

# INTELLIGIBILITY IN CLASSROOM NOISE FOR YOUNG SCHOOL AGED CHILDREN\*

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## INTRODUCTION

Favourable classroom acoustics contribute to children's level of academic performance [1, 2]. Inappropriate classroom noise levels reduce speech intelligibility and compromise psycho-educational and psychosocial development [2, 3]. The low frequency background noise found in a many classrooms can mask some speech sounds through upward spread of masking [4]. Other components of Classroom noise share certain spectral and temporal characteristics with target (e.g., teacher) speech. The extent to which noise masks speech depends on the long term spectrum of the noise, fluctuations in noise intensity over time, and the intensity of noise relative to the intensity of speech [2].

Such background noise reduces the intelligibility of speech by masking or distorting acoustic cues in the speech signal. Background noise in the classroom thus increases the attentional demands on students. This load is potentially greatest for the youngest children, which is a particular problem as this group creates the most background noise [5].

**Background.** Studies of speech perception in noise have focussed adults, but some studies have examined the performance of children, including hearing-impaired children [2, 3]. Previous studies have used adult multi-talker babble as background noise, not noise that is representative of the background noise a child is exposed to in the classroom (i.e., voices of other children, furniture noise, ventilation and other equipment noise). The present study used noise recorded from an occupied classroom to obtain a more representative sample.

Studies of speech perception in noise for young children often require the child to respond verbally or in writing. Oral response are open to errors, as young children frequently display poor articulation [6]. Written responses may tax the young child's abilities, delaying testing and reducing prospects for the child to complete the study. Computer-based testing using pictures reduces opportunities for such errors and increases the quality of the data.

The present study sought to: (a) measure the speech perception abilities of young children using real classroom noise; (b) examine how identification accuracy varied for children of different ages, in the various listening conditions; and (c) confirm the age-appropriateness of the word list and task devised for this study.

## METHOD AND PROCEDURE

Subjects were 40 students, consisting of ten subjects in each of Kindergarten (aged 5), grade 1 (aged 6), grade 2 (aged 7) and grade 3 (aged 8). Inclusion criteria were: 1) normal appearance of the ear canal and tympanic membrane; 2) pure tone air conduction thresholds no worse than 15 dB HL at 1, 2 and 4 kHz in either ear; 3) acoustic immittance measures for compliance between 0.3 and 1.6 ml; 4) middle ear pressure between 50 and -150 daPa bilaterally; 5) native speakers of English.

**Experimental Speech Stimuli.** Speech stimuli were 60 words (24 monosyllables, 12 spondees, 12 trochees, 12 trisyllables identified as being within the vocabulary of young children and able to be represented pictorially). Each word was spoken by one adult female speaker. The words were sampled as .WAV files at 22.5 kHz using the Time Frequency Response (TFR) software [7] and processed to equalize the RMS value of the vowels for syllables in the monosyllabic, spondee and trisyllabic words. The RMS of the entire syllable was adjusted to achieve 1.75 mV RMS for a 100 ms window centered on the peak of the vowel. The secondary syllable in the trochees was edited to have an RMS value equalling approximately 0.88 mV for a 100 ms sample of the vowel (i.e., half the RMS of the primary syllable), in order to distinguish trochees from spondees. The RMS values of individual final consonants were adjusted as required to ensure the item sounded natural. Each word was mixed with the sample of classroom noise at a signal-to-noise ratio (SNR) of 0 dB,

-6 dB, and -12 dB, using a mixer program [7]. This mixer computed the RMS level of the signal, then computed the RMS level of the noise. The RMS value was then equalized to the RMS value of the original signal. Noise was also appended to this composite file, providing a 200 ms buffer of classroom noise at the beginning and end of the composite signal.

All aspects of the experiment were controlled by a PC computer, running the ECoS/Win experiment control software [8]. All test signals were replayed over a 16-bit Sound Blaster SB16 sound card and presented bilaterally over Telephonics TDH 49 supra aural headphones. Words were played at 65 dB SPL over the headphones to simulate the vocal intensity normally used by school teachers in the classroom, speaking at a distance of 1 meter. Subjects were tested individually in a portable classroom (ambient background noise at the test location from 54.9 to 59.3 dBC), while seated in front of a computer monitor that displayed the response alternatives. On each trial, the listener pointed to one of the 12 pictures on the monitor that best represented the word presented over the headphones.

Kindergarten and Grade 1 subjects participated in two sessions of 15 minutes each, with the quiet and -6 dB SNR conditions in the first session, followed by the 0 dB SNR and the -12 dB SNR in the second condition, within the same day. Grade 2 and 3 children participated for one 30-minute session, with the quiet, 0 dB SNR condition, -6 dB SNR condition, and -12 dB SNR condition presented. Word type (monosyllables-front to mid vowels; monosyllables - mid to back vowels; spondees; trochees; and trisyllables) was blocked within SNR conditions for all children.

## RESULTS AND DISCUSSION

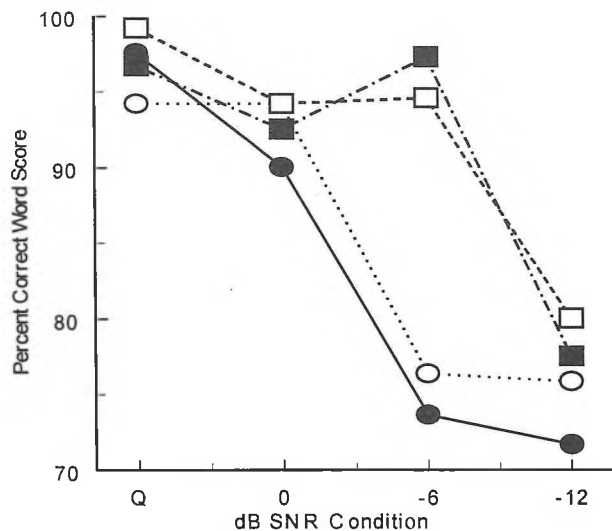
Older children tended to perform better than younger children in all listening conditions. Trisyllables were more understandable than bisyllables (spondees and trochees), which were generally more understandable than monosyllables. A pronounced effect was found with MF words, as SNR decreased to -6 dB: Kindergarten and Grade 1 children performed much worse than the older children (Figure 1). Kindergarten subjects also had lower scores than older children for spondees in the -6 dB SNR condition.

Although direct comparisons between this study and previous studies is not possible due to stimuli and procedural differences, some generalizations are possible. First, in the quiet conditions, our children performed at a level comparable to that reported in other studies. In the 0 dB SNR and -6 dB SNR conditions, children in this study performed better than those in previous studies. We conclude that the word lists and testing protocols devised for this study were at an age-appropriate level.

Monosyllables with initial consonants having low intensity were particularly susceptible to masking, leading to frequent confusions with similar sounding words (e.g., confusions of *hair* with *chair* and *bear*). Classroom noise appeared to interact with target speech to create the perception of new phonemes, not present in the target stimuli. The lower intensity of the second syllable in the trochees was readily masked by background noise, causing overall scores to be lower for two-syllable trochees than for two-syllable spondees. Such errors for key individual contact words may well cause younger children to lose the context of the teacher's message so that they may not be able to follow along effectively in classroom activities.

## GENERAL DISCUSSION

In general, our children performed at least as well as children tested under similar conditions in previous studies. We conclude that the word lists used here were age-appropriate and within the vocabulary of our children, and that the task was both understood and within of the ability of our subjects. MANOVAs showed that Kindergarten and Grade 1 children are especially affected by noise,

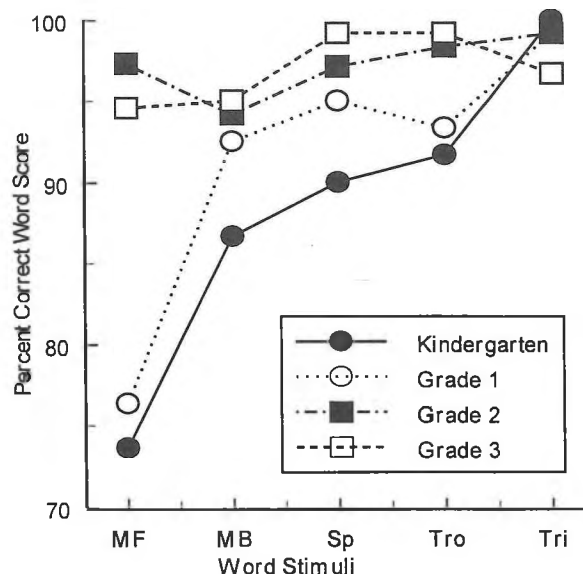


**Figure 1.** Mean percent correct word identification for monosyllable: front-mid vowel stimuli at each SNR condition for each group of listeners. (Symbols as for Figure 2.)

particularly for monosyllable: front-mid vowel words. Post hoc analyses indicated that in such conditions the performance of Kindergarten and Grade 1 subjects in this study decreased significantly when the SNR reached -6 dB, while the performance of Grade 2 and 3 subjects significant declined only when the SNR reached -12 dB. Kindergarten subjects also performed more poorly for trisyllables in the -12 dB SNR condition compared with children in other grades. In the -6 dB SNR condition, Kindergarten subjects also had significantly lower mean scores than Grade 3 subjects for spondees. These are not atypical listening conditions: studies of classroom acoustics have reported classroom noise levels consistent with or exceeding -6 dB SNR. The present study shows that in such circumstances, younger children may have particular difficulty understanding speech, especially monosyllable words containing low intensity initial consonants.

Currently, Canada lacks federal or provincial standards for classroom noise levels. The American Speech-Language and Hearing Association has recommended that classrooms should be constructed such that the SNR at the child's ear is greater than +15 dB SNR, and the noise level in an unoccupied classroom does not exceed 35 dB(A) or NCC = 20 dB [9]. Studies of ambient classroom noise show that most classrooms do not meet these guidelines [10].

There is mounting evidence that Atypical classroom noise levels have significant, negative effects on the performance of young children. The present study adds further weight to this body of evidence, particularly for the youngest, school-aged children. Perhaps the evidence for degraded speech perception in presence of excessive classroom noise will be useful in persuading legislators and educators of the need for improved acoustic conditions for classrooms. This would include actions to a) reduce noise levels in unoccupied classrooms through reductions in ventilation and other noise sources; b) construction specifications to better control sound transmission and reverberation; and the availability of sound-field FM amplification systems to improve signal to noise ratio throughout the classroom environment, for all students.



**Figure 2.** Mean percent correct word identification in the -6 dB SNR condition for each type of word stimulus for the four groups of listeners.

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