel-consonant combinations that did not constitute meaningful words, but were allowable in the English language. The percent correct recognition, therefore, provided a measure of phoneme and whole syllable recognition in a context that offered only phonological constraints. There were 12 lists of ten syllables each. Each list contained the same 30 phonemes (10 initial consonants, 10 vowels and 10 final consonants); each nonsense syllable occurred only once throughout the lists.

The meaningful word lists consisted of consonant-vowel-consonant words found in the English language. There were 12 lists of 10 monosyllabic words each. Thirty phonemes were used in each list. These are the same phonemes as in the

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nonsense syllables. Each phoneme appeared only once in each list, and the same 30 phonemes appeared in every list. Each word appeared in only one of the 12 lists. The frequency of occurrence of the words varied widely as determined in the Thorndyke-Lorge (1944) word count: 40% occurring 100 or more times per million, 40% occurring 11 to 99 times per million, 17% occurring 2 to 10 times per million, and 3% occurring one or less times per million. These lists were used to provide a measure of phoneme and word recognition in a context that provided both phonological and lexical constraints in English.[1]

The high-probability (HP) sentences consisted of four monosyllabic words in meaningful sentences. All sentences were declarative sentences. There were 20 high-probability sentences. They were used to provide a measure of word recognition in a context that provided semantic and syntactic cues in the English language. Note that the 80 words used in the HP sentences were not the same as those used in the nonsense syllables or word lists, nor were they restricted to consonant-vowel-consonant words.

The low-probability (LP) sentences consisted of four monosyllabic words that had the syntactic constraints of the English language but were semantically anomalous

[1] Note that the lists differ from the AB word lists (Boothroyd, 1968, 1984). In the Boothroyd and Nittrouer (1988) lists each consonant maintains the same position (pre- or post-vocalic) throughout the lists. In the AB lists, consonant position varies from list to list.

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i.e., they had highly improbable meanings. There were 20 low-probability sentences. These sentences provided a measure of word recognition in a context that provided syntactic cues in the English language. The difference between the percent correct word recognition in the low and high-probability sentences was intended to provide a measure of the effect of sentence meaning. However, the low-probability sentences still retained meaning and in effect the difference in word recognition is a difference between high and low plausibility. Note that two different sets of 80 words were used for the HP and LP sentence lists.

The zero-probability (ZP) sentences consisted of random sequences of four monosyllabic words. These sentences were constructed from the words used in the high and low-probability sentences, resulting in 40 zero-probability sentences. These sentences provided a measure of word recognition without syntactic and semantic cues. The difference between the percent correct word recognition in zero-probability and low-probability sentences provided a measure of the effect of syntax only. The difference between the percent correct word recognition in zero-probability and high-probability sentences provided a measure of the combined effect syntax and sentence meaning. By comparing word recognition in ZP sentences and isolated word lists, it was also possible to estimate the combined effect of consonant clusters and placing words in random strings of four words.

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Recording of Test Materials

The CVC words, nonsense syllables, and sentences (HP, LP, ZP) were recorded by an adult male talker who was a native speaker of American-English. He was instructed to say all the sentences using falling prosody as is found in short declarative sentences. The recording was done in a sound attenuating IAC room. The speaker was 18-inches away from the microphone. The stimuli were recorded on digital audio tape. Recordings were played back in analogue form and redigitized at 16 bits and 22050 samples per second. After digitization, amplitude distributions were computed for each list (consonant-vowel-consonant words, nonsense syllables, high, low and zero predictability sentences) using DADISP software from DSP Corporation. Root-mean square amplitude was expressed in dB re: one digital unit, integrated over a 40 ms time window. Where necessary, the amplitudes of a list were increased or decreased so that the 70th percentiles of the amplitude distribution were within $\pm$ one decibel for all lists. The stimuli were then mixed with speech-shaped noise at seven signal-to-noise ratios in 3 dB steps from –6 to 12 dB. The resulting seven sets of materials (plus the noise-free stimuli) were then transferred to analog tape.

The original plan was to use the seven signal-to-noise ratios from –6 to 12 dB. However, the length of testing, subject fatigue and the number of hours judges would be required to listen to subjects' responses made it prudent to reduce the number of signal-to-noise ratios used. In selecting these signal-to-noise ratios,

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there were two concerns, first, that the native American-English speakers would score close to 100 percent correct recognition at several of the signal-to-noise levels, particularly when responding to intact sentence materials. Second, the Korean speakers would score close to zero percent correct recognition at several of the signal-to-noise levels when responding to materials with less contextual information, particularly the nonsense syllables. A pilot study was undertaken to address these concerns. It was found that the group means remained between 20 and 90 percent for signal-to-noise ratios of 0 dB and 3 dB, thus minimizing floor and ceiling effects. For this reason, the two signal-to-noise ratios 3 dB and 0 dB were used in this experiment. The results of the pilot study are reported in Appendix D.

Equipment

The speech stimuli were presented via an ACS4 m language laboratory system. Data on the frequency response of the system can be found in Appendix E. The equipment had a main (teacher's) console and 32 individual student consoles. The teacher's console had four tape recorders and each of them could be directed to any number of the students' consoles at the teacher's discretion. Each of the 32 consoles was equipped with a tape recorder, a headset with a microphone attached, and controls for opening the cassette holder and changing volume. None of these controls worked unless the teacher pushed a matching button on the main console. Thus, students were able to modify volume, insert and remove tapes etc. only if the teacher had pushed the student's equivalent button on her machine.

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Procedure

Subjects were tested alone or in small groups. They were asked to set a comfortable listening level during the presentation of practice material. Subjects received oral instructions in which they were told to repeat the stimuli they heard. Subjects were informed whether the stimuli were real words, nonsense words, intact sentences (HP), sentences that made little sense (LP) or sentences that made no sense (ZP). Subjects were instructed to guess if not sure. Subjects heard two lists of 10 nonsense syllables, two lists of 10 consonant-vowel-consonant words, 10 high-probability sentences, 10 low-probability sentences and 10 zero-probability sentences. All subjects were given the stimuli in quiet and at 3 and 0 dB signal-to-noise levels. All responses were tape-recorded.

Auditing of Subject Responses

Three native American-English speakers with no known hearing, speech or language problems acted as judges. They were given a hard copy of the individual lists of words, nonsense syllables and sentences that each listener had heard. Then the judges listened to the subjects' taped responses in all three listening conditions. If the responses were considered correct, the judges checked the word or sentence. If they perceived an incorrect response, they wrote phonetically what they perceived the subjects were saying in the space provided. A sample of the lists the judges received can be found in Appendix F. The judges' responses were examined for phoneme substitutions that are consistent with a

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Korean accent in English. Consistent substitutions that reflect Korean accented English were counted as correct responses. See Appendix G.

Data Analysis

The data were subjected to analyses of variance. When significance was found, a post hoc least-significant-difference test was performed. The analysis of variance shows significance of differences, but it does not quantify them. The proper method of quantifying the observed effects is one of the issues that arise in the interpretation of differences between two speech perception measures. One method is to use percentage point differences under two or more conditions. However, this method can be subject to floor and ceiling effects. Even when noise is introduced to offset these effects, it cannot be assumed that the percentage difference between two scores reflects the same magnitude of context effect across the complete range of possible scores.

Some writers have suggested alternative ways of computing the difference and many researchers have opted to compare materials in terms of the signal-to-noise ratio required to produce a certain score (typically 50% correct). Rosenzweig and Postman (1957) and Florentine and her colleagues (1986) manipulated the signal-to-noise ratio to keep the recognition probability at 50%. Context effects were then measured in terms of change of signal-to-noise ratio as discussed previously. This method, which has been used in several more

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recent studies, has the advantage of avoiding floor and ceiling effects but it does not lend itself easily to incorporation into mathematical models.

Bilger (1984) advocates using differences between arcsine-transformed scores to measure context effects. One signal-to-noise ratio is used and the probability of recognition with and without context is measured. This method reduces the ceiling and floor effects, but it is not clear that a difference between two arcsine transforms necessarily reflects the true magnitude of a context effect. The arcsine transformation is also difficult to incorporate into more extensive mathematical models.

Boothroyd and Nittrouer (1988) have recommended a transformation, which uses the ratio of the logs of the error probability, yielding a k factor. The k factor relates the probabilities of recognition of speech units with and without context. Using probability theory, Boothroyd and Nittrouer show that the k factor can be interpreted as the number by which the channels of statistically independent information would need to be multiplied in order to obtain the same performance increase as that produced by adding context. Thus,

$$k=\log(1-p_c)/\log(1-p_i) \quad \text{.....(1)}$$

where k= the k factor for the specific context.

p_c= the probability of recognition of an item with that context present.

p_i= the probability of recognition of an item with

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that context absent.

The value of k=1 if context has no effect and increases as the effect of context increases.

Boothroyd and Nittrouer also developed the j factor, which relates the probability of recognition of the whole to the probability of recognition of the parts of the whole. The j factor can be interpreted as the number of statistically independent parts in the whole. The extent to which j is less than the actual number of parts in the whole reflects the use of internal contextual information. The equation to be used is

$$j=\log(p_w)/\log(p_p) \quad \text{.....(2)}$$

where j=the j factor.

p_w=the probability of recognition of a whole.

p_p=the probability of recognition of a part.

When context has no effect, the value of j should equal the number of parts in the whole. As the effect of context increases the value of j should decrease approaching unity (1) where the recognition of one part is sufficient for the recognition of the whole.

These transforms have a number of advantages. They reduce the floor and ceiling effects. They can be incorporated into more general mathematical models and, most importantly, they are based on theoretical constructs that support their use as measures of the relative contributions of contexts in a manner that is

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independent of the magnitude of the distortion.

In the analysis of data, context effects, that is, the difference between scores obtained using materials with and without particular linguistic information, were quantified in the following three ways:

1. as a simple difference between two percentage scores,
2. as the difference between the arcsine transforms of two percentage scores, as recommended by Bilger,
3. using the k factor transform of Boothroyd and Nittrouer.

The phoneme and syllable recognition data were also compared using the j factor transform of Boothroyd and Nittrouer.

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Chapter 4

Results

Raw data

All subjects listened to all stimuli in each of the three listening conditions of quiet and signal-to-noise ratios of 3 dB and 0 dB for a total of 21 scores per subject. The raw data can be found in Appendix H. Each subject provided percent correct scores for recognition of:

1. words in high-probability sentences,
2. words in low-probability sentences,
3. words in zero-probability sentences,
4. whole words in consonant-vowel-consonant word lists,
5. phonemes in consonant-vowel-consonant word lists,
6. whole syllables in consonant-vowel-consonant nonsense lists,
7. phonemes in consonant-vowel-consonant nonsense lists.

The judges' scores were examined and the actual percent differences among their scores were found to be small. Moreover, the responses of the three judges all followed the same pattern, that is, all their scores were highest for the same materials, second highest for the same materials, lowest for the same materials, etc. An analysis of variance did find a significant interaction between language groups, materials and judges. However because the actual differences were small and all three judges ranked the scores in the same way, it was concluded

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that these differences would not have a significant effect on the results and so data were collapsed across the three judges (See Appendix I).

Similarly, data for the two noise conditions were examined. An analysis of variance showed a significant effect of noise level. Overall, however, the patterns of the subjects' responses across materials at the two different signal-to-noise ratios were similar to each other. This was true in both subject groups. Therefore it was decided to collapse the data across noise levels to provide a single estimate of performance in noise to be compared with performance in quiet.

A primary benefit of collapsing across judges and noise levels was an improvement in the test-retest reliability of the various measures. The resulting mean scores are shown for each subject in Table 4.1, together with means for the two subject groups.

Performance in quiet

Figure 4.1 illustrates the mean scores for the two subject groups when listening in quiet. It will be seen that group mean scores for the English speakers are consistently higher than for the Korean speakers. In simple paired 't' tests the difference was significant ($p<0.05$) for all stimuli except recognition of whole nonsense syllables and constituent phonemes in nonsense syllables.

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Table 4.1. Individual and group values for percent recognition of words and phonemes in the various test materials. Data have been collapsed across three judges and two noise conditions.

First language	Words correct (%) -in sentences						Syllables correct (%) -in CVC lists				Phonemes correct (%) -in CVC lists			
	High probability		Low probability		Zero probability		Meaningful		Non-meaningful		Meaningful		Non-meaningful	
	Quiet	Noise	Quiet	Noise	Quiet	Noise	Quiet	Noise	Quiet	Noise	Quiet	Noise	Quiet	Noise
Korean	82.5	54.6	75.3	43.8	69.2	29.6	76.7	38.3	43.3	27.5	93.9	68.1	75.9	62.8
Korean	99.2	69.6	85.0	66.1	85.0	50.0	74.3	49.2	43.3	15.0	87.7	73.6	77.2	60.6
Korean	95.0	42.3	95.0	63.5	84.2	45.4	48.3	39.2	73.3	24.2	78.3	61.7	91.1	65.8
Korean	77.5	35.8	74.2	43.2	60.8	28.7	78.3	35.0	81.7	15.8	90.0	61.7	93.9	58.6
Korean	82.5	57.5	83.3	62.9	77.5	39.6	83.3	45.8	56.7	21.7	93.9	70.6	82.2	63.6
Korean	87.5	68.8	82.5	61.7	86.7	30.0	91.7	51.7	71.7	25.8	97.1	80.5	88.9	66.9
Korean	92.5	54.6	71.7	49.6	55.8	50.8	75.4	45.0	50.0	11.7	90.7	70.6	78.9	55.3
Korean	94.2	83.3	85.8	64.6	86.7	51.7	93.0	36.7	61.7	17.5	97.7	71.4	84.4	60.3
Mean	88.9	58.3	81.6	56.9	75.7	40.7	77.6	42.6	60.2	19.9	91.1	69.8	84.1	61.7
Std.Dev.	7.5	15.4	7.6	9.7	12.3	10.1	13.8	6.1	14.4	5.7	6.2	6.2	6.7	3.8
Std Err	2.7	5.4	2.7	3.4	4.4	3.6	4.9	2.2	5.1	2.0	2.2	2.2	2.4	1.4
English	100.0	99.6	99.2	86.3	99.2	66.3	98.3	66.7	85.0	53.3	98.9	85.6	95.0	80.6
English	100.0	98.3	99.2	85.0	98.3	64.6	100.0	53.3	58.3	33.3	100.0	79.4	82.8	72.2
English	100.0	89.8	97.5	79.6	90.8	60.8	98.3	65.8	85.0	15.8	99.4	83.3	95.0	63.3
English	99.2	81.7	93.3	70.0	83.3	37.1	86.7	56.7	58.3	33.3	93.3	79.7	83.3	68.3
English	98.3	96.7	97.5	75.0	98.3	66.3	84.3	49.2	45.0	19.2	94.8	77.2	83.9	61.9
English	98.3	83.3	100.0	75.0	86.7	59.6	93.3	47.5	41.7	22.5	95.0	78.9	76.7	55.0
English	100.0	100.0	100.0	86.7	91.7	77.5	85.0	47.5	60.0	35.8	95.1	77.8	86.1	65.8
English	99.2	92.9	99.2	78.8	90.3	67.5	96.7	49.2	56.7	26.7	97.8	78.9	81.9	58.9
Mean	99.4	92.8	98.2	79.5	92.3	62.4	92.8	54.5	61.3	30.0	96.8	80.1	85.6	65.8
Std Dev	0.7	7.2	2.2	6.1	5.8	11.6	6.5	7.9	16.1	11.9	2.5	2.9	6.4	8.0
Std Err	0.3	2.6	0.8	2.1	2.1	4.1	2.3	2.8	5.7	4.2	0.9	1.0	2.3	2.8

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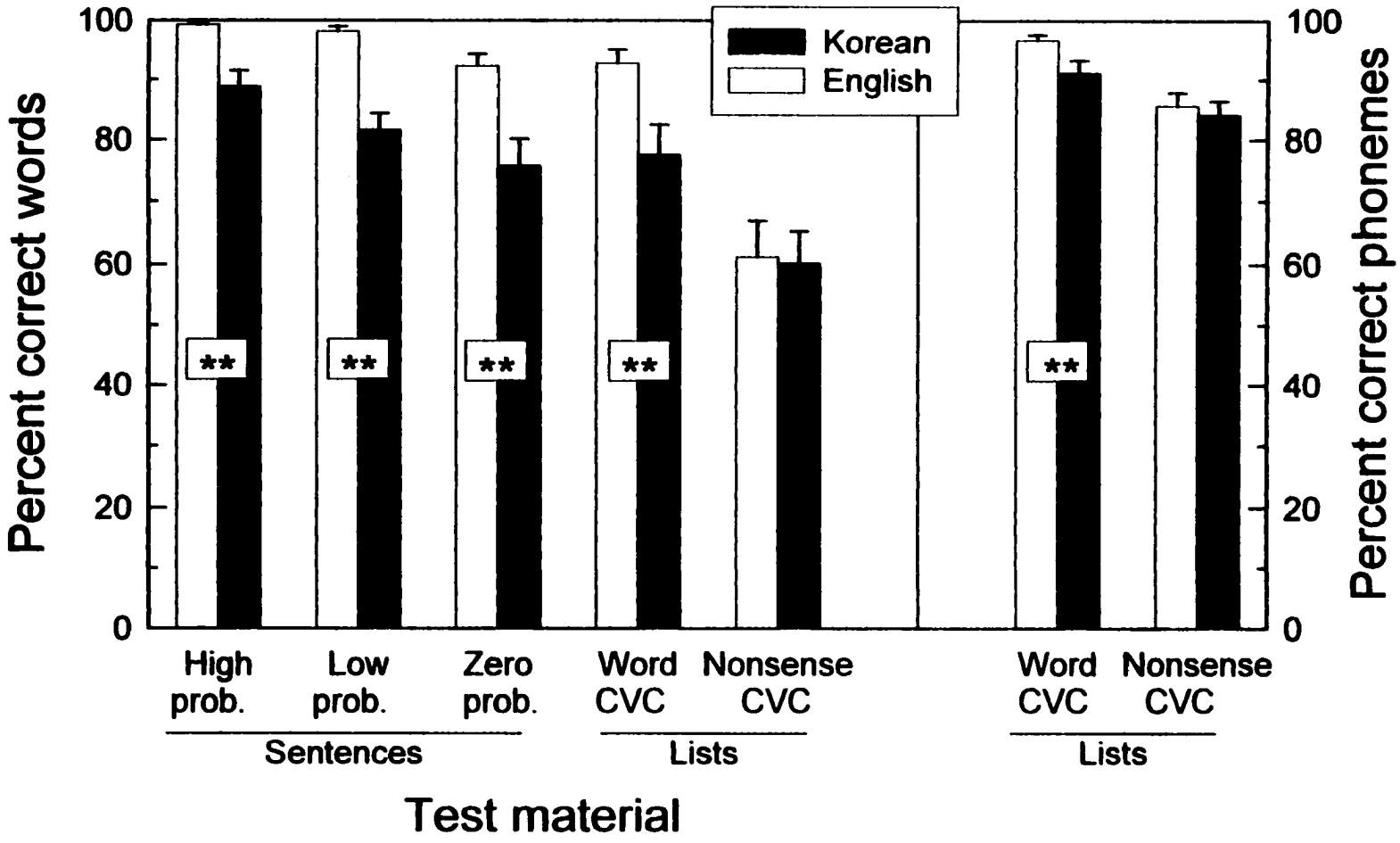

Figure 4.1. Group mean scores (+1 se) for English and Korean speakers listening in quiet, as a function of material and type of score. Significant differences between the groups are indicated by asterisks (** $p<0.001$).

