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The Relationship Between Speech Perception in Noise and Phonological Awareness Skills for Children with Normal Hearing

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INTRODUCTION

The developmental nature of the ability to understand speech in background noise has been well documented for a wide range of stimuli (e.g., Finitzo-Heiber and Tillman 1978; Elliott 1979; Neuman and Hochberg 1983; Nittrouer and Boothroyd 1990; Nozza et al. 1990; Litovsky 1997; Fallon et al. 2000; 2002; Johnson 2000; Hall et al. 2002; Jamieson et al. 2004; Bradley and Sato 2008). Understanding speech in noise becomes especially important as children enter school. In many instances, teaching and learning are being attempted in environments that are not conducive to listening and understanding (see Picard and Bradley 2001 for a summary). For example, Bradley and Sato (2008) examined closed-set perception of words in 41 classrooms of first, third and sixth grade students. Results revealed an effect of age and signal-to-noise ratio. Best-fit regression lines derived from the data indicated that expected SNRs needed for 95% (near ideal) performance would be +15.5, +12.5, and +8.5 dB for the first, third and sixth grade children, respectively. Sound level measurements taken during teaching activities revealed that conditions needed for optimal speech communication only occurred for approximately 20% of first graders, 34% of second graders and 49% of sixth graders.

Numerous factors have been suggested to explain the difficulties experienced by children when listening to speech in the presence of background noise. Cognitive factors, including memory, attention, and fatigue may affect perception during difficult listening tasks (Hnath-Chisolm et al. 1998; Oh et al. 2001; Wightman et al. 2003). In adverse listening environments, children may need to allocate greater resources to understanding speech (Wightman and Kistler, 2005). Developmental changes in language also can play an important role in speech perception in adverse listening environments. While multiple cues are available to help listeners understand speech, children must learn to use those cues. For example, children have been shown to differ from adults in their use of contextual cues (Elliott 1979; Nittrouer and Boothroyd 1990). They also differ in the weights assigned to some acoustic parameters of speech, with these weights changing as children gain more experience with their native language (Nittrouer 1996; Nittrouer and Miller 1997; Nittrouer and Crowther 1998; Mayo et al. 2003). When access to cues is limited, as would occur in the presence of background noise, children perform more poorly than adults (see Werner & Liebold 2004, for a review).

The ability to access the phonological structure of speech is an important aspect of language processing (see Nittrouer, 2002 for a review). The work of Nittrouer and colleagues (Nittrouer 1996; Nittrouer and Burton, 2005) comparing performance of children with diverse linguistic experience on phonological awareness tasks and a test of perceptual

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weighting, supports the importance of early language experience on the development of phonological processing and speech perception.

It has been suggested that phonological awareness, an aspect of phonological processing which relates to an individual's ability to recognize and manipulate the sound structure of speech (e.g., syllables and phonemes), may be related to children's ability to understand speech in noise (Mody et al. 1997; Nittrouer 2002). Fallon et al. (2000) state that "limited phonological awareness on the part of young children…. especially pre-readers…. may also impair performance on speech-identification tasks …. Even if a child can use phonological strategies to aid identification, noise may disrupt this process" (p. 3023). Nittrouer (2002) states that "the ability to apprehend phonological structure from the signal facilitates speech perception in noisy backgrounds" (p. 238).

To date, the relationship between phonological awareness and speech perception in noise for young children has not been thoroughly examined. Understanding speech requires both top-down and bottom-up processing. Top-down processing requires knowledge of the topic and context as well as knowledge of the structure of language. Bottom-up processing requires parsing and decoding of the sounds that are heard. The relative contribution of each type of processing may vary depending upon the listening situation and also may interact with peripheral factors such as hearing thresholds. Children who have greater knowledge of the sound structure of speech may be able to use those skills to assist speech recognition under adverse conditions, where the acoustic cues required for bottom-up processing are less accessible. The extent to which children can utilize both types of processing may affect their speech-perception abilities in degraded listening environments. Such relationships may be especially important for young children entering school, where noisy environments and less developed language skills can negatively impact the learning process.