In the following analysis, data for word recognition and phoneme recognition will be dealt with separately.

The individual percent correct scores for words in sentences, consonant-vowel-consonant word lists, and for syllables in nonsense syllable lists were arcsine transformed to increase homogeneity of variance and subjected to analysis of variance with one group factor (native language at two levels) and one repeated-measures factor (test material at five levels). The results are shown in Table 4.2. The main effects of native language and test material were highly significant, as was the interaction between the two.

These findings confirm that the Korean speakers had more difficulty with word recognition in the quiet condition than the English speakers did and that the difference measured in terms of arcsine-transformed percent correct scores varied across the test materials. In post hoc testing, using the Least-Significant-Difference test, the English-Korean difference was found to be significant ($p<0.0001$) for all but one of the test materials. The nonsense consonant-vowel-consonant lists showed no evidence of a language effect ($p=0.815$).

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Table 4.2 Repeated-measures analysis of variance in arcsine-transformed data for word recognition in isolation and in sentences, in quiet, by native-Korean and English speakers.

Effects	df Effect	MS Effect	df Error	MS Error	F Ratio	p-level
GROUP	1	3899.70	14	120.24	32.43	< 0.0005
MATERIAL	4	2169.44	56	61.33	35.37	< 0.0005
GxM	4	231.38	56	61.33	3.77	0.0087

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This Least-Significant-Difference test also provided information on the effect of test material within the two groups. For the Korean speakers, the mean score for nonsense consonant-vowel-consonants was significantly lower ($p<0.005$) than for all other materials. There was no evidence, however, of differences among consonant-vowel-consonant words in lists, words in zero-probability sentences, and words in low-probability sentences ($p>0.05$). The mean score for high-probability sentences was significantly different from that for zero-probability ($p=0.0039$), but not from that for low-probability ($p=0.0672$). These findings show that changing from nonsense syllables to real words makes the perceptual task easier for the Korean speakers. So also does the addition of sentence context. But it is not clear from these data whether the sentence help comes mainly from syntactic context, semantic context, or both.

From these findings, it may be concluded that, under the quiet condition of this study:

1. Word recognition overall was significantly poorer for Koreans than for English talkers,
2. The magnitude of the difference, however, varied from context to context. The scores for Korean and English talkers respectively were
    a) For lists of nonsense syllables, 60.2% and 61.3%, for a nonsignificant difference of 0.9 percentage points,
    b) For lists of consonant-vowel-consonant words, 77.6% and 92.8%, for a difference of 15.2 percentage points,

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c) For zero-probability sentences, 75.7% and 92.3%, for a difference of 16.6 percentage points,

d) For low-probability sentences, 81.6% and 98.2%, for a difference of 16.6 percentage points,

e) For high-probability sentences, 88.9% and 99.4%, for a difference of 10.5 percentage points.

3. In general, the difference of word recognition between Korean and English talkers increased with increasing contextual evidence – suggesting that Korean talkers are as adept as the English talkers at phonemically based word recognition but are less adept at taking advantage of contextual evident when it is available.
4. Note that, although the non-native penalty is less for high-probability than for low-probability and zero-probability sentences, this finding is partly dependent on the ceiling effect.

The post-hoc analysis for the English speakers gives similar findings except that there is a clear benefit from the addition of syntactic context (p=0.0172). The absence of an obvious benefit from semantic context (p=0.4069) is attributable to the fact that near-perfect scores were obtained by the English speakers for the low-probability sentences. Even the arcsine transforms can't eliminate ceiling effects when scores reach 100%.

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We now turn to the data for phoneme recognition in quiet. The individual percent correct scores for phonemes in consonant-vowel-consonant words and nonsense syllables in quiet were also arcsine transformed and subjected to analysis of variance with one group factor (native language at two levels) and one repeated-measures factor (test material at two levels). These results are shown in Table 4.3. The main effect of test material was significant. The effect of native language was marginally significant ($p=0.058$) and the interaction between language and test material was not significant.

These findings imply that Korean speakers suffer the least penalty at the phonemic level. Moreover, the difference between the two language groups is considerably less than that found for word recognition. Although the analysis of variance indicates no interaction between language and materials, paired 't' test suggest that unlike the English talkers, the Korean talkers suffered a significant penalty for recognition of phonemes in words but not for phonemes in nonsense syllables.

The following conclusions may be drawn from the phoneme-recognition findings under the quiet condition of this study:

1. There is weak evidence that phoneme recognition is a little more difficult for Korean talkers than for English speakers,

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Table 4.3 Repeated-measures analysis of variance in the arcsine-transformed data for phoneme recognition in words and nonsense syllables, in quiet, by native-Korean and English speakers.

Effects	df Effect	MS Effect	df Error	MS Error	F Ratio	p-level
GROUP	1	185.96	14	43.71	4.25	0.0582
MATERIAL	1	916.49	14	36.13	25.36	0.0001
GxM	1	91.14	14	36.13	2.52	0.1346

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2. There is also weak evidence that the non-native penalty increases with increasing context. Percent correct recognition of phonemes by Korean and English talkers, respectively, were
    a) In nonsense syllables, 84.1% and 85.6%, for a nonsignificant difference of 1.5 percentage points,
    b) In meaningful consonant-vowel-consonant words, 91.1% and 96.8%, for a difference of 5.7 percentage points.

Clearly, the difference between Korean and English talkers under the quiet condition of this study is smaller for phoneme recognition in words than for word recognition.

Performance in noise

Figure 4.2 illustrates the mean scores for the two subject groups when listening in noise. It will be seen that group mean scores for the English speakers are consistently higher than for the Korean speakers. In simple paired 't' tests the difference was significant ($p<0.05$) for all measures except phoneme recognition in nonsense syllables. With one exception, these findings are the same as those obtained under the quiet condition. The exception is the scores for recognition of whole nonsense syllables, where the Korean speakers now perform significantly less well than the English speakers.

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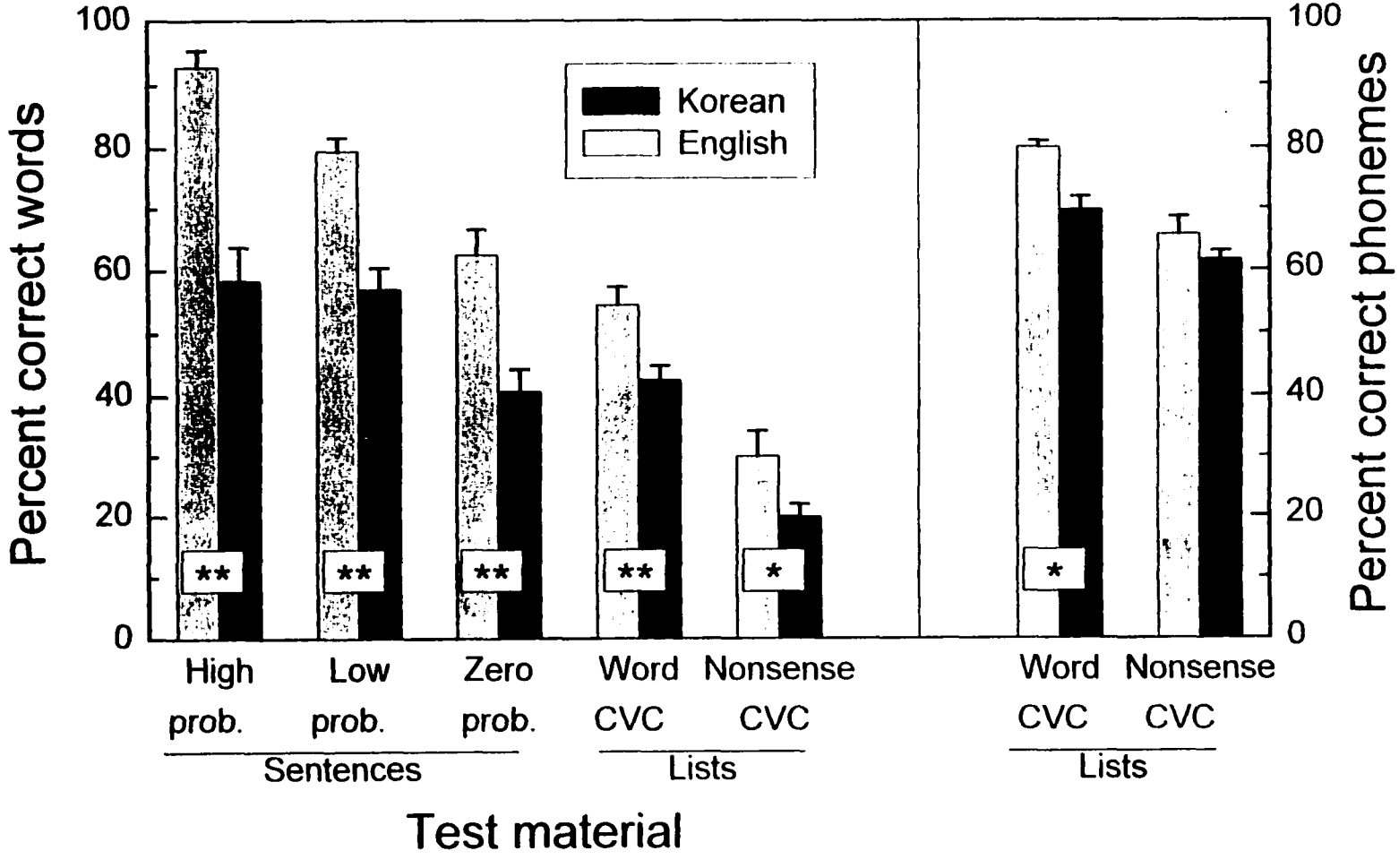

Figure 4.2. Group mean scores (+1 se) for English and Korean speakers listening in noise, as a function of material and type of score. Significant differences between the groups are indicated by asterisks (** $p<0.01$, *$p<0.05$).

As with the earlier data, word and phoneme-recognition data will be discussed separately.

The individual percent correct scores for words in sentences, and consonant-vowel-consonant words and nonsense syllables in lists, were arcsine transformed to increase homogeneity of variance and subjected to analysis of variance with one group factor (language at two levels) and one repeated-measures factor (word recognition at five levels). The result is shown in Table 4.4. The main effects of first language and test material were significant ($p=<0.0001$ and $p<0.0001$ respectively), as was the interaction between the two ($p=<0.0001$). These findings confirm that the Korean speakers had more difficulty than the English speakers did and that the difference varied across the test materials. The magnitude of these effects (in percentage points) was greater when listening in noise than when the testing was done in quiet (Table 4.2). In post hoc testing, using the Least-Significant-Difference test, the English-Korean difference of word recognition in all materials (sentences and consonant-vowel-consonant words and nonsense syllable lists) was significant (from $p=0.0165$ to $p<0.0001$).

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Table 4.4 Repeated-measures analysis of variance in arcsine-transformed data for word recognition in sentences and in isolation, in noise, by native-Korean and English speakers.

Effects	df Effect	MS Effect	df Error	MS Error	F Ratio	p-level
GROUP	1	4482.40	14	114.26	39.23	<0.0001
MATERIAL	4	3276.95	56	35.14	93.27	<0.0000
GxM	4	332.85	56	35.14	9.47	<0.0001

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The post hoc testing also provided information on the effect of test material within the two groups. For the Korean speakers, the mean score for consonant-vowel-consonant nonsense syllables was significantly lower than for all other materials. The difference between the nonsense syllable and word list scores was highly significant ($p=<0.0001$). The differences between consonant-vowel-consonant words in lists and words in zero-probability sentences was not significant ($p=0.6604$). In other words, the additional processing load caused by putting monosyllabic words into 4-word strings did not have a significant negative effect on word recognition. Unlike the data in quiet, the mean score for low-probability sentences was significantly different from that of zero-probability sentences ($p=0.0008$). The mean score for high-probability sentences, however, was not significantly different from that for low-probability sentences ($p=0.7040$). These findings imply that changing from nonsense syllables to real words makes the perceptual task easier for the Korean speakers. So also does the addition of syntactic context. It appears, however, that semantic context in English contributes the least to the word recognition by Korean listeners.

In the post-hoc analysis for the English speakers the difference between materials was found to be significant ($p<0.0001$) with one exception. The difference between the word lists and the zero-probability sentences was not significant ($p=0.8$). In other words, putting monosyllabic words into random strings of 4 does not appear to have a negative effect on performance.

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From these findings, it may be concluded that, under the noisy condition in this study,

1. Word recognition overall was significantly poorer for Korean than for English talkers,
2. The magnitude of the difference, however, varied from context to context. The scores for Korean and English talkers, respectively were:
    a) For lists of consonant-vowel-consonant nonsense syllables, 19.9% and 30.0%, for a difference of 10.1 percentage points,
    b) For lists of consonant-vowel-consonant words, 42.6% and 54.5%, for a difference of 11.9 percentage points,
    c) For zero-probability sentences, 40.7% and 62.4%, for a difference of 21.7 percentage points,
    d) For low-probability sentences, 56.9% and 79.5%, for a difference of 22.6 percentage points,
    e) For high-probability sentences, 58.3% and 92.8%, for a difference of 34.5 percentage points.
3. As in the quiet condition, the difference between word recognition in noise between Korean and English talkers increased with increasing contextual information – suggesting that the Korean talkers are as adept as the English talkers at phonemically-based word recognition but are less adept at taking advantage of contextual information when it is available.

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4. The magnitude of the context effect on word-recognition scores between various levels of contextual information for Korean and English talkers respectively were:
    a) For lexical information (the difference between percent correct word recognition of consonant-vowel-consonant words and nonsense syllables) was 22.7% and 24.5%, suggesting that both language groups use this source of contextual information to the same degree,
    b) For words in strings (the difference between percent correct word recognition of zero-probability sentences and consonant-vowel-consonant word lists) was -1.9% and 7.9%. Neither reached the 5% level of significance,
    c) For syntactic information (the difference between percent correct word recognition in low- and zero-probability sentences) was16.2% and 17.1%, suggesting that Korean and English talkers use syntactic information to the same degree,
    d) For plausibility of sentence meaning (the difference between high- and low-probability sentences) was 1.4% and 13.3%, suggesting that the English talkers use semantic sentential information to a greater degree than do the Korean talkers.

The individual percent correct scores for phonemes in consonant-vowel-consonants words and nonsense syllables in noise were also arcsine

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transformed and subjected to analysis of variance with one group factor (native language at two levels) and one repeated-measures factor (test material at two levels). The result is shown in Table 4.5. The main effect of test material was significant ($p=<0.0001$). The effect of native language was also significant ($p=0.006$), as was the interaction between language and test material ($p=0.05$). In post hoc testing, using the Least-Significant-Difference test, the English-Korean difference in phoneme recognition in words was found to be significant. Phoneme recognition in nonsense syllables between the two groups was not significantly different. These findings imply that the Korean speakers suffer the least penalty at the phonemic level.

The post hoc testing also provided information on the effect of test material within the two groups. For the Korean speakers, the difference between phoneme recognition in nonsense syllables and words was significant ($p<0.0036$). These findings show that changing from nonsense syllables to real words makes phoneme recognition easier for the Korean speakers.

Post-hoc analysis for the English speakers also show a significant difference between the phoneme recognition in words and nonsense syllables ($p=0.00001$). These results show a strong effect of lexical context on phoneme recognition for both groups.

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Table 4.5 Repeated-measures analysis of variance in arcsine-transformed data for phoneme recognition in words and nonsense syllables, in noise, by native-Korean and English speakers.

Effects	df Effect	MS Effect	df Error	MS Error	F Ratio	p-level
GROUP	1	215.82	14	20.95	10.30	0.0063
MATERIAL	1	495.27	14	9.94	49.84	<0.0001
GxM	1	45.54	14	9.94	4.58	0.0504

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The following conclusions may be drawn from the phoneme-recognition findings in the noise condition of this study.

1. Phoneme recognition was, on average, poorer for the Korean than for English talkers.
2. The magnitude of that difference was different across material. The scores for Korean and English talkers respectively were:
    a) For lists of nonsense syllables, 61.7% and 65.8%, for a nonsignificant difference of 4.1 percentage points,
    b) For lists of consonant-vowel-consonant words, 70.4% and 82.3%, for a significant difference of 10.3 percentage points
3. The difference between phoneme recognition in the nonsense syllable and word lists were 8.1% and 14.3%, indicating the strong effect of lexical context.

K Factor Analysis

Thus far, the effect of context on word and phoneme recognition has been expressed in terms of differences in percent correct in the 't' tests and arcsine-transformed scores in the analyses of variance. Boothroyd and Nittrouer (1988) proposed that a more valid measure of the magnitude of a context effect is the ratio of the logarithms of the error probabilities. They refer to this metric as a k factor (see page 36).

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Pairs of scores for individual subjects were used to derive k factors for the following:

1. The effect of meaningful sentence context on word recognition, i.e., HP scores vs. ZP scores.
2. The effect of plausible sentence meaning on word recognition, i.e., HP scores vs. LP scores.
3. The effect of syntax on word recognition, i.e., LP scores vs. ZP scores.
4. The effect of word meaning on the recognition of CVC monosyllables, i.e., word scores for words vs. nonsense syllables
5. The effect of word meaning on the recognition of phonemes within CVC monosyllables, i.e., phoneme scores for words vs. nonsense syllables.

Means were then calculated for each subject group. Student's 't' was used to determine:

1. Whether the mean value of k for each group was significantly different from unity (1).
2. Whether the mean value of k differed significantly between the groups.

The results of these analyses are shown in Table 4.6. Specific context effects will be reported in turn.

The first column in Table 4.6 shows the k factor obtained by comparing the error probabilities for words in high-probability and zero-probability sentences. This

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measure reflects the effect of both semantic and syntactic context together. The sentential context effect is significant for both subject groups (i.e. The mean value of k is significantly >1). Furthermore, there is a significant difference between the two groups (p=0.0132).

Figure 4.3 illustrates the scores for individuals in the two subject groups when comparing word recognition with and without sentential context (high-semantic plausibility and syntactic context). The wide range of responses among Korean subjects should be noted. Korean subject 8's responses are within the lower range of the English subjects' responses. It is interesting to note that this is not the Korean subject who used English the most frequently (Korean 2), nor is it the subject who learned English at the youngest age (Korean 5). The curves show predicted relationships between pairs of measures based on the mean k values shown in Table 4.6. It will be seen that both groups derived help from sentence context but the English speakers gained significantly more help than did the Korean speakers (k=3.22 and 1.84 respectively).

The second column in Table 4.6 shows the k factor obtained by comparing the error probabilities for words in high-probability and low-probability sentences. This measure reflects the effect of high-semantically-plausible context. The semantically- plausible context effect is significant for the English, (i.e., k>1), but not for the Korean speakers. Again, there is a significant difference between the two groups (p=0.0065).

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Table 4.6 K factors reflecting the influence of linguistic contexts on word or phoneme recognition by native-Korean and native-English speakers. The data were collapsed across two noise conditions. Shaded areas show significance at p=0.05.

Scoring Unit	word	word	word	word	word	phonemes
Context	sentences	semantics	syntax	four word strings	word meaning	word meaning
Subjects						
Korean 1	2.3	1.4	1.6	0.7	1.5	1.2
Korean 2	1.7	1.1	1.6	1.0	4.2	1.4
Korean 3	0.9	0.5	1.7	1.2	1.8	0.9
Korean 4	1.3	0.8	1.7	0.8	2.5	1.1
Korean 5	1.7	0.9	2.0	0.8	2.5	1.2
Korean 6	3.3	1.2	2.7	0.5	2.4	1.5
Korean 7	1.1	1.2	1.0	1.2	4.8	1.5
Korean 8	2.5	1.7	1.4	1.6	2.4	1.4
avg	1.84	1.09	1.70	0.98	2.76	1.27
sd	0.78	0.37	0.49	0.35	1.14	0.22
se	0.30	0.13	0.17	0.12	0.40	0.08
t(7)	2.84	0.73	4.03	-0.16	4.37	3.46
p 1-tail	0.0125	0.2445	0.0025	0.4387	0.0016	0.0053
English 1	5.0	2.8	1.8	1.0	1.4	1.2
English 2	3.9	2.2	1.8	1.4	1.9	1.2
English 3	2.4	1.4	1.7	0.9	6.2	1.8
English 4	3.7	1.4	2.6	0.6	2.1	1.4
English 5	3.1	2.5	1.3	1.6	3.2	1.5
English 6	2.0	1.3	1.5	1.4	2.5	1.9
English 7	**	**	1.4	2.3	1.5	1.4
English 8	2.4	1.7	1.4	1.7	2.2	1.7
avg	3.22	1.89	1.69	1.35	2.62	1.53
sd	1.08	0.57	0.43	0.55	1.57	0.28
se	0.41	0.22	0.16	0.21	0.59	0.10
t(6)	5.45	4.10	4.25	1.67	2.74	5.06
p 1-tail	0.0008	0.0032	0.0019	0.0694	0.0145	0.0007
tdiff(13)	2.87	3.24	0.06	1.6	0.21	2.1
pdiff	0.0132	0.0065	0.9537	0.1329	0.8376	0.0542

* Within group 't' values test the null hypothesis that k=1(i.e. that context has no effect)

** K not calculable because one or both scores were 100 percent

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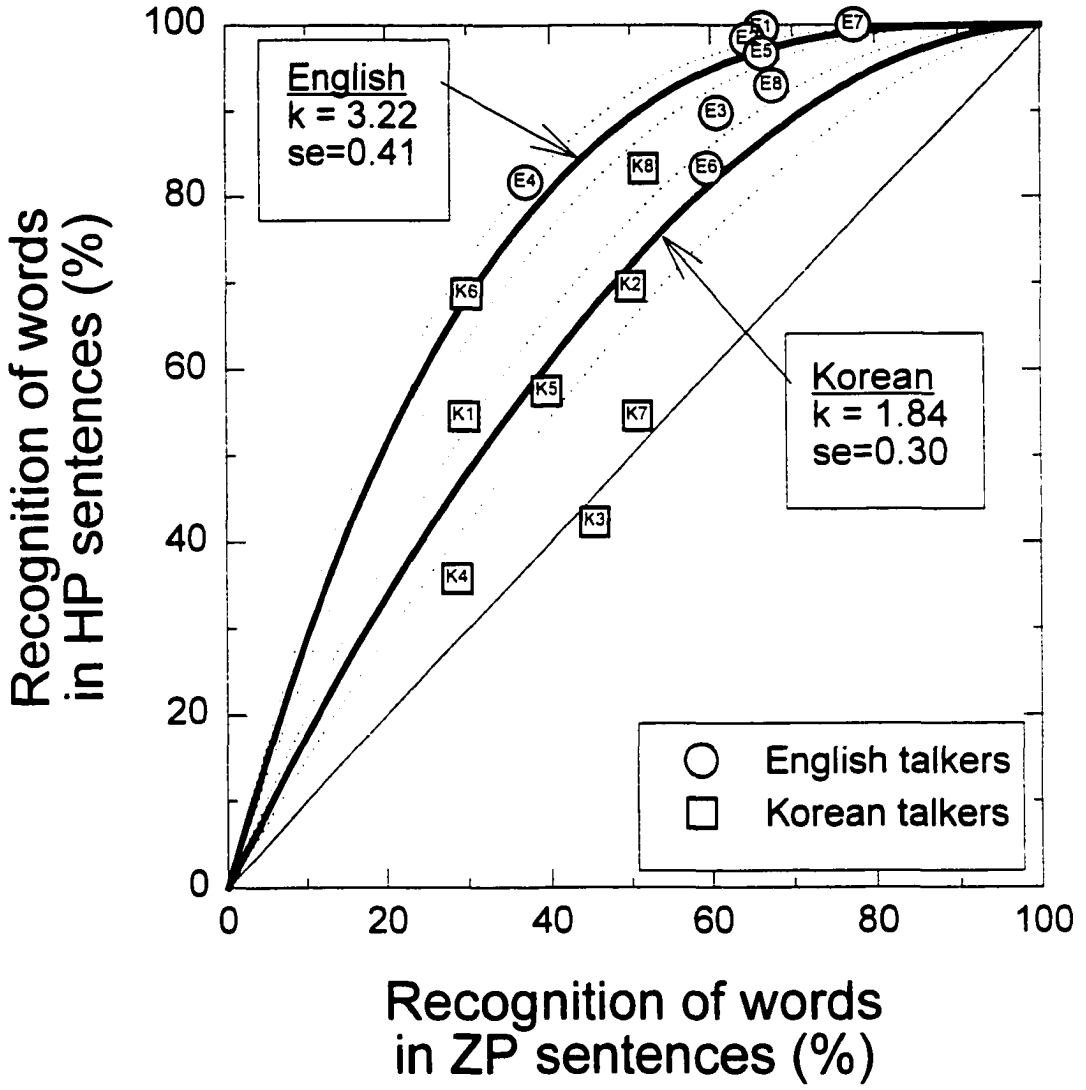

Figure 4.3 Word recognition in HP sentences as a function of word recognition in ZP sentences for 8 English and 8 Korean subjects. Lines show the function: $y = 1-(1-x)^k$ where the factor k represents the group mean benefit of sentence context.

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Figure 4.4 illustrates the scores for individuals in the two subject groups when comparing word recognition with high- and low-semantically-plausible context (high-probability and low-probability sentences). Korean subjects 2 and 8 had the best scores among the Koreans for the low-probability sentences. Their scores approach but are not within the range of the English subjects' responses. The curves show predicted relationships using mean k values shown in Table 4.6. It will be seen that The English speakers derived significant help from semantic context (k=1.89) but the Korean speakers did not (k=1.09).

The third column in Table 4.6 shows the k factor obtained by comparing the error probabilities for words in low-probability and zero-probability sentences. The comparison reflects the effect of syntactic context. The syntactic context effect is significant for both English and Korean speakers (k>1). Here, however, there is no significant difference between the two groups (p=0.9537).

Figure 4.5 illustrates the scores for individuals in the two subject groups when comparing word recognition with and without syntactic context (low-probability and zero-probability sentences). The curves show predicted relationships using the average of the two mean k values shown in Table 4.6. It will be seen that both Korean and English speakers derived the same degree of help from syntactic context (k=1.70). However, there is no overlap between individual English and Korean subjects' responses to low-probability sentences.

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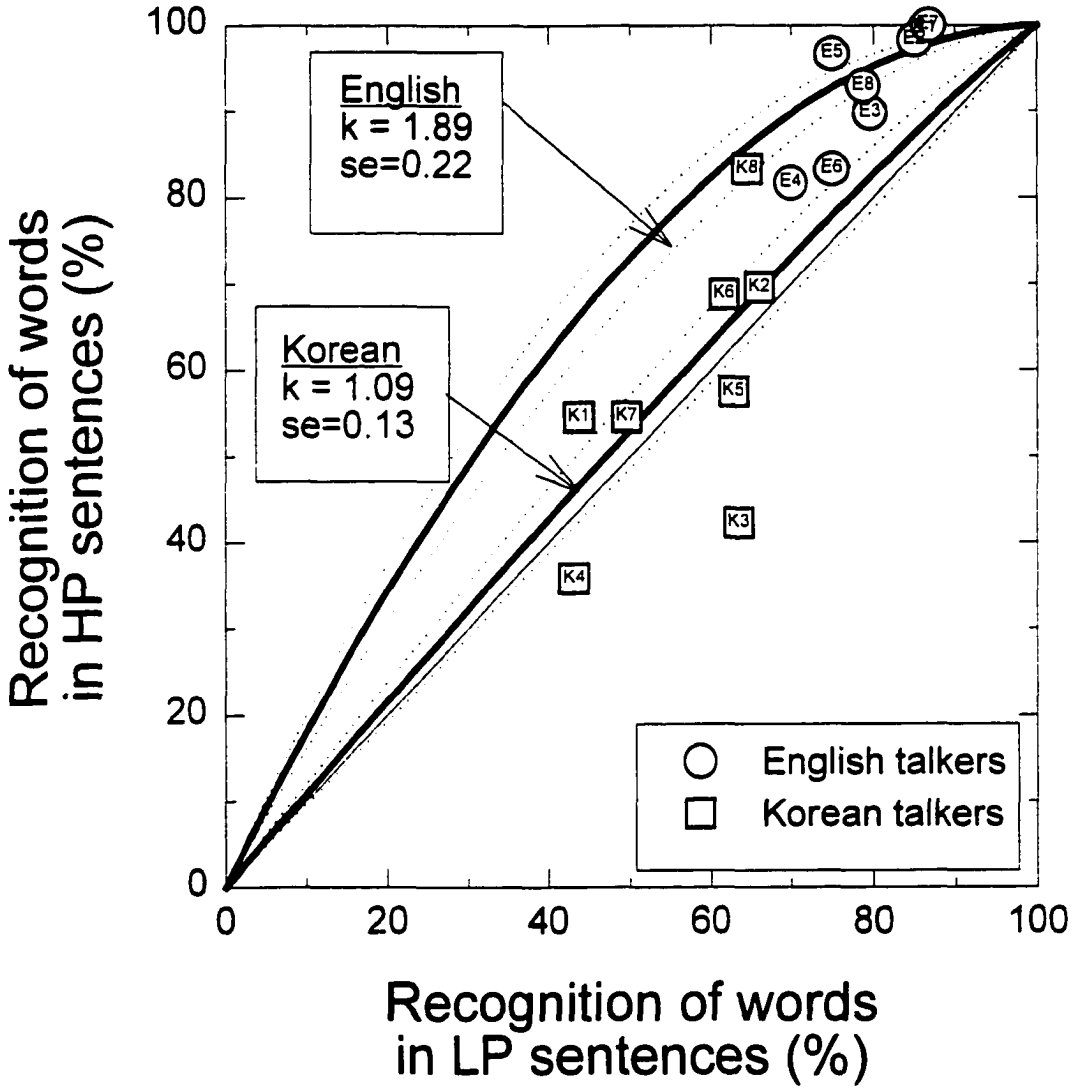

Figure 4.4 Word recognition in HP sentences as a function of word recognition in LP sentences for 8 English and 8 Korean subjects. Lines show the function: $y = 1-(1-x)^k$ where the factor k represents the group mean benefit of semantic context.

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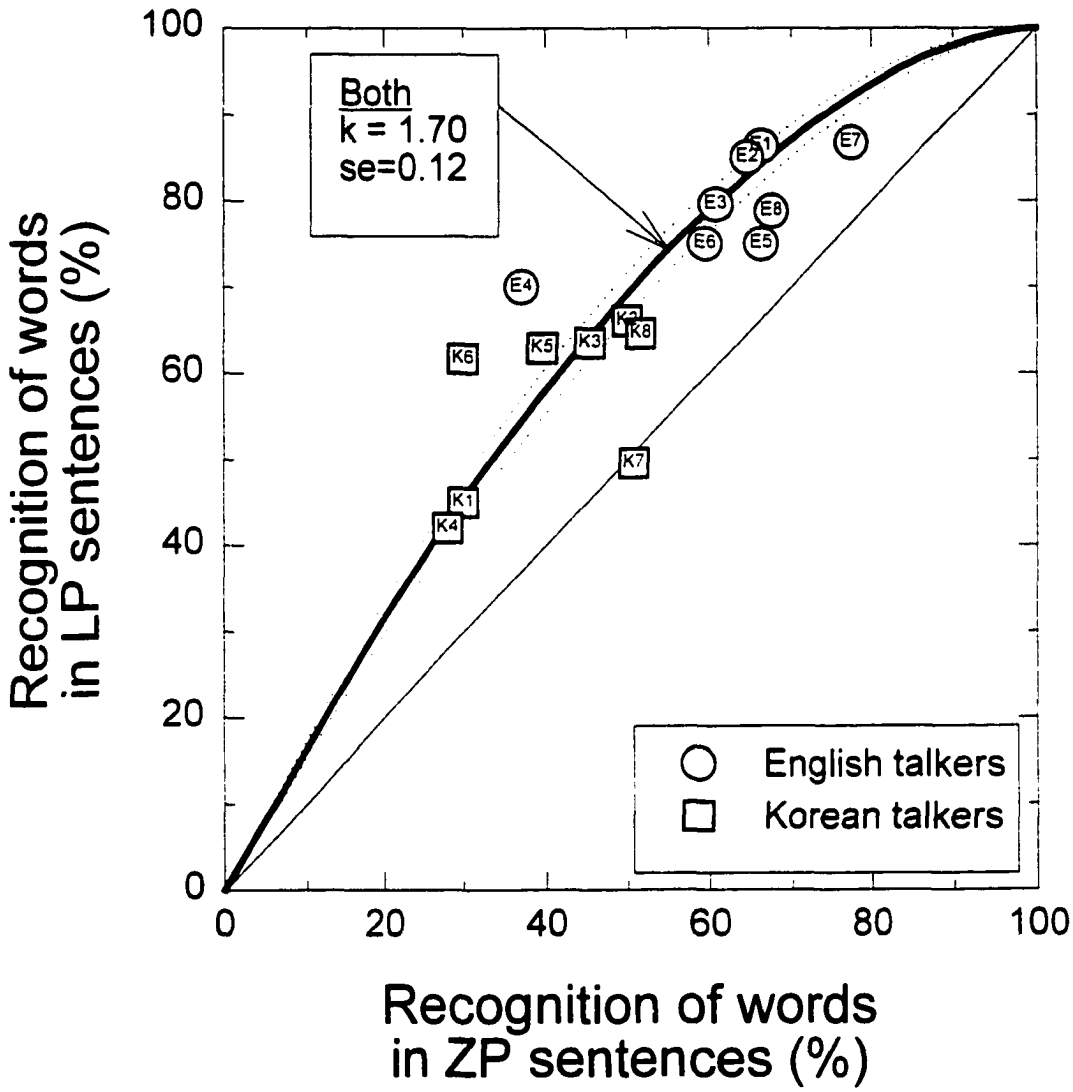

Figure 4.5 Word recognition in LP sentences as a function of word recognition in ZP sentences for 8 English and 8 Korean subjects. Line shows the function: $y = 1-(1-x)^k$ where the factor k represents the group mean benefit of syntactic context.

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The fourth column in Table 4.6 shows k factors for two subject groups when comparing word recognition in four word strings (zero-probability sentences) with lists of consonant-vowel-consonant words (word lists). There was no significant effect for either group or difference between the two groups.

Figure 4.6 illustrates the scores for individuals in the two subject groups when comparing word recognition in four word strings and in isolation (zero-probability sentences and consonant-vowel-consonant word lists). The curves show predicted relationships between k values derived from Table 4.6 It will be seen that both Korean and English speakers derived no significant handicap from having words presented in groups (k=1.09). However, it is apparent in figure 4.6 that there is greater variability among the English subjects' responses to the zero-probability sentences than there is among the Korean subjects' responses.

The fifth column in Table 4.6 shows the k factor obtained by comparing the error probabilities for whole consonant-vowel-consonant words and nonsense syllables. This measure reflects the effect of lexical context on syllable recognition. The lexical context effect is significant for both English and Korean speakers (k>1). There is, however, no significant difference between the two groups p=0.8376).

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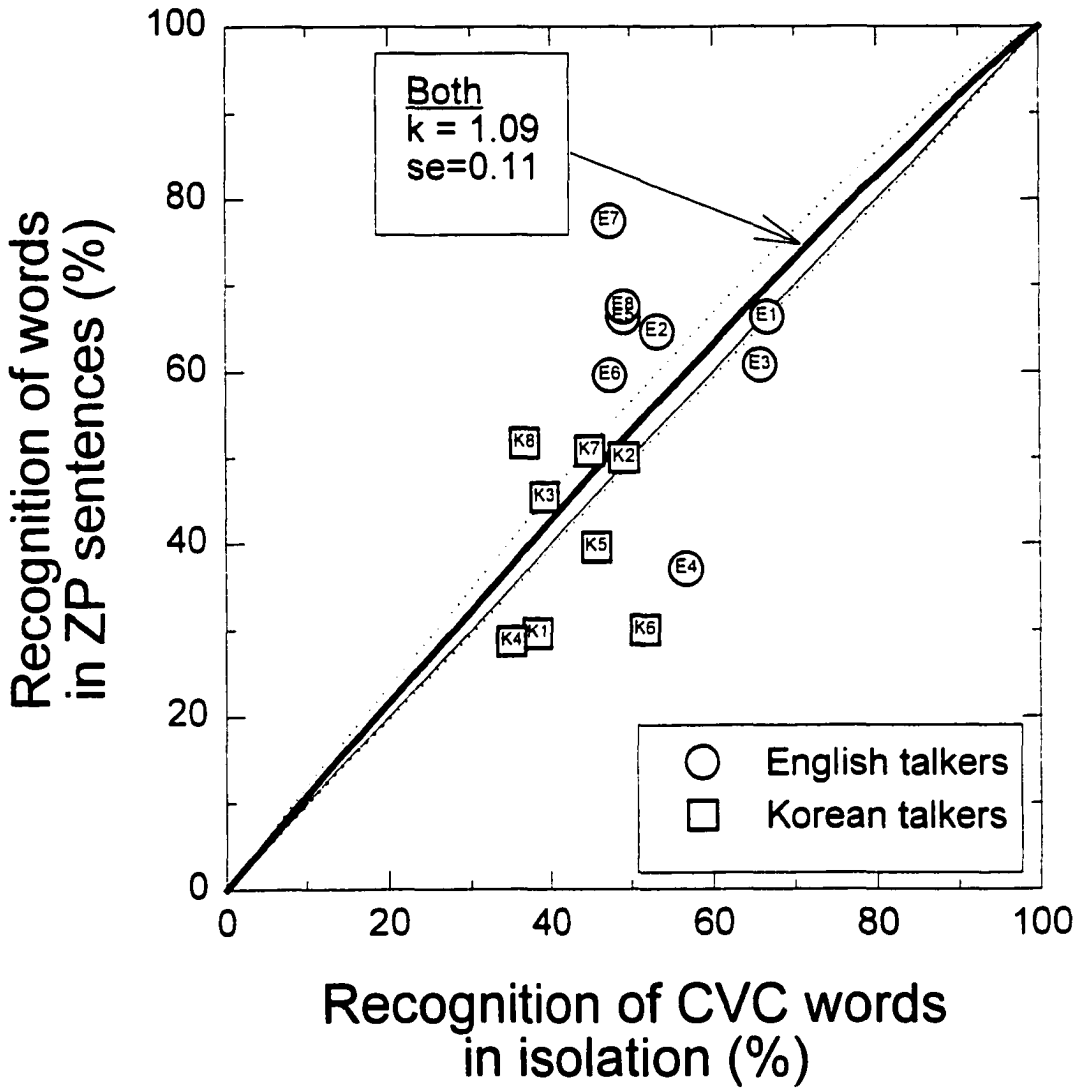

Figure 4.6 Word recognition in ZP sentences as a function of word recognition in lists of CVCs for 8 English and 8 Korean talkers. Lines show the function: $y = 1-(1-x)^k$ where the factor k represents the group mean effect of placing words in strings of 4.

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Individual scores for the recognition of syllables in consonant-vowel-consonant words and nonsense syllable are shown in Figure 4.7. Again the English subjects have greater variability of responses for the recognition of consonant-vowel-consonant nonsense syllables than do the Koreans. The curves show predicted relationships using the average of the mean two k values from Table 4.6. It will be seen that both the English and Korean speakers derived help from lexical context (k=2.69). Thus, the effect of adding lexical context contributed almost equally to single word recognition by Korean and English speakers in this study.

The sixth column in Table 4.6 shows the k factors obtained by comparing the error probabilities for phoneme recognition in consonant-vowel-consonant words and nonsense syllables. This measure reflects the effect of lexical context on phoneme recognition. The lexical context effect is significant for both English and Korean speakers. There is a marginally significant difference between the two groups at a 0.05 confidence level. The English talkers obtained somewhat more benefit from lexical context (k=1.53) than did the Korean talkers (k=1.27).

Individual scores for the recognition of phonemes in consonant-vowel-consonant words and nonsense syllable are shown in Figure 4.8. The individual scores for each language group are clustered together. The one exception is Korean 6 whose responses are in accord with the English subjects'. The curves show predicted relationships using mean k values from Table 4.6.

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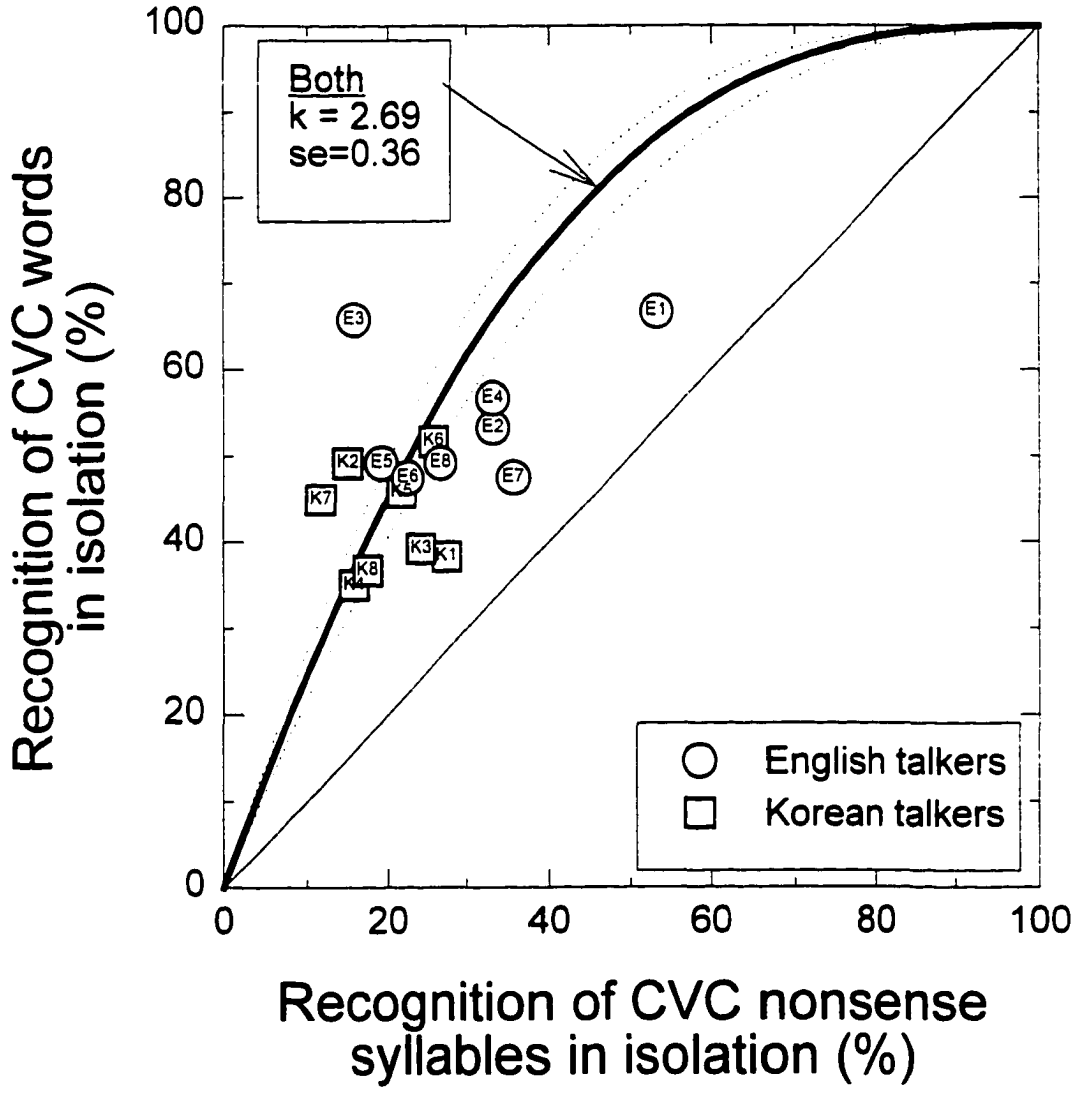

Figure 4.7 Recognition of CVC words as a function of recognition of CVC nonsense syllables for 8 English and 8 Korean subjects (in noise). Lines show the function: $y = 1-(1-x)^k$ where the factor k represents the group mean benefit of lexical context.

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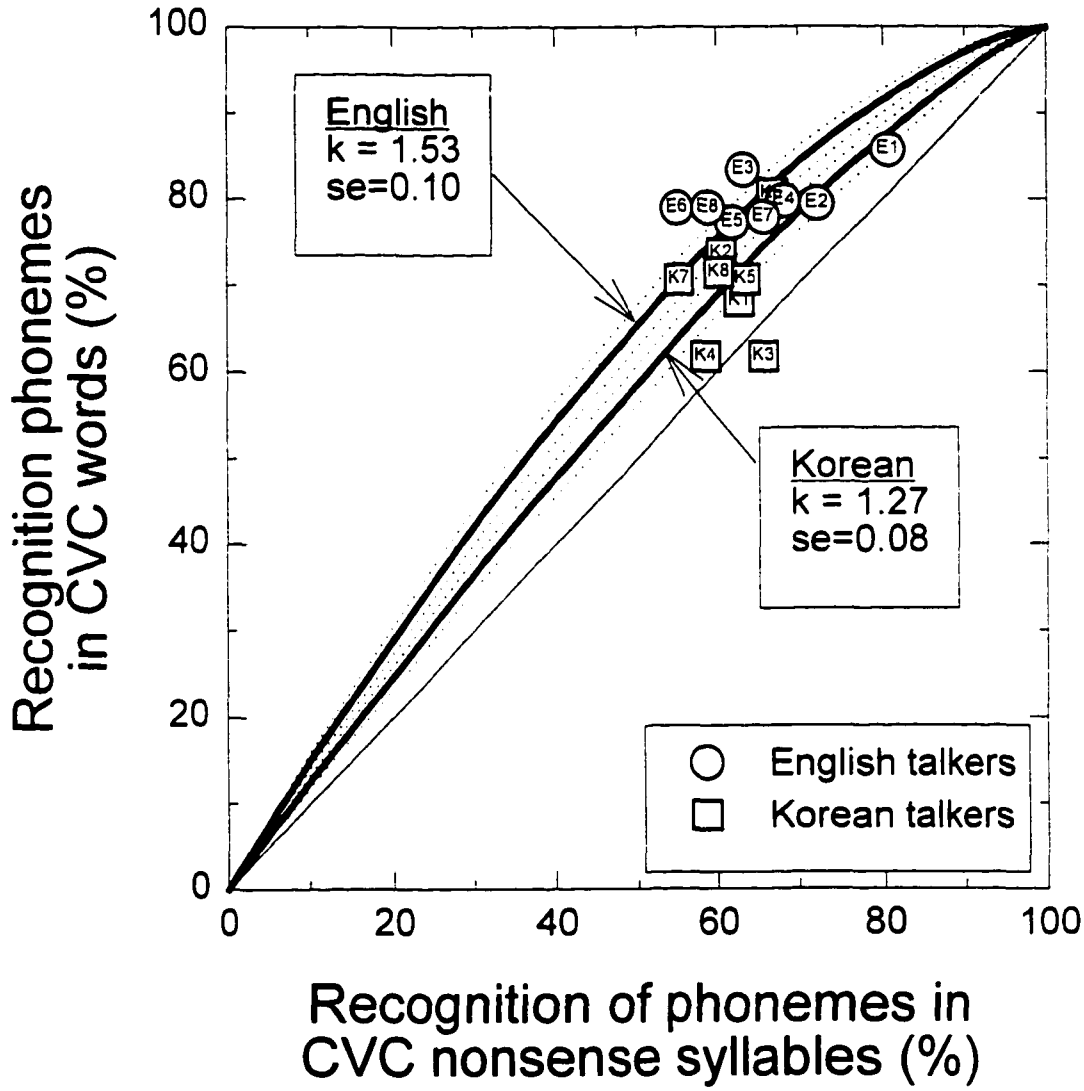

Figure 4.8 Phoneme recognition in CVC words as a function of recognition in CVC nonsense syllables for 8 English and 8 Korean talkers (in noise). Lines show the function: $y = 1-(1-x)^k$. The factor k represents the group mean benefit of lexical context.

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Comparison of mean k factor with percent difference scores and arcsine transformed scores

It was pointed out in Chapter 3 that the appropriate method for quantifying context effects is by no means agreed upon. The obvious approach is to compute difference in percent correct scores. Bilger (1984) recommends using the difference between arcsine-transform curves. The k-factor approach comes from Boothroyd and Nittrouer (1988). It was considered appropriate to compare analyses obtained with all three methods.

Table 4.7 shows the simple percent correct difference scores for sentences, words and nonsense syllables with and without context. Table 4.8 shows the differences between the arcsine-transformed scores. Comparison of Tables 4.6, 4.7 and 4.8 shows that the three methods of expressing the context effects give the same results in terms of deciding which context effects are significant and which measures show a significant difference between groups.

Context effects expressed in terms of j factor

Thus far, the effect of context on word and phoneme recognition has effectively been expressed in terms of differences between pairs of scores obtained using different contexts. As indicated in Chapter 3, Boothroyd and Nittrouer (1988) proposed yet another measure, the j factor. The j factor compares parts and wholes

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Table 4.7 Percentage point difference reflecting the influence of linguistic contexts on word or phoneme recognition by native-Korean and native-English speakers. The data were collapsed across two noise conditions. Shaded areas show significance at p=0.05.

Scoring Unit	word	word	word	word	word	phoneme
Context / *Subjects*	sentences	Semantics	syntax	four word strings	word meaning	word meaning
Korean 1	25.0	10.8	14.2	-8.7	10.8	5.3
Korean 2	19.6	3.5	16.1	0.8	34.2	13.1
Korean 3	-3.1	-21.2	18.1	6.3	15.0	-4.2
Korean 4	7.2	-7.4	14.6	-6.3	19.2	3.1
Korean 5	17.9	-5.4	23.3	-6.2	24.2	6.9
Korean 6	38.8	7.1	31.7	-21.7	25.8	13.6
Korean 7	3.8	5.0	-1.3	5.8	33.3	15.3
Korean 8	31.7	18.8	12.9	15.0	19.2	11.1
Mean	17.6	1.4	16.2	-1.9	22.7	8.0
Std.Dev.	14.3	12.4	9.4	11.3	8.3	6.6
Std.Err.	5.1	4.4	3.3	4.0	2.9	2.3
t 1-tail	3.3	0.1	4.6	-0.7	7.4	3.0
p 1-tail	0.0	0.5	1.0	0.3	0.0	0.0
English 1	33.3	13.3	20.0	-0.4	13.3	5.0
English 2	33.8	13.3	20.4	11.3	20.0	7.2
English 3	29.0	10.2	18.8	-5.0	50.0	20.0
English 4	44.6	11.7	32.9	-19.6	23.3	11.4
English 5	30.4	21.7	8.8	17.1	30.0	15.3
English 6	23.8	8.3	15.4	12.1	25.0	23.9
English 7	22.5	13.3	9.2	30.0	11.7	11.9
English 8	25.4	14.2	11.3	18.3	22.5	20.0
Mean	30.3	13.3	17.1	8.0	24.5	14.3
Std.Dev.	7.1	3.9	7.9	15.6	11.9	6.6
Std.Err.	2.5	1.4	2.8	5.5	4.2	2.3
t 1-tail	11.7	8.1	5.4	1.3	5.6	5.7
p 1-tail	<0.0005	<0.0005	0.0004	0.124	0.0004	0.0004
t diff	4.6	4.9	0.4	3.2	0.7	2.9
p diff	0.0004	0.0002	0.6952	0.0641	0.4954	0.0116

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Table 4.8 Arcsine difference reflecting the influence of linguistic contexts on word or phoneme recognition by native-Korean and native-English speakers. The data were collapsed across two noise conditions. Shaded areas show significance at p=0.05.

Scoring Unit	word	word	word	word	word	phoneme
Context	sentences	semantics	syntax	four word	word	word
Subjects				strings	meaning	meaning
Korean 1	16.31	6.91	9.40	-5.89	15.84	3.54
Korean 2	12.82	2.36	10.46	0.53	14.33	8.88
Korean 3	-1.97	-13.60	11.62	4.03	17.73	-2.76
Korean 4	4.88	-4.82	9.70	-4.32	7.58	1.99
Korean 5	11.47	-3.52	15.00	-4.02	21.29	4.71
Korean 6	25.33	4.74	20.60	-14.16	20.24	9.90
Korean 7	2.39	3.19	-0.80	3.72	12.87	10.12
Korean 8	22.17	13.81	8.36	9.65	19.22	7.48
Mean	11.67	1.13	10.54	-1.31	16.14	5.48
Std.Dev.	9.55	8.34	6.06	7.37	4.51	4.49
Std.Err.	3.38	2.95	2.14	2.60	1.60	1.59
t(7)	3.46	0.38	4.92	-0.50	7.49	3.45
p 1-tail	0.0100	0.3792	0.0009	0.3263	0.0001	0.0053
English 1	35.35	20.07	15.28	-0.28	33.34	4.26
English 2	32.34	17.08	15.26	7.30	0.00	5.38
English 3	22.34	9.14	13.20	-3.30	21.07	14.64
English 4	30.15	8.73	21.42	-12.57	28.20	8.31
English 5	27.77	21.64	6.13	11.07	10.29	10.65
English 6	17.09	6.56	10.53	7.73	19.56	16.40
English 7	31.46	23.80	7.67	20.13	16.95	8.49
English 8	21.47	13.35	8.12	11.91	8.61	13.92
Mean	27.25	15.05	12.20	5.25	17.25	10.25
Std.Dev.	6.31	6.54	5.09	10.22	10.82	4.43
Std.Err.	2.23	2.31	1.80	3.61	3.83	1.56
t(7)	12.21	6.51	6.77	1.45	5.54	5.91
p 1-tail	0.0000	0.0000	0.0003	0.0952	0.0003	0.0007
t diff(14)	2.27	2.61	0.20	1.45	0.35	1.93
p diff	0.0018	0.0023	0.5633	0.1632	0.9283	0.0504

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using a single kind of material to get a measure of the listener's tendency to perceive words or sentences as wholes rather than as combinations of independent parts. When context has no effect, the value of j should equal the number of parts in the whole. Thus, if context had no effect on a four word sentence a listener would have a tendency to hear four independent parts (words). The j factor would be 4 because there are four parts to the sentence (the four words). As the effect of context increased, the j factor would become less.

Pairs of scores for individual subjects were used to derive j factors for the following:

1. The perception of words and phonemes in lists of meaningful consonant-vowel-consonant words.
2. The perception of syllables and phonemes in lists of nonsense syllables.

Means were then calculated for each subject group. Student's 't' was used to determine:

1. Whether the mean value of j for each group was significantly less than the number of phonemes per syllable (i.e. j=3)
2. Whether the mean value of j differed significantly between the groups.

The results of these analyses are shown in Table 4.9. Specific context effects will be reported in turn.

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The first column of Table 4.9 shows the j factor obtained by comparing the recognition probabilities for whole consonant-vowel-consonant words with the recognition probabilities of individual phonemes in the words. The lexical context effect is significant for both subject groups (i.e. The mean value of j is significantly <3). Furthermore, there is a significant difference between the two groups.

The second column of Table 4.9 shows the j factor obtained by comparing the recognition probabilities for whole consonant-vowel-consonant nonsense syllables with the recognition probabilities of individual phonemes in the syllables. The j factor for the English group is not significantly different from 3 (j=3.01). This finding would indicate that the English speakers are deriving no contextual advantage in the nonsense syllable. In the Korean group j is significantly greater than 3 (j=3.40) indicating that nonsense syllable context is interfering with correct recognition of phonemes. The evidence for a difference between the j factor for the two groups is, however, extremely weak (p 2-tail=0.10468).

Summary of results

1. The Koran speakers performed less well than did the English, overall.
2. The difference in performance between the two groups increased significantly with the addition of noise (except phoneme recognition in nonsense consonant-vowel-consonant syllables where there was no significant difference between the two groups in either quiet or noise.

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Table 4.9 J factors representing the effects of lexical context with meaningful consonant-vowel consonant words and nonsense consonant-vowel-consonant syllables. Shaded areas show significance at p=0.05.

	J factors	
Subjects	c-v-c words	c-v-c syllables
Korean 1	2.49	2.77
Korean 2	2.32	3.78
Korean 3	1.94	3.40
Korean 4	2.17	3.45
Korean 5	2.24	3.38
Korean 6	3.05	3.37
Korean 7	2.29	3.62
Korean 8	2.98	3.44
avg	2.43	3.40
sd	0.39	0.29
se	0.14	0.10
t(7)	-4.11	3.91
p 2-tail	0.00	0.01
English 1	2.60	2.91
English 2	2.73	3.38
English 3	2.29	4.03
English 4	2.51	2.89
English 5	2.75	3.45
English 6	3.14	2.50
English 7	2.96	2.45
English 8	2.99	2.50
avg	2.75	3.01
sd	0.28	0.57
se	0.10	0.20
t(7)	-2.57	0.06
p 2-tail	0.04	0.95
tdiff(14)	1.84	1.73
pdiff	0.09	0.10

The difference in performance increased as linguistic context was added. In other words, the Korean speakers took less advantage of context than did the English.

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3. The difference in performance increased as linguistic context was added. In other words, the Korean speakers took less advantage of context than did the English.
4. For the least redundant material (phoneme recognition in nonsense syllables), the difference in performance between the Korean and English speakers approached zero.
5. In terms of effective use of context, when listening in noise, the following effects were found:
    a) Both groups took advantage of plausible sentence context to enhance word recognition, but the English talkers took significantly more advantage than did the Korean talkers.
    b) The English talkers took advantage of high-plausibility sentence meaning but there was no evidence that the Koreans did.
    c) The two groups took similar advantage of sentence syntax.
    d) The two groups took similar advantage of word meaning to enhance recognition of consonant-vowel-consonsant monosyllables.
    e) Both groups took advantage of word meaning to enhance recognition of phonemes within consonant-vowel-consonant words, but the English talkers took more advantage than did the Koreans.
    f) Both groups took advantage of dependencies among phonemes when recognizing whole consonant-vowel-consonant words, but the English took more advantage than did the Korean talkers.

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g) The English talkers treated consonant-vowel-consonant nonsense syllables as three independent phonemes, but the Korean talkers tended to be negatively affected by the nonsense context - apparently looking for dependencies where none existed.

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Chapter 5

Discussion

The purpose of the study was to determine the role linguistic context has in the speech perception of a non-native population. It was concerned with the ability of native Korean speakers to identify words and phonemes in English with and without different linguistic contexts. The questions addressed were:

1) How do Korean and English talkers compare in terms of the recognition of words and phonemes, presented with the varying types of linguistic context, in quiet and in noise?
2) How do Korean and English talkers compare in terms of their use of various types of linguistic context to enhance word and phoneme recognition.

Perception in quiet

Korean talkers performed less well than did the English talkers in quiet. At first sight, this finding appears to contradict the general conclusion reached in the review of the literature, that non-native talkers suffer no perceptual penalty in quiet. In much of that literature, however, non-native and native listeners were deliberately matched in terms of perception in quiet, so direct comparison is inappropriate. Bergman (1980) did show a native language effect in quiet, but only for one subject group – non-native listeners over 60 years old. Again,

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comparison is inappropriate because the subjects in the present study were much younger.

In fact, the term "quiet" should probably not have been applied to the least degraded condition in the present study. The room and equipment used for this study, though designed for use as a language laboratory, was anything but ideal. The listening equipment was not free from electronic noise. To make matters worse, the frequency response of the equipment was poor – being deficient in the high frequencies (as shown in Appendix E). In other words, the "quiet" condition in the present study represented listening under an already degraded condition. Evidence in support of this conclusion is provided by the fact that the English talkers obtained less than perfect scores when tested in "quiet" with materials having reduced redundancy.

Because of these physical and equipment limitations, the findings of the present study provide no useful information either about speech perception under ideal conditions by the two groups, or about differences between the two groups when listening under ideal conditions.

Perception in noise

It was clear that both subject groups had difficulty with speech perception under the more severely degraded noise conditions. Moreover, the Korean talkers had

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more difficulty than did the English talkers. This finding is in agreement with literature reviewed in Chapter 2.

One aspect of the present results, however, was unexpected. The difference between the two groups, which will be called the "non-native penalty," increased with increasing linguistic redundancy. It had been expected that the native Korean talkers would make greater use of sentence context than the native English talkers in order to compensate for difficulties of phoneme and word recognition. Instead, it was found that there was no non-native penalty for the recognition of phonemes in nonsense syllables and only a small penalty for the recognition of words in isolation. The penalty grew when words were placed in sentences and was greatest when those sentences had highly probable meanings. Under this last condition, the English subjects recognized over 90% of the words but the Korean talkers recognized only 60%.

Use of semantic context

An even more unexpected finding was the absence of any evidence that the Korean talkers made use of differences in high and low plausibility sentences to enhance the recognition of words under the noise condition. Regardless of the method used to quantify the context effect, that effect was not significantly greater than zero for the Korean talkers. On average, they recognized 57% of the words in low-probability sentences and 58% in high-probability sentences. This result was in marked contrast to that found with the English talkers who

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recognized 79% of the words in Low Probability in sentences and 93% in High-probability sentences. When expressed as a k factor, the average use of high plausibility semantic context by the English talkers was equivalent to a proportional increase of 1.89 in the available channels of independent information – i.e., an increase of 89%. Note that this value is within the range of 1.97+/-0.19[1] reported by Boothroyd and Nittrouer (1988) in native English-speaking college students, using the same test materials.

There is, in fact, some prior evidence of the failure of non-native talkers to take advantage of highly plausible semantic context. Mayo et al., (1997) found no significant difference of scores for the high- and low-probability items of the SPIN test in post-puberty second-language learners. They did, however, find differences in subjects who learned the second language before age 6. As shown in Table 3.2, the Korean talkers in the present study were reported to have learned English, on average, at age 13. The majority can be considered to have learned English after puberty.

A factor that could account for some of the non-native penalty when dealing with high-probability sentence is the intrusion of word order errors in repetition. It can be argued that the sentence repetition task is most effectively accomplished, not by echoing the input, but by perceiving meaning and using it to regenerate the sentence. For the Korean talkers applying such a strategy, any deficit of

[1] Here and elsewhere, the reported range gives the 95% confidence limits of the mean.

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syntactic knowledge could result in a word order error, even when all four words were recognized. Because errors of order were counted as errors of recognition, this effect would serve to depress scores for High-probability sentences. In fact, such a word order effect was observed. It is doubtful, however, that the incidence was high enough to account for all of the non-native penalty in the use of sentence meaning.

It should also be pointed out that there was a lot of variability in the k factors for the Korean speakers, as will be seen from Table 4.6 and Figure 4.4. In fact, one member of the group obtained a score for the High-probability sentences that was over 20 percentage points lower than that obtained for the low-probability sentences[2]. This one subject had a major influence on the group mean. Even without this subject, however, it is clear that with one exception, the Korean talkers, on average, tended to take less advantage of high plausibility semantic context than did the English talkers. Korean subject 8's responses for High-probability sentences were within the lower range of the English subjects. It is interesting to note that this Korean speaker was not the Korean who used English the most, nor was she the Korean who learned English at the youngest age.

[2] Although such a result seems illogical, application of binomial theory for p = 0.5 and n=40 (the number of words in the LP and HP materials) shows that a difference of this magnitude is within the 95% confidence limits under the assumption that the S's "true" scores for HP and LP sentences are not different.

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It is possible to explain the difference in use of semantic context by English and Korean talkers in terms of processing strategy. Given that noise masking prevented the recognition of words solely on the basis of acoustic input, it can be hypothesized that the English talkers took maximum advantage of potential sentence meaning in order to make and test possible interpretations of the degraded input. Such an approach could be described as a "top-down" strategy. Apparently, the Korean talkers did not do this but, instead, attempted to identify the words on their own merits before assembling them into a meaningful sentence. Such an approach could be described as a "bottom-up" strategy. However, the Korean subjects did make use of syntax. This finding then clouds the argument for bottom-up processing. It seems reasonable though, to think that the non-native talkers may use most of their processing capacity in dealing with the initial stages of word and syntactic recognition. There may be no capacity left for considering and using possible sentence meanings.

It should be noted that there was some evidence, though admittedly weak, that the Korean speakers made use of high plausibilitysemantic context under the "quiet" condition of the study. One interpretation of this data is that the Koreans have the ability to perceive and "fall apart" in a noisy environment. However, if one thinks of perceptual processing as having a finite number of channels to carry information, another explanation presents itself. That is, the Koreans may be using most if not all of their processing capacity to perceive the message in

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the "quiet" condition. When noise is added, they do not have enough available processing abilities (channels) to handle the additional information.

Use of syntactic context

In view of the Korean talkers' apparent failure to take advantage of sentence meaning in the noise condition, the presence of a language effect for the use of syntax is surprising. Both groups increased their word recognition scores by 16 to 17 percentage points when changing from random word strings to sentences with appropriate syntax but unlikely meaning. The corresponding k factor was 1.65. Although at the high end, this value is within the range of 1.38+/-0.33 reported by Boothroyd and Nittrouer (1988) for English-speaking college students listening to the same materials.

If the Korean talkers took so little advantage of sentence meaning, why did they prove as adept as English talkers in the use of syntax? After all, sentence meaning relates to world knowledge – about which the non-native talkers should know as much as the native talkers. In contrast, the syntax is specific to English – in which the non-native talkers were expected to be disadvantaged. One possible explanation is that the effect is not so much one of syntax as of intonation contour. When the recordings were prepared, the speaker was asked to produce all sentences with the same intonation – essentially giving equal stress to each word, a slight pause between words, and a terminal pitch fall, with

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lengthening, on the fourth word. Nevertheless, there was a tendency for the speaker to give more natural contours to the high and low-probability sentences than to the zero-probability sentences. In a replication of this experiment, it would be advisable to construct all sentences from words that are excised from the same recordings so as to avoid potential effects of differences in suprasegmental properties.

Even if the absence of a difference in use of syntax can be explained in terms of suprasegmental effects, the fact that the Korean talkers took full advantage of these effects is, in itself, worthy of note.

Another explanation is the possibility that syntax doesn't require as much processing capacity as semantic/sentential meaning. All sentences in this study used words that tended to be concrete. What was manipulated was the relationship among objects in high- and low-probability sentences, that is, the low-probability sentences were less plausible than the high-probability sentences. Since Korean subjects may have as much knowledge of plausible and implausible relationships among the referents in the sentences, they may have simply accepted the low-probability sentences as having meaning, but less plausible meaning.

In the original design of the sentence materials used in this study, Boothroyd and Nittrouer had aimed at three sentence types:

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1. Sentences with neither syntax nor meaning,
2. Sentences with syntax but no meaning, and
3. Sentences with both syntax and meaning,

in order to separate the effect of syntax and meaning. In fact, the materials fall far short of this simple categorization and it is for this reason that Boothroyd and Nittrouer described the sentence types in terms of zero, low and high-probability. A more accurate description might be

3. Inappropriate syntax
4. Appropriate syntax, but low plausibility re meaning
5. Appropriate syntax and high plausibility re meaning.

It would be wrong, therefore to infer that Korean talkers take advantage of syntax but not of meaning when listening to sentences in noise. A more reasonable inference is that they do take advantage of meaning but are less sensitive to relative plausibility than are English talkers.

Perception of random word strings

The data provided no evidence that either group was disadvantaged by being asked to recall and repeat strings of four words. There was weak evidence that the English talkers actually recognized more words in the zero-probability sentences than they did in the lists of isolated words (p [1-tail]=0.07). Even if this is a real effect, however, it is difficult to give it too much significance because of differences in the vocabulary. The isolated words consisted exclusively of

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consonant-vowel-consonant words. The zero-probability sentences included consonant blends. Clearly there were differences in both phonetic makeup and word frequency between the two types of material. In addition, one would expect differences in pitch, pitch contour, and duration as a result of producing words in strings of four. In fact, the most surprising aspect of these data is the fact that the change from isolated words to random strings had so little effect. One might have expected, for example, that the short-term memory demands and the possibility of production interference would have rendered the task of word repetition in strings of four more difficult – and that the difficulty would increase for the non-native talkers. Apparently, this was not the case.

Use of word meaning to enhance word recognition

Both groups took advantage of word meaning when asked to recognize consonant-vowel-consonant monosyllables. Scores for the English talkers rose from 27 to 49% with the shift from nonsense to meaningful word. Scores for the Korean talkers rose from 20 to 43%. The corresponding k factors were 2.62 and 2.76, with no evidence of a significant difference. Boothroyd and Nittrouer (1988) did not report the k value for this comparison but their reported group mean scores for English-speaking college students lead to a value of 2.32 which is similar to that found in the present study.

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Use of word meaning to enhance phoneme recognition

Phoneme recognition within consonant-vowel-consonant words was significantly enhanced by word meaning for both groups – more so for the English talkers than for the Korean talkers (p [2-tail]=0.054). Values of k were 1.53 and 1.27, respectively. Interestingly, the value for the Korean talkers is within the range of 1.32+/-0.06 reported by Boothroyd and Nittrouer (1988) for English-speaking college students. The value for the English talkers in the present study is above the upper limit of this range.

The Korean talkers' use of word meaning to enhance phoneme recognition within consonant-vowel-consonant syllables is in marked contrast to their apparent failure to take full advantage of sentence meaning to enhance word recognition in 4-word sentences. A possible interpretation of this discrepancy is that, when recognizing words, the Korean talkers take full advantage of a "top-down" strategy, rather than attempting to recognize constituent phonemes on their own merits. The two findings can be reconciled if one assumes that the Korean talkers use the word as the primary unit of recognition – emphasizing a "top-down" strategy in relation to the constituent phonemes and a "bottom-up" strategy in relation to the sentence context.

Parts and wholes in consonant-vowel-consonant monosyllables.

For the English talkers, j factors for consonant-vowel-consonant words and nonsense syllables averaged 2.75 and 3.01, respectively. The value for words is

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somewhat higher than the range of 2.46+/-0.08 reported by Boothroyd and Nittrouer (1988) for English-speaking college students – suggesting that the present subjects were not taking full advantage of the phoneme dependencies within meaningful consonant-vowel-consonants. The value for nonsense syllables fits nicely within the range of 3.07+/- 0.14 found by Boothroyd and Nittrouer (1988). This value is not significantly different from the value of 3.0 that is predicted on the assumption that consonant-vowel-consonant nonsense syllables are being perceived as collections of three independent phonemes.

For the Korean talkers, j factors for consonant-vowel-consonant words and nonsense syllables averaged 2.43 and 3.40, respectively. The value for words is within the range of 2.46+/-0.08 reported by Boothroyd and Nittrouer (1988) for English-speaking college students – suggesting that the present subjects were taking full advantage of the phoneme dependencies within meaningful consonant-vowel-consonants. The value for nonsense syllables is considerably above the range of 3.07+/- 0.14 found by Boothroyd and Nittrouer (1988). This value is significantly different ($p=0.005$) from the value of 3.0 that is predicted on the assumption that consonant-vowel-consonant nonsense syllables are being perceived as collections of three independent phonemes.

This last finding is of particular interest. It implies that there were negative dependencies among the constituent phonemes in consonant-vowel-consonant monosyllables. To put it simply, the recognition of one or two phonemes in a

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syllable lowered the probability of recognition of the third. This phenomenon is explained by the fact that the Korean talkers were biased against giving a nonsense syllable as a response and towards perceiving the syllables as meaningful words. This phenomenon was observed and commented on by the judges and it occurred in spite of the fact that subjects were told when they would be listening to nonsense syllables.

These data could be interpreted as providing further support for the conclusion that the Korean talkers, unlike the English talkers, were unable to adopt a "bottom-up" strategy when faced with the task of recognizing the phonemes within nonsense syllables. Instead, they persevered with a "top-down" approach. This approach served them well when asked to repeat meaningful consonant-vowel-consonant syllables – as evidenced by a j-factor that was in the range of "normal" found in other studies.

Phoneme recognition in consonant-vowel-consonant nonsense syllables

One aspect of linguistic context not, so far, addressed in the present study is phonology. The phoneme set of a language, the relative frequencies of occurrence of those phonemes, sequential probabilities, and phonotactic constraints all serve to influence decisions made about the acoustic speech signal. These influences are analogous to the influences of vocabulary, word frequency, and syntax on word recognition.

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The present study provides no data on speech perception with and without phonological context. In fact, it is difficult to see how such an experiment could be designed. It can be assumed, however, that the recognition of phonemes in nonsense syllables reflects a combination of psychoacoustic capabilities and the effects of phonological context just outlined. There is no reason to assume that the Korean and English speakers differ in terms of psychoacoustic capabilities. The absence of a significant language effect on the recognition of phonemes in nonsense syllables must, therefore, be accepted as evidence for the absence of a non-native penalty in terms of the use of phonological context.

This last conclusion is difficult to reconcile with the fact that the most obvious characteristic of the non-native talker is a deviant phonology. It will be recalled, however, that the judges in the present study were instructed to ignore substitutions that are known to be characteristic of Korean-accented English.

Procedural issues (threats to validity)

Any study of speech perception faces the issue of how to determine what the perceptions were. In this study, the subjects said what they heard. Thus, their perception went through a "filter" of speech production. In this case, the Korean speakers' production acts as a broader filter than would English speakers' production because of the influence of the first language on second language production (accent). In turn, the response was filtered again when the judges listened to and wrote what they thought the subjects said. In essence, the

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perception went through several filters: the report of the subjects' perceptions, the perception of those responses by the judges, and then their written production of that perception. As mentioned earlier in this chapter, the Korean subjects seemed biased against giving a nonsense response to a nonsense syllable, however, their mean score was no different from the English subjects. The question arises as to whether these scores are the result of a non-native penalty or a result of the evaluation strategy used. In this research, the judges were given the list of stimuli heard by the subjects. They were instructed to transcribe what they heard. Did the judges transcribe what they heard, or did they look at the "script" and then decide that was what the talker intended? If they responded in the latter fashion, it is possible that giving the judges the influence of knowing the correct answer and giving the subjects the "benefit of the doubt" would enhance the Koreans' scores and thereby mask real difficulties, even at the phoneme level. The earlier conclusion, therefore, of the absence of a non-native penalty at the phonological level must be treated with great caution.

Another potential threat to validity is the limited number of stimuli. Each subject heard ten sentences of each type (high-probability, low-probability and zero-probability) in signal-to-noise ratios of 0 and 3, and in quiet. Thus, to avoid repetition of sentences, it would have been necessary to present 30 different sentences to each subject. There were only 20 high-probability sentences and 20 low-probability sentences. Thus, a minimum of ten sentences in the high- and low-probability stimuli were heard more than once. To minimize

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syllable, however, their mean score was no different from the English subjects. The question arises as to whether these scores are the result of a non-native penalty or a result of the evaluation strategy used. In this research, the judges were given the list of stimuli heard by the subjects. They were instructed to transcribe what they heard. Did the judges transcribe what they heard, or did they look at the "script" and then decide that was what the talker intended? If they responded in the latter fashion, it is possible that giving the judges the influence of knowing the correct answer and giving the subjects the "benefit of the doubt" would enhance the Koreans' scores and thereby mask real difficulties, even at the phoneme level. The earlier conclusion, therefore, of the absence of a non-native penalty at the phonological level must be treated with great caution.

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the possible learning effect inherent in repetition, the presentation of these sentences were separated by other stimuli, however, one can not rule out the possibility that learning effects covered existing difficulties and resulted in minimizing the non-native penalty. Thus, conclusions based on these findings should be interpreted with caution. In future investigations, it would be prudent to add twenty more sentences each to the high- and low-probability sentence lists.

Generalizability

This study was designed to gain information about non-native listeners' perceptions in different linguistic contexts under degraded listening conditions. The findings of the present study suggest that a primary limitation of the non-native listener is a tendency to rely on a word recognition strategy and an inability to focus on sentence meaning or phonetic detail when the occasion demands it. Although this research was conducted on a Korean speaking non-native population, the finding may well reflect a universal problem for non-native listeners who acquire a second language after puberty. Before accepting this conclusion, however, further research is necessary.

Educational implications

Signal-to-noise ratios ranging from +5 dB to –7 dB have been reported in many classrooms, (Sanders, 1965; Paul, 1967; Blair, 1977; Fnitzo-Hieber, 1988). Crandell, Smaldino and Flexer (1995) recommend that signal-to-noise ratios in

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learning environments for children and those with sensorineural hearing losses should be at least + 15 dB for maximum speech recognition. Since the second-language population also has difficulty recognizing speech in noise. Improving the signal-to-noise ratio in the classroom should also improve this population's ability to recognize speech.

There are two ways to improve the signal-to-noise ratio. One would be to increase the speech signal relative to the noise present. Crandell (1994) studied the speech recognition of normal hearing native- and non-native-English speaking children using sound-field amplification. The children listened to PBK monosyllabic word lists that were recorded in amplified and unamplified conditions at speaker-listener distances of 6, 12 and 24 feet, in a classroom environment having a signal-to-noise ratio of +6 dB and a reverberation time of 0.4 sec. Speech perception by the non-native children improved about 22 percentage points at 12 feet and 30 percentage points at 24 feet.

The second approach to improving the signal-to-noise ratio is to reduce the noise. This can be done with acoustic treatment of existing classrooms and planning for sound reduction in new classrooms.

If, as the results of this study suggest, second-language speakers have a serious problem of adherence to an inefficient perceptual strategy, the question arises as to whether this is an inevitable situation or one that can be remediated

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with different teaching strategies in the first place – or with remedial strategies at a later date. The suggestion that Koreans in this study focus on word recognition and then may identify the constituent phonemes or the sentence could be a result, not of first language influence, but of second-language-teaching methodology. Many second-language-learning programs focus on the acquisition of vocabulary. The results of this study would indicate that a shifting focus to the acquisition of skills dealing with sentential information through tasks such as sentence completion, responding in full sentences, and sentence identification may benefit the second-language learner. Before acting on these suppositions, however, further research is needed.

Further research

The absence of evidence that Korean subjects made full use of sentence meaning is surprising. There is a need to examine this issue more carefully using more materials and more subjects to confirm or contradict this finding. It would also be interesting to determine whether this situation applies also to written comprehension or if it is specifically an auditory problem.

This study found that Korean listeners who learned English post-puberty were unable to use contextual information as efficiently as native speakers. It would be interesting to extend this research to other second-language populations.

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The materials used in this study ranged from consonant-vowel-consonant nonsense syllables to four word sentences. While this covered several levels of linguistic context, these stimuli are not representative of continuous discourse speech used in schools or work. Thus, the speech perception tasks used in this study are not representative of those used in natural communication i.e. topic driven information with complex sentence structure. Further research making the type of perceptual demands required in academic and work environments is necessary.

Conclusions

To the extent that these two groups of subjects are representative of the larger population of Korean-speaking and English-speaking people, the following conclusions can be drawn:

When faced with the tasks used in this study, Korean talkers, on average, recognize words and phonemes less well than do English talkers.

The non-native penalty increases with increasing degradation of the acoustic input (noise).

The non-native penalty also increases as the linguistic redundancy in the materials increases - being highest for word recognition in highly probable sentences and lowest (possibly zero) for phoneme recognition in nonsense syllables.

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Korean talkers, on average, do not appear to take full advantage of sentence meaning to enhance word recognition in sentences. In contrast, the English subjects take considerable advantage of sentence meaning.

Both groups take considerable advantage of word meaning to enhance recognition of consonant-vowel-consonant monosyllables.

On average, Korean subjects, however, tend to perceive nonsense syllables as meaningful words. In contrast, English subjects tend to treat nonsense syllables as collections of three independent phonemes.

These last three observations are in keeping with a hypothesis that the Korean subjects (and, by implication, similar non-native listeners in general) tend to remain fixed on a word recognition strategy - regardless of the immediate nature of the perceptual task. In contrast, the English subjects (and, by implication, similar native listeners in general) appear to demonstrate flexibility of strategy - taking full advantage of sentence meaning when it is available and focusing on phonetic detail when neither sentence nor word meaning is available. This theory, and its educational implications and generalizability, remain to be tested.

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Appendix A Student Questionnaire

Name _____ **Social Security Number**_____
Date of Birth _____

1. What is your first language? _____

2. Do you speak any other languages besides your first language and English?
Yes _____ **No** _____
If yes, what other language do you speak? _____

3. At what age did you learn English? _____

4. Where do you speak English?
at home _____
at school _____
at work _____
with friends _____
with family _____
other _____

5. When do you speak English?
all of the time _____
most of the time _____
some of the time _____
as little as possible ___

6. Where do you hear English spoken?
at home _____
at school _____
at work _____
at church _____
with friends _____
on the radio _____
on the television ___
other _____

7. How well do you think you speak English?
very well _____
well _____
okay _____
fair _____
poor _____

8. How well do you think you understand English?
Very well _____
Well _____
Okay _____
Fair _____
Poor _____

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Appendix B CUNY Human Subjects Committee Consent and Informed Consent Form

THE
GRADUATE SCHOOL
AND
UNIVERSITY CENTER
THE CITY UNIVERSITY OF NEW YORK

OFFICE OF RESEARCH AND UNIVERSITY PROGRAMS
SPONSORED RESEARCH
33 WEST 42 STREET, NEW YORK, NY 10036-8099
212 642-2059 FAX 212 642-2546

April 9, 1997

Ms. Marion Levine
Ph.D. Program in Speech and Hearing Sciences

Re: Your human subjects proposal, "The Use of Context by a Second Language Population"

Dear Ms. Levine:

Thank you for your response to the conditions set by the Committee on the Protection of Human Subjects for final approval of your proposal. Your proposal is now approved. Please note that this approval is good for one year; if your reseach extends beyond that time, you will need to apply for continuation approval.

Best wishes for every success in your research.

Sincerely,

Hilry Fisher
Director

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THE
GRADUATE SCHOOL
AND
UNIVERSITY CENTER
THE CITY UNIVERSITY OF NEW YORK

PH.D. PROGRAM IN SPEECH AND HEARING SCIENCES
33 WEST 42 STREET, NEW YORK, NY 10036-8099
212 642-2352 FAX 212 642-2379

Informed Consent

The Use of Context by a Second Language Population

The purpose of this project is to see how people who have English as their second language understand English words, sentences and nonsense in different listening situations.

You will be asked to listen to words, nonsense words, sentences and nonsense sentences and repeat what you hear. Your responses will be tape recorded. You have the right to listen to any or all of your recording.

This study will involve one session that should not exceed fifty minutes

You will also be asked to answer a questionnaire about your use of English.

There are no known risks in taking part in this study. Your answers and identity will be kept confidential. No one at Fashion Institute of Technology, except the investigator, will know the results of the study or see the questionnaire

You can refuse to join this project, and are free to withdraw at any time after it is started.

The results of this study will have absolutely no impact on your grades or academic standing at school.

If you have an further questions about the study you may contact Professor Marion Levine, English and Speech Department at (212) 217-7559 or at the Speech and Hearing Sciences Department of the Graduate Center of City University of New York at (212) 642 2352.

Professor Levine has explained the study to me, and has answered my questions fully. I agree to take part.

SUBJECT'S SIGNATURE DATE

INVESTIGATOR'S SIGNATURE DATE

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Appendix C Speech stimuli

CONSONANT-VOWEL-CONSONANT WORD LISTS

List 1	List 2	List 3	List 4	List 5	List 6
pass	hall	pies	boss	time	make
rule	come	mock	sip	caught	laws
cause	beg	room	pal	beg	rice
time	rose	dad	coat	rid	bell
log	suit	loan	rod	loon	tote
sick	made	beg	moon	mop	cod
mean	like	tail	hem	doze	ham
bed	peace	keep	take	says	deep
hope	dip	hiss	league	pack	pig
date	ten	sought	dies	heel	soon

List 7	List 8	List 9	List 10	List 11	List 12
seal	hide	call	lean	lice	dike
dawn	tame	buys	hag	mail	ball
boom	rule	same	bed	tomb	mace
hog	cause	miss	sews	bag	rig
toes	big	rot	cop	soap	lose
mid	sass	hoop	root	rake	sop
cat	pope	load	pick	pen	comb
like	don	peck	maim	keys	ten
pep	meek	tag	toss	hid	pad
race	let	dean	dial	dot	heat

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CONSONANT-VOWEL-CONSONANT NONSENSE SYLLABLES

List 1	List 2	List 3	List 4	List 5	List 6
m aɪ g	b eɪ p	k ɛ z	b i g	r u k	p u k
k ɔ s	r ɑɪ k	p ɪ d	t æ t	t eɪ t	k ɪ z
h eɪ m	l i m	s u m	p ɛ m	l aɪ l	t eɪ d
d ɪ t	m ɪ n	r ɪ g	r oʊ s	b ɔ p	d ɔ s
t u p	p u t	t eɪ n	k ɑ l	p ɪ m	h ɪ m
b ɑ k	s oʊ g	l oʊ l	h u n	k æ z	l i t
p oU d	t æ z	m ɑ t	d ɪ z	d oʊ n	s æ n
s ɛ m	d ɑ s	d ɔ k	l eɪ p	h ɑ d	b ɛ p
l æ l	h ɔ d	b ɪ s	s ɔ k	m ɪ s	m oʊ g
r ɪ z	k ɛ l	h æ p	m ɑɪ d	s ɛ g	r ɑ l

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CVC Nonsense syllables continued

List 7	List 8	List 9	List 10	List 11	List 12
r ɪ t	r eɪ g	l ɛ n	p æ z	r eɪ m	k ɪ g
s eɪ z	t u k	d æ p	h i s	l ɔ k	p eɪ k
b ɔ d	m ɔ t	p ɪ t	m ɛ k	m u l	t ɪ s
k u m	k ɪ p	b ɪ m	s oʊ m	d æ s	d ɔ d
l ɛ p	b oʊ d	s i g	t ɑ l	h ɛ z	m i z
p oʊ n	h ɑ s	h ɑ l	l ɔ t	t i d	r ɛ m
h ɪ s	l æ n	k eɪ z	k eɪ d	p oʊ t	h æ p
d æ k	s ɑɪ l	r u s	b ɪ p	b ɑ n	l ɑ n
t i g	d ɛ z	t ɔ d	d u g	k ɑɪ p	s oʊ t
m ɑ l	b i m	m oʊ k	r ɪ n	s ɪ g	b u l

HIGH PREDICTABILITY SENTENCES (HP)

Tough guys sound mean.
Warm sun feels good.
Birds like long worms.
Dad buys new shirts.
Cows give sweet milk.
Cooks make hot food
Feed your dog meat.
Take that trash out.
Dull paint won't shine.
Most boys play ball.

Tall men jump high.
Red wine can stain.
Tell mom those jokes.
Sharp nails might hurt.
Fall nights turn cool.
Apes swing from trees.
Boats sail at sea.
Small kids need help.
Pour me more tea.
Fresh bread smells great.

LOW PREDICTABILITY SENTENCES (LP)

Thin books look bright
Wide pens swim fast.
Cats get good ears.
Feet catch slow thieves.
Ducks eat old tape.
Cups kill fat leaves.
Throw his rat ice.
Lead this coat home.
Green hands don't fall.
Pink chalk bakes phones.

Blue chairs speak well.
Dumb shoes will sing.
Find girls these clouds.
Tin hats may laugh.
Late forks hit low.
Knees talk with mice.
Teeth sleep on fields.
Sad cars want chills.
Lend them less joy.
Soft rocks taste strange

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ZERO PROBABILITY SENTENCES (ZP)

Sing his gets throw.
Tin bread blue more.
Pour this kids lead.
Jokes boats speak fast.
Trees night from might.
Rock Mom see strange.
Apes home ducks cloud.
Soft these ice give.
Birds warm great fields.
Knees on sleep feels.
Sad slow cars bakes.
Chairs pink well wine.
Milk can swim girls.
Make meat teeth don't.
Play mean help less.
Stain tape dull mice.
Old ball paint swing.
Shoes trash feet want.
Find worms coat tail.
Leave joy high talk.

Guys late phones chalk.
Hats ears rat will.
Cups small at fresh
With chills me red.
Sharp thin books look.
Hurt tell laugh low.
Taste long cats thieves.
Lend men feet those.
Bright tea green catch.
Dumb good fall new.
Forks may shirt jump.
Good take sail sun.
Shine them won't wide
Hands cooks cows nails.
That like fat smells.
Dog you sweet Dad.
Out cool pens most.
Hot wear hit need.
Food boys kill fall.
Sound tough turn buys.

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Appendix D

Pilot Study to Establish Appropriate Signal-to-Noise Ratios

Introduction

The purpose of the proposed dissertation research study is to measure and compare the effects of syntactic and semantic context on word recognition and lexical context on phoneme recognition in noise by a native-Korean-speaking sample and a native-American-English-speaking sample. This research is a replication in non-native listeners of the Boothroyd and Nittrouer 1988 study which measured the effects of the various linguistic contribution to word and phoneme recognition. In their study they used single syllable words and nonsense syllables as well as three types of sentences (semantically and syntactically correct, semantically anomalous and semantically and syntactically anomalous). These stimuli were presented in seven levels of noise.

The initial design of the proposed research was to replicate the Boothroyd and Nittrouer study that used seven signal-to-noise conditions. However, the length of testing, subject fatigue and the number of hours judges would be required to listen to subjects' responses made it prudent to reduce the number of signal-to-noise ratios used. Thus, it became critical to find the signal-to-noise ratios that are difficult enough for native-American-English listeners to avoid the ceiling effect without being too difficult for the native-Korean listeners. Specifically, I was concerned that the native-Korean speakers would have greatest difficulty with

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consonant-vowel-consonant nonsense syllables (the stimuli with the least contextual information) in noise (Hirsch, Reynolds and Joseph 1954, Howes 1957, Rosenzweig and Postman 1957, Pollack, Rubenstein and Decker 1959, Savin 1963, Giolas and Epstein 1961, Schultz 1964), and therefore score zero at several signal-to-noise levels.

Conversely, the native-American-English speakers would be less affected by the noise and would score 100 percent at several signal-to-noise levels on the high-probability sentences, the stimuli with the most contextual information (Miller, Heise and Lichten1951).

The purpose of the pilot study was to determine the range of signal-to-noise ratios to be used in the dissertation study.

Stimuli

The speech stimuli, 12 lists of ten consonant-vowel-consonant nonsense syllables, 12 lists of ten consonant-vowel-consonant words, twenty intact sentences (high-probability), twenty semantically anomalous and syntactically intact sentences (low-probability) and twenty syntactically and semantically anomalous sentences (zero-probability) were developed by Boothroyd and Nittrouer (1988).

All the stimuli were recorded by an adult male talker onto digital auditory tape. They were digitized at 16 bits and 2205 samples per second. After digitization, amplitude

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distributions were computed for each list (consonant-vowel-consonant words, nonsense syllables, high-, low- and zero-probability sentences). Amplitudes were expressed in five ms digital units integrated over a 40 ms time window. When necessary, the amplitude of a list were increased or decreased so that the 70 th. percentiles of the amplitude was within $\pm$ one decibel for all lists. The stimuli were then mixed with speech distribution shaped noise at seven signal-to-noise ratios, 12, 9, 6, 3, 0, -3 and -6 dB. The resulting seven sets of materials (plus the noise free stimuli) were then transferred to analog tape.

Subjects and Procedure

The subjects for this pilot study were five undergraduate college students who had English as their first language and five undergraduate students who had Korean as their first language. All students were capable of following English lectures and had no known hearing impairment.

The Korean students were told they would hear three lists of nonsense syllables in quiet and then in several levels of noise. The tester informed them that these words were not real words. They were asked to repeat what they heard and guess when they were not sure. After each set of three lists, the tester informed the subjects that the noise would increase. If any subject seemed concerned about his/her performance, the tester would reassure him/her that the purpose of the test was to see how much noise was needed before reaching the twenty percent correct target level. The lists were presented first in quiet and then at

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decreasing signal-to-noise ratios starting at +12 dB. The testing was stopped at the signal-to-noise ratio where the subject averaged 20 percent correct responses or less.

The native-American-English-speaking subjects were told they would be listening to sentences in quiet and then in various amounts of noise. They were to repeat what they heard and guess when they were unsure. They listened to five semantically and syntactically intact (high-probability) sentences in increasing signal-to-noise ratios starting with -6 dB. With each 3 dB decrease in the signal-to-noise ratio another five-high probability sentences were presented. The testing was stopped at the signal-to-noise ratio at which the subjects scored 80 percent or more.

Results

One judge listened to all the subjects' responses. The judge checked each correct response. The judge wrote incorrect responses phonetically. Each subject provided three scores at each test level, that was, the number of words correct in each five sentence group for the American-English subjects, and the number of consonant-vowel-consonant nonsense syllables correct in each ten word list for the Korean subjects. These scores were converted to percent correct and then averaged.

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The data are shown in Tables 1 and 2 for the Korean subjects (listening to consonant-vowel-consonant nonsense syllables) and American-English subjects (listening to intact sentences), respectively. Group means (+/- one standard deviation) are illustrated as a function of signal-to-noise ratio in Figure 1. It will be seen that signal-to-noise ratios of 0 and 3 dB satisfy the requirements of mean scores greater than 20 percent for Korean subjects listening to nonsense syllables and mean scores less than 90 percent for American subjects listening to intact sentences.

Discussion

This study was conducted in an effort to find signal-to-noise ratios that would minimize floor and ceiling effects. Although there was considerable inter-subject variability, the group means remained between 20 and 90 percent for signal-to-noise ratios of 0 dB and 3 dB. The lowest expected score will be for Korean subjects listening to nonsense syllables (and scored by whole syllable). The highest expected scores will be for American subjects listening to intact sentences (and scored by word). These signal-to-noise conditions should satisfy the requirements of the main study for which this was a pilot.

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Table 1. Percent correct recognition of whole nonsense syllables by five native-Korean talkers in quiet and seven signal-to-noise ratios.

	Signal-to-noise ratios					
Subjects	Quiet	+12	+9	+6	+3	0
JI	45	45	50	40	33	23
JY	44	43	16	20	33	16
HJK	63	36	63	53	16	13
JK	70	53	43	53	33	26
EL	73	73	60	50	33	40
MEAN	59	50	46.4	43.2	29.6	23.6
STD DEV	13.73	14.21	18.77	14.02	7.60	10.55

Table 2. Percent correct recognition of words in intact sentences by five native-American-English talkers in five signal-to-noise ratios.

	Signal-to-noise ratios				
Subjects	+6	+3	0	-3	-6
TT	100	80	40	15	NR
NA	100	80	40	10	NR
CK	100	80	80	10	0
KC		95	95	35	NR
JC		100	55	20	NR
MEAN	100	87	62	18	
TD DEV	0	9.75	24.65	10.37	

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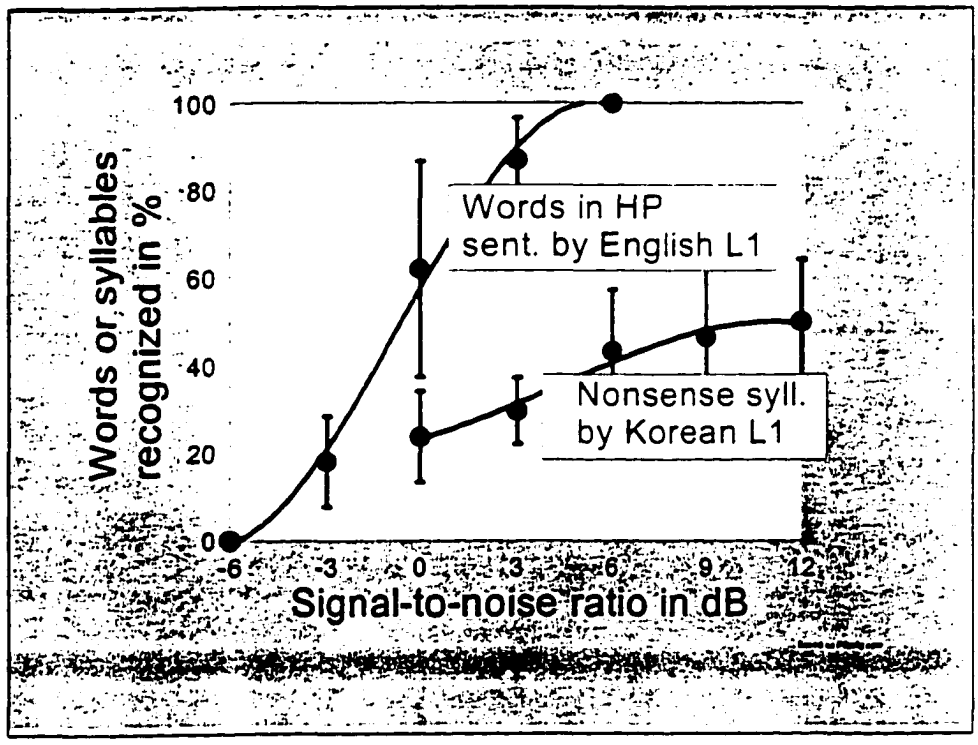
Figure 1. Percent correct recognition of speech units as a function of signal-to-noise ratio. The upper curve shows percent recognition of words in intact sentences by native-American-English speakers. The lower curve shows percent recognition of whole nonsense syllables by native-Korean speakers. Data points are group means (n=5). Error bars show +/- one standard deviation.



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Appendix E

Calibration data for ACS4 m language laboratory

The ACS4 m language laboratory is equipped with headsets with attached microphones at each of the student stations. The frame of the student console needs to be removed in order to separate the headsets from the student units. Because of this, several of the headsets were evaluated electrically at the language laboratory at Fashion Institute of Technology of SUNY. They were found to have similar responses.

One headset was disconnected and brought to the Speech and Hearing Sciences Department at the Graduate Center CUNY where the frequency response of the earphones and microphone were measured on a B and K sound level meter. The results are on the next two pages.

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Appendix E. Calibration data for the ACS 4 language laboratory

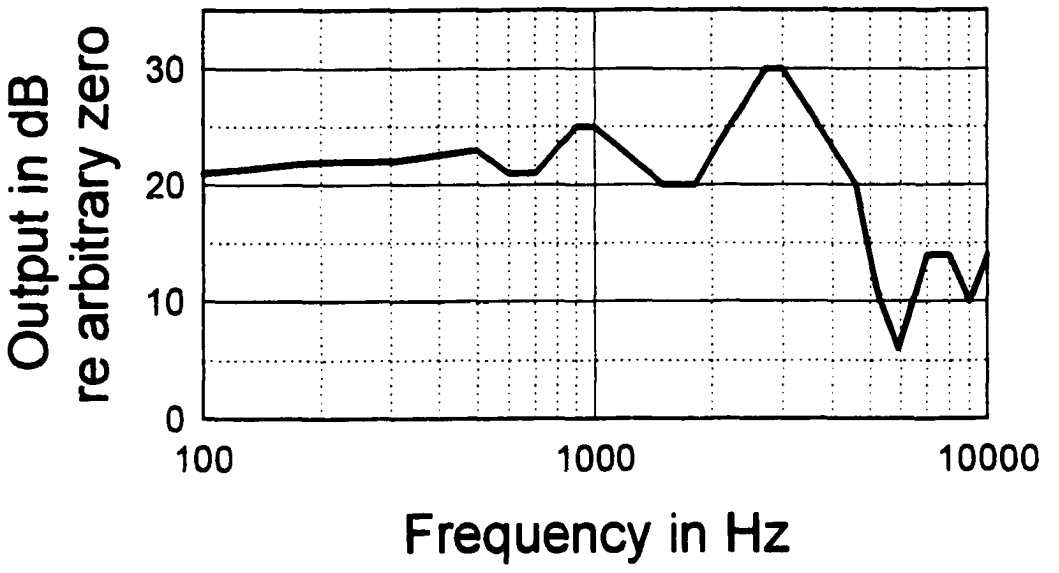

Figure E1. Frequency response of a sample earphone from the ACS 4 language laboratory system. Acoustic output is shown for a constant voltage input. Note that this response determined the quality of the sound presented to the subjects.

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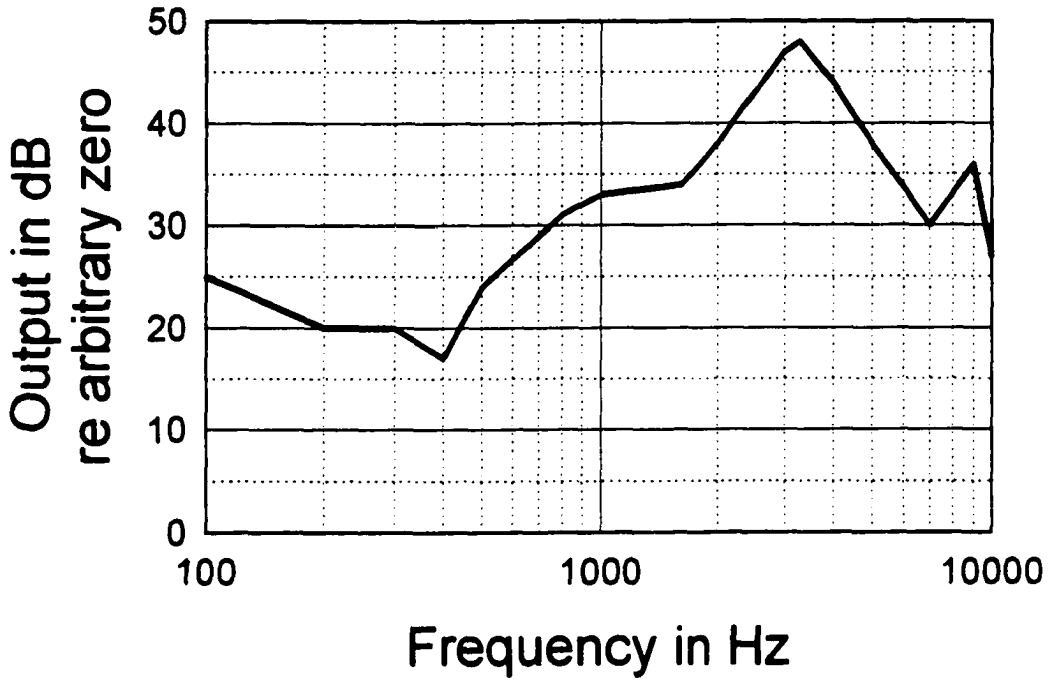

Figure E2. Frequency response of a sample microphone and amplifier from the ACS 4 language laboratory system. Acoustic output from a TDH50 earphone (flat response to 8000 Hz) is shown for a constant acoustic input to the ACS microphone.

Note that this response determined the quality of the recordings heard by the 3 judges.

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Appendix F

Sample judges' form for evaluating subjects' responses

ZP-Q

Good take sail sun.
___ ___ ___ ___

Shine them sail sun.
___ ___ ___ ___

Make meat teeth don't.
___ ___ ___ ___

Hands cooks cows nails.
___ ___ ___ ___

That like fat smells.
___ ___ ___ ___

.

ZP-0

Hats ears rat will.
___ ___ ___ ___

Cups small at fresh.
___ ___ ___ ___

With chills me red.
___ ___ ___ ___

Sharp thin books look.
___ ___ ___ ___

Hurt tell laugh low.
___ ___ ___ ___

Taste long cats thieves.

ZP-3

Sing his gets throw.
___ ___ ___ ___

Tin bread blue more.
___ ___ ___ ___

Pour this kids lead.
___ ___ ___ ___

Jokes boats speak fast.
___ ___ ___ ___

Trees night from might.
___ ___ ___ ___

.

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HP-Q

Tough guys sound mean.

Warm sun feels good.

Birds like warm worms.

Dad buys new shirts.

Cows give sweet milk.

HP-3

Apes swing from trees.

Boats sail at sea.

Small kids need help.

Pour me more tea.

Fresh bread smells great.

HP-0

Tall men jump high.

Red wine can stain.

Tell mom those jokes.

Sharp nails might hurt.

Fall nights turn cool.

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LP-Q

Cups kill fat leaves.

Throw his rat ice.

Lead this coat home.

Green hands don't fall.

Pink chalk bakes phones.

LP-3

Blue chairs speak well.

Dumb shoes will sing.

Find girls these clouds.

Tin hats may laugh.

Late forks hit low.

LP-0

Knees talk with mice.

Teeth sleep on fields.

Sad cars want chills.

Lend them less joy.

Soft rocks taste strange.

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CVC-0
List 11

lice	mail	tomb	bag	soap	rake
_ _ _	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _
pen	keys	hid	dot		
_ _ _	_ _ _	_ _ _	_ _ _		

List 12

dike	ball	mace	rig	lose	sop
_ _ _	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _
comb	ten	pad	heat		
_ _ _	_ _ _	_ _ _	_ _ _		

CVC-3
List 7

seal	dawn	boom	hog	toes	mid
_ _ _	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _
cat	like	pep	race		
_ _ _	_ _ _	_ _ _	_ _ _		

List 8

hide	tame	rule	cause	big	sass
_ _ _	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _
pope	don	meek	let		
_ _ _	_ _ _	_ _ _	_ _ _		

CVC-Q
List 4

boss	sip	pal	coat	rod	moon
_ _ _	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _
hem	take	league	dies		
_ _ _	_ _ _	_ _ _	_ _ _		

List 5

time	caught	beg	rid	loon	mop
_ _ _	_ _ _	_ _ _	_ _ _	_ _ _	_ _ _

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doze says pack heel

ZP-Q

Dog you sweet Dad.

Out cool pens most.

Hot wear hit need.

Food boys kill fall.

Sound tough turn buys.

ZP-0

Taste long cats thieves.

Lend men feet those.

Bright tea green catch.

Dumb good fall new.

Forks may shirt jump.

ZP-3

Rock Mom see strange.

Apes home ducks cloud.

Soft these ice give.

Birds warm great fields.

Knees on sleep feels.

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HP-Q

Cooks make hot food

Feed your dog meat.

Take that trash out.

Dull paint won't shine.

Most boys play ball.

HP-3

Tough guys sound mean.

Warm sun feels good.

Birds like warm worms.

Dad buys new shirts.

Cows give sweet milk.

HP-0

Apes swing from trees.

Boats sail at sea.

Small kids need help.

Pour me more tea.

Fresh bread smells great.

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LP-Q

Blue chairs speak well.
___ _____ _____ ___

Find girls these clouds.
___ _____ _____ _____

Late forks hit low.
___ _____ ___ ___

Dumb shoes will sing.
___ _____ ___ ___

Tin hats may laugh.
___ _____ ___ _____

LP-3

Knees talk with mice.
___ _____ ___ ___

Teeth sleep on fields.
___ _____ ___ _____

Lend them less joy.
___ _____ ___ _____

Sad cars want chills.
___ _____ _____ _____

Soft rocks taste strange.
___ _____ _____ _____

LP-0

Thin books look bright
___ _____ ___ _____

Cats get good ears.
___ ___ ___ _____

Ducks eat old tape.
___ ___ _____ _____

Wide pens swim fast.
___ _____ _____ _____

Feet catch slow thieves.
___ _____ ___ _____

.

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Appendix G

Rules for Judging Accuracy of Subjects' Responses

Judges were instructed to be aware of the following substitutions when listening to sentences and in words. When listening to nonsense syllables, they were instructed to write exactly what they heard.

The following substitutions were taken from Speaking Clearly: Improving Voice and Diction, by Jeffrey C. Hohner, Maring A Sokoloff, and Jane L. Salish, McGraw Hill Publishing Company, 1976.

Substitution	Example	
/b/ for /v/	/gib/ for /giv/	give
/p/ for /v/	/h p/ for /h v/	have
/r/ for /l/	/ret/ for /let/	let
/l/ for /r/	/l /for /r /	raw
/I/ for /i/	/sIt/ for sit/	seat
/U/ for /u/	/sUt/ for /sut/	suit
/u/ for /U/	/sut/ for /sUt/	soot

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Appendix H

Raw Data

Table H1 Percent correct raw word recognition scores in sentences for subjects in the three listening conditions as determined by judge 1.

First	HP SENTENCES			LP SENTENCES			ZP SENTENCES		
language	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0
Korean 1	80.0	59.4	57.5	80.0	55.0	40.0	77.5	35.0	15.0
Korean 2	100.0	80.0	60.0	87.5	80.0	71.3	82.5	55.6	45.0
Korean 3	97.5	67.5	23.5	100.0	70.0	63.5	87.5	65.0	37.5
Korean 4	82.5	62.5	15.0	82.5	60.0	47.5	72.5	61.3	37.5
Korean 5	87.5	72.5	47.5	90.0	67.5	60.0	77.5	57.5	32.5
Korean 6	90.0	67.5	70.0	87.5	70.0	65.0	95.0	30.0	30.0
Korean 7	95.0	67.5	45.0	80.0	57.5	47.5	55.0	70.0	47.5
Korean 8	97.5	85.0	80.0	85.0	75.0	50.0	85.0	60.0	45.0
MEAN	91.3	70.2	49.8	86.6	66.9	55.6	79.1	54.3	36.3
SD	7.4	8.6	22.1	6.5	8.7	10.8	11.9	14.2	10.6
English 1	100.0	100.0	100.0	100.0	92.5	80.0	100.0	75.0	55.0
English 2	100.0	100.0	97.5	100.0	87.5	82.5	97.5	75.0	52.5
English 3	100.0	90.0	90.6	95.0	90.0	62.5	82.5	62.5	55.0
English 4	100.0	82.5	80.0	92.5	70.0	62.5	82.5	40.0	32.5
English 5	97.5	95.0	97.5	97.5	90.0	60.0	97.5	85.0	45.0
English 6	97.5	80.0	85.0	100.0	72.5	70.0	82.5	60.0	55.0
English 7	100.0	100.0	100.0	100.0	90.0	82.5	90.0	82.5	70.0
English 8	97.5	85.0	77.5	100.0	75.0	67.5	83.5	65.0	55.0
MEAN	99.1	91.6	91.0	98.1	83.4	70.9	89.5	68.1	52.5
SD	1.3	8.3	9.1	2.9	9.3	9.4	7.8	14.6	10.6

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Table H2 Percent correct raw syllable and phoneme recognition scores in whole consonant-vowel-consonant words and nonsense syllables for all subjects in the three listening conditions as determined by judge 1.

First	CVC WHOLE WORDS			CVC PARTS OF WORDS			NONSENSE WHOLE WORDS			NONSENSE PARTS OF WORDS		
language	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0
Korean 1	75.0	30.0	40.0	96.7	63.3	56.7	35.0	10.0	20.0	66.2	55.0	56.7
Korean 2	77.8	55.0	35.0	88.0	78.3	65.0	45.0	15.0	10.0	76.7	58.3	56.7
Korean 3	50.0	55.0	20.0	76.7	73.3	46.7	70.0	20.0	15.0	90.0	68.3	55.0
Korean 4	90.0	50.0	30.0	96.7	78.3	55.0	75.0	10.0	10.0	91.7	55.0	53.0
Korean 5	75.0	50.0	35.0	91.7	76.7	56.7	60.0	25.0	15.0	86.7	66.7	61.7
Korean 6	95.0	60.0	45.0	98.0	86.5	76.7	75.0	35.0	15.0	90.0	71.7	61.7
Korean 7	77.8	65.0	30.0	91.1	80.0	61.7	50.0	20.0	5.0	78.3	70.0	46.7
Korean 8	89.4	35.0	35.0	96.5	75.0	65.0	60.0	30.0	5.0	83.3	63.3	53.3
MEAN	78.7	50.0	33.8	91.9	76.4	60.4	58.8	20.6	11.9	82.9	63.5	55.6
SD	13.9	12.0	7.4	7.1	6.6	8.9	14.6	9.0	5.3	8.7	6.7	4.9
English 1	100.0	60.0	65.0	100.0	83.3	86.7	85.0	70.0	35.0	95.0	85.0	75.0
English 2	100.0	60.0	45.0	100.0	80.0	73.3	50.0	30.0	25.0	78.3	76.7	66.7
English 3	95.0	75.0	55.0	98.3	88.3	60.0	80.0	15.0	10.0	93.3	65.0	55.0
English 4	85.0	50.0	50.0	95.0	75.0	75.0	60.0	55.0	20.0	81.7	75.0	61.7
English 5	83.9	55.0	35.0	94.6	83.3	71.7	45.0	20.0	15.0	78.3	61.7	60.0
English 6	85.0	55.0	35.0	88.3	81.7	70.0	35.0	25.0	10.0	73.3	60.0	50.0
English 7	85.0	60.0	30.0	95.3	83.3	68.3	60.0	55.0	15.0	86.7	78.3	51.7
English 8	90.0	55.0	35.0	93.3	78.3	71.7	35.0	25.0	10.0	75.0	60.0	48.3
MEAN	90.5	58.8	43.8	95.6	81.7	72.1	56.3	36.9	17.5	82.7	70.2	58.5
STD DEV	6.9	7.4	12.2	3.9	4.0	7.4	18.9	20.2	8.9	8.2	9.7	9.1

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Table H3 Percent correct raw word recognition scores in sentences for subjects in the three listening conditions as determined by judge 2.

First	HP SENTENCES			LP SENTENCES			ZP SENTENCES		
language	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0
Korean 1	82.5	46.9	47.5	62.5	52.5	25.0	60.0	40.0	15.0
Korean 2	97.5	72.5	57.5	82.5	70.0	62.5	85.0	63.85	42.5
Korean 3	90.0	55.6	25.0	85.0	65.0	47.5	75.0	50.0	20.0
Korean 4	67.5	50.0	20.0	67.5	42.5	41.7	42.5	8.33	25.0
Korean 5	75.0	67.5	40.0	70.0	62.5	50.0	75.0	47.5	20.0
Korean 6	80.0	62.5	65.0	75.0	55.0	50.0	77.5	32.5	25.0
Korean 7	87.5	60.0	42.5	67.5	50.0	37.5	55.0	57.5	32.5
Korean 8	87.5	80.0	82.5	85.0	72.5	52.5	85.0	60.0	37.5
MEAN	82.9	59.3	42.5	72.9	56.8	44.9	67.1	42.8	25.7
SD	9.3	11.2	20.6	8.8	10.4	11.2	15.3	18.1	9.5
English 1	100.0	100.0	100.0	97.5	90.0	80.0	97.5	72.5	52.5
English 2	100.0	100.0	97.5	97.5	87.5	82.5	97.5	75.0	52.5
English 3	100.0	90.0	90.6	97.5	90.0	72.5	100.0	67.5	57.5
English 4	97.5	82.5	82.5	92.5	72.5	70.0	80.0	40.0	25.0
English 5	100.0	97.5	97.5	97.5	90.0	60.0	97.5	87.5	42.5
English 6	97.5	82.5	82.5	100.0	80.0	72.5	87.5	65.0	50.0
English 7	100.0	100.0	100.0	100.0	90.0	85.0	90.0	85.0	72.5
English 8	100.0	97.5	100.0	97.5	87.5	82.5	95.0	80.0	65.0
MEAN	99.4	93.8	93.8	97.5	85.9	75.6	93.1	71.6	52.2
SD	1.2	7.7	7.6	2.3	6.4	8.4	6.8	15.0	27.5

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Table H4 Percent correct raw syllable and phoneme recognition scores in whole consonant-vowel-consonant words and nonsense syllables for all subjects in the three listening conditions as determined by judge 2.

First	CVC WHOLE WORDS			CVC PARTS OF WORDS			NONSENSE WHOLE WORDS			NONSENSE PARTS OF WORDS		
language	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0
Korean 1	75.0	30.0	40.0	91.7	68.3	71.7	40.0	40.0	35.0	78.3	71.7	61.7
Korean 2	70.0	55.0	50.0	85.0	81.7	73.3	35.0	20.0	25.0	75.0	63.3	63.3
Korean 3	40.0	45.0	20.0	73.3	63.3	48.3	75.0	35.0	25.0	91.7	73.3	60.0
Korean 4	80.0	40.0	25.0	86.7	66.7	43.3	90.0	25.0	25.0	96.7	61.7	63.7
Korean 5	80.0	55.0	35.0	93.3	78.3	65.0	60.0	30.0	10.0	83.3	68.3	55.0
Korean 6	90.0	55.0	45.0	96.7	76.7	80.0	60.0	25.0	20.0	85.0	63.3	66.7
Korean 7	73.3	60.0	30.0	89.3	75.0	55.0	50.0	20.0	5.0	78.3	56.7	48.3
Korean 8	89.4	40.0	35.0	96.5	76.7	68.3	60.0	20.0	15.0	85.0	65.0	53.3
MEAN	74.7	47.5	35.0	89.0	73.3	63.1	58.8	26.9	20.0	84.2	65.4	59.0
SD	15.7	10.4	10.0	7.6	6.4	12.9	17.9	7.5	9.6	7.2	5.5	6.2
English 1	95.0	70.0	65.0	96.7	83.3	85.0	85.0	70.0	40.0	95.0	85.0	80.0
English 2	100.0	60.0	50.0	100.0	80.0	81.7	60.0	50.0	35.0	83.3	83.3	70.0
English 3	100.0	75.0	60.0	100.0	91.7	83.3	85.0	15.0	10.0	95.0	66.7	58.3
English 4	85.0	60.0	50.0	95.0	83.3	75.0	55.0	30.0	30.0	83.3	68.3	65.0
English 5	83.9	60.0	50.0	94.7	83.3	70.0	45.0	20.0	15.0	78.3	61.7	61.7
English 6	100.0	55.0	45.0	100.0	83.3	76.7	45.0	30.0	15.0	78.3	61.7	28.6
English 7	85.0	65.0	30.0	95.0	88.3	71.7	60.0	55.0	15.0	88.3	76.7	55.0
English 8	100.0	70.0	35.0	100.0	90.0	73.3	65.0	50.0	20.0	88.3	75.0	45.0
MEAN	93.6	64.4	48.1	97.7	85.4	77.1	62.5	40.0	22.5	86.2	72.3	57.9
STD DEV	7.6	6.8	11.6	2.6	4.1	5.6	15.6	19.1	11.0	6.6	9.1	15.7

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Table H5 Percent correct raw word recognition scores in sentences for subjects in the three listening conditionss as determined by judge 3.

First	HP SENTENCES			LP SENTENCES			ZP SENTENCES		
language	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=C	QUIET	S/N=3	S/N=0
Korean 1	85.0	56.3	60.0	83.5	55.0	35.0	70.0	47.5	25.0
Korean 2	100	80.0	67.5	85.0	72.5	40.5	87.5	55.6	37.5
Korean 3	97.5	60.0	22.5	100	75.0	60.0	90.0	60.0	40.0
Korean 4	82.5	52.5	15.0	72.5	35.0	32.8	67.5	20.0	20.0
Korean 5	85.0	77.5	40.0	90.0	77.5	60.0	80.0	52.5	27.5
Korean 6	92.5	80.0	67.5	85.0	65.0	65.0	87.5	45.0	17.5
Korean 7	95.0	65.0	47.5	67.5	57.5	47.5	57.5	55.0	42.5
Korean 8	97.5	87.5	85.0	87.5	80.0	57.5	90.0	60	47.5
MEAN	91.9	69.8	50.6	83.9	64.7	49.8	78.8	49.4	32.2
SD	6.8	13.0	24.0	10.1	15.1	12.5	12.3	13.0	11.1
English 1	100.0	97.5	100.0	100.0	92.5	82.5	100	77.5	65.0
English 2	100.0	97.5	97.5	100.0	87.5	82.5	100	72.5	60.0
English 3	100.0	90.0	87.5	100.0	92.5	70.0	90.0	72.5	50.0
English 4	100.0	82.5	80.0	95.0	75.0	70.0	87.5	45.0	40.0
English 5	97.5	95.0	97.5	97.5	90.0	60.0	100	87.5	50.0
English 6	100.0	87.5	82.5	100.0	82.5	72.5	90.0	65.0	62.5
English 7	100.0	100.0	100.0	100.0	90.0	82.5	95.0	85.0	70.0
English 8	100.0	97.5	100.0	100.0	75.0	85.0	92.5	80.0	60.0
MEAN	99.7	93.4	93.1	99.1	85.6	75.6	94.4	73.1	57.2
SD	0.9	6.1	8.4	1.9	7.3	8.8	5.1	13.5	9.8

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Table H6 Percent correct raw syllable and phoneme recognition scores in whole consonant-vowel-consonant words and nonsense syllables for all subjects in the three listening conditionss as determined by judge 3.

First	CVC WHOLE WORDS			CVC PARTS OF WORDS			NONSENSE WHOLE WORDS			NONSENSE PARTS OF WORDS		
language	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0	QUIET	S/N=3	S/N=0
Korean 1	80.0	45.0	45.0	93.3	78.3	70.0	55.0	35.0	25.0	83.3	73.3	58.3
Korean 2	75.0	55.0	45.0	90.0	73.3	70.0	50.0	10.0	10.0	80.0	61.7	60.0
Korean 3	55.0	60.0	35.0	85.0	80.0	58.3	75.0	25.0	25.0	91.7	71.7	66.7
Korean 4	65.0	40.0	25.0	86.7	71.7	55.0	80.0	15.0	10.0	93.3	65.0	53.3
Korean 5	95.0	65.0	35.0	96.7	81.7	65.0	50.0	30.0	20.0	76.7	65.0	65.0
Korean 6	90.0	55.0	50.0	96.7	81.7	81.7	80.0	35.0	25.0	91.7	71.7	66.7
Korean 7	75.0	60.0	25.0	91.7	78.3	73.3	50.0	20.0	0.0	80.0	56.7	53.3
Korean 8	100.0	40.0	35.0	100	75.0	68.3	65.0	25.0	10.0	85.0	70.0	56.7
MEAN	79.4	52.5	36.9	92.5	77.5	67.7	63.1	24.4	15.6	85.2	66.9	60.0
SD	15.2	9.6	9.2	5.2	3.8	8.4	13.6	9.0	9.4	6.3	5.8	5.6
English 1	100.0	75.0	65.0	100.0	90.0	85.0	85.0	70.0	35.0	95.0	85.0	73.3
English 2	100.0	50.0	55.0	100.0	83.3	78.3	65.0	35.0	25.0	86.6	71.7	65.0
English 3	100.0	65.0	65.0	100.0	90.0	86.7	90.0	25.0	20.0	96.6	71.7	63.3
English 4	90.0	70.0	60.0	90.0	86.7	83.3	60.0	35.0	30.0	85.0	75.0	65.0
English 5	85.0	55.0	40.0	95.0	81.7	73.3	45.0	25.0	20.0	95.0	63.3	63.3
English 6	95.0	55.0	40.0	96.7	81.7	80.0	45.0	30.0	25.0	78.3	66.7	63.3
English 7	85.0	60.0	40.0	95.0	83.3	71.7	60.0	60.0	15.0	83.3	80.0	53.3
English 8	100.0	60.0	40.0	100.0	86.7	73.3	70.0	35.0	20.0	82.3	71.7	53.3
MEAN	94.4	61.3	50.6	97.1	85.4	79.0	65.0	39.4	23.8	87.8	73.1	62.5
STD DEV	6.8	8.3	11.8	3.6	3.4	5.8	16.5	16.6	6.4	6.9	6.9	6.5

Appendix I

Analyses of Judges' Responses

Table J1. Simple 3-way analysis of variance in the group mean recognition scores in noise. Variables = Judge (3 levels), L1 (2 levels: Korean,English), and Measure (7 levels: words in HP, LP, and ZP sentences, words and phonemes in CVC words, and words and phonemes in CVC nonsense)

Source of Variance	Sum of Squares	Degrees of Freedom	Estimated Mean Square	F Ratio	p level
Judge	55.86	2	27.93	4.05	0.0453
L1	2961.00	1	2961.00	429.09	<0.0001
Measure	11585.84	6	1930.97	279.83	<0.0001
LxM	1053.63	6	175.60	25.45	<0.0001
LxJ	66.96	2	33.48	4.85	0.0286
MxJ	94.20	12	7.85	1.14	0.4135
LxMxJ	82.81	12	6.90		
Total	15900.29	41			

Table J2. Main effect of judge (data collapsed across L1 and speech perception Measure)

Judge	Mean Score (%)
J1	57.2
J2	57.2
J3	59.7

p=0.045

Table J3. Interaction between judge and L1 (data collapsed across speech perception Measure)

	Mean Score (%)	
Judge	Korean	English
J1	50.4	64.1
J2	47.3	67.2
J3	51.3	68.1

p=0.029

Comment: There is evidence of significant differences among the judges. There is also evidence of an interaction between judge and L1. In particular, J3 tends to give higher scores to English talkers and J2 tends to give lower scores to Korean talkers. The effects are small, however, and there is no evidence of an interaction between judge and speech perception measure.

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