While phonological awareness has been shown to be a good predictor of reading ability and difficulties with this skill have been associated with a variety of speech and language problems (e.g., McBride-Chang 1995; Mody et al. 1997; Hogan et al. 2005), evidence for a relationship between phonological awareness and speech perception in noise for typically developing children is less clear. Because children with reading disabilities often demonstrate delays in phonological awareness (e.g., Boets et al. 2007; Holm et al. 2007), *indirect* evidence supporting the relationship between phonological awareness skills and speech perception in noise has been intimated from studies which have shown poorer speech perception in noise for children with reading disabilities relative to those without reading disabilities (Mody et al. 1997; Nittrouer 2002). For example, Brady et al. (1983) demonstrated that 8-year-olds who were poor readers performed as well as children with normal reading abilities on a speech perception task in quiet but their scores were significantly poorer in the presence of noise (0 dB SNR). No significant differences were found between groups for environmental sounds presented in noise, suggesting that the problems experienced by the poor readers were related to difficulties processing speech rather than to more general auditory perception skills. However, not all studies of speech perception in noise have shown poorer performance by children with reading disabilities. Snowling et al. (1986) found no differential effects of noise when comparing perception of words and nonwords by 9-to 12-year olds with and without reading disabilities. Snowling et al. concluded that differences between the two studies may have been related to age (subjects in their study were older) as well as procedural differences. Listeners in the Brady et al. study always heard speech in noise first, while Snowling and colleagues randomized presentation of their no-noise and noise conditions. Thus, there is mixed evidence of a relationship between phonological awareness and speech perception abilities in noise for children who are poor readers.

Interestingly, studies have shown that adults who have no experience with alphabetic writing due to illiteracy or literacy in a non-alphabetic language, demonstrate poorer phonological awareness skills than those with experience in alphabetic writing (Morais et al. 1979; Read et al. 1986). Morais et al. (1979) reported that illiterate adults in Portugal were unable to add or delete phones at the beginning of non-words. However, adults who learned to read at age 15 years or later were able to perform the task. Morais et al. concluded that “the ability to deal explicitly with the phonetic units of speech is not acquired spontaneously. Learning to read, whether in childhood or as an adult, evidently allows the ability to manifest itself” (p. 330). Similarly, Read et al. (1986) found that Chinese adults who were literate in Chinese characters but had never learned an alphabetic writing system could not add or delete consonants at the beginning of syllables as well as subjects who were literate in the alphabetic system. These investigators concluded that “it is not literacy in general which leads to segmentation skill, but alphabetic literacy in particular” (p. 41). While such studies have not examined speech perception in noise, there is no evidence to suggest that people without alphabetic writing experience perform more poorly when listening to speech in noise (in their native language) than their peers with knowledge of alphabetic writing.

Although the results of previous studies suggest there may be a relationship between phonological awareness and speech perception in noise, the available results do not allow firm conclusions to be drawn in this regard. The goal of the present study was to provide data that will allow a clearer characterization of this potential relationship in typically developing children. Doing so may result in a better understanding of how children learn to listen in noise as well as providing information to identify children who are at risk for difficulties listening in noise.

In the present study, three phonological awareness tasks were chosen to represent a range of skills: a Syllable-Counting task, an Initial-Consonant-Same task, and a Phoneme-Deletion task (Mann and Liberman, 1984; Nittrouer, 1999). By selecting such tasks, developmental trends in phonological awareness might be more apparent. The Syllable-Counting task examined the basic skill of judging the general sound structure of words. The Initial-Consonant-Same task examined the ability to segment sounds in words, requiring more advanced phonological awareness skills. Finally, the Phoneme-Deletion task was considered the most complex of the three, requiring listeners to isolate and delete sounds in words in order to create a real word from a nonsense word.

Speech-perception-in-noise tasks (identification of nonsense syllables, recognition of words in isolation, identification of words in sentences) were chosen to examine both linguistic/contextual and acoustic-phonetic processing of speech. Recognition of nonsense syllables relies almost entirely on acoustic-phonetic processing, while word-recognition relies on acoustic-phonetic processing as well as additional lexical cues. Identification of words in sentences benefits the most from contextual information, which may improve perception in adverse listening environments. For the current study, all speech stimuli were presented in three levels of noise, selected because they represent levels that children would be expected to encounter in typical environments.

METHODS

Subjects

Thirty-six children (equal numbers of 5-, 6-, & 7-year olds) with normal hearing participated in this study. All children had thresholds ≤ 15 dB HL for octave frequencies from 250 through 8000 Hz. The Bankson Bernthal Quick Screen of Phonology (BBQSP; Bankson and Bernthal 1990) was used to identify and exclude children with speech production errors that would influence scoring. To estimate the receptive vocabulary of each child, the Peabody

Picture Vocabulary Test (PPVT-III; Dunn and Dunn 1997) was administered. The Digit Span Test (Wechsler 1994) was administered as a measure of short-term memory. The PPVT and Digit Span Test were included to examine normal variability and rule out poor vocabulary or short-term memory as confounding factors on the experimental tasks. Children who performed <2 standard deviations below the mean on either task were excluded from the study.

Stimuli

Three phonological awareness tasks (Syllable-Counting, Initial-Consonant-Same, Phoneme-Deletion), were administered. Similar tasks have been used in previous studies (e.g., Liberman et al. 1974; Mann and Liberman, 1984; Stanovich et al. 1984; Nittrouer 1996; 1999; Carroll et al. 2003) and were selected for the current study to represent a range of skills. All test materials for the phonological tasks were spoken by a female talker and digitally recorded in a sound booth using a condenser microphone (AKG Acoustics C535 EB) with a flat frequency response (+/−2 dB) from 0.2 to 20 kHz. Speech tokens were amplified (Shure M267) and sampled at a rate of 44.1 kHz with a quantization of 16 bits.

Test stimuli for the speech perception in noise tasks were 15 vowel-consonant-vowel (VCV) nonsense syllables constructed using the consonants /p, b, t, d, k, ɡ, l, r, m, n, s, ʃ, z, f, v/ in an /ɑ/ context, 45 monosyllabic words (PBK ; Haskins 1949, Reference Note 1), and 45 meaningful sentences with 3 key words each (BKB; Bench et al. 1979). The nonsense syllables and sentences were spoken by two different female talkers and recorded using the same apparatus as stimuli for phonological awareness tasks. The PBK words were obtained from recordings (female talker) developed at Brigham Young University (Harris 1991, Reference Note 2). For all stimuli, each sound file was mixed with speech-shaped noise at three SNRs (0, +5, +10 dB) for a total of 135 presentations per subject (45 presentations each for nonsense syllables, words and sentences [15 presentations at each of the three SNRs]). For words and sentences, three different versions of stimulus sets (15/set) were created using a Latin square design to ensure that no subject heard the same tokens more than once.

Procedures

Stimuli were presented binaurally through headphones (Sennheiser M25) at an average RMS level of 50 dB SPL. This level was chosen to simulate more challenging listening environments, where speech may not be heard at optimal conversational levels. For all tasks, items were presented using a computer game format with visual feedback (e.g., removal of a puzzle piece to reveal an interesting picture) given immediately after each response. This feedback was not contingent upon correct responses, but was used only to maintain interest in the task. Testing was completed in a single 1.5–2 hour session and children were given breaks, as needed, throughout the session. For all children, phonological awareness tasks were completed first, followed by speech perception tasks.

Speech Perception in Noise—For all children, the order of presentation was nonsense syllables, words, and sentences. Nonsense syllables were presented in a closed-set format with the 16 choices (15 consonants + “other”) displayed on a touch-screen monitor and each nonsense syllable was heard three times (once at each of 3 different SNRs). Children were instructed to repeat each nonsense syllable and, in most cases, the experimenter scored their

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[2] Harris, R.W. (1991). *Speech Audiometry Materials*. Hearing and Speech Sciences Laboratory, Brigham Young University, Provo, UT.

responses. Some of the older children used the touch screen or mouse to indicate their own responses. These children also repeated their responses so that the experimenter in the room could verify that their touch-screen response was consistent with the verbal response. Nonsense syllables and words were scored as either correct or incorrect. Sentences were scored as correct only when all three key words within each sentence were correct.

Phonological Awareness—For all children, the order of presentation was Syllable-Counting task, Initial-Consonant-Same task, then Phoneme-Deletion task. The *Syllable Counting task* consisted of 24 1–3 syllable test items (e.g., dog, letter, nobody). Children were instructed to indicate the number of syllables heard by clapping or tapping 1, 2, or 3 times. The *Initial-Consonant-Same task* consisted of 24 multiple-choice trials. In each trial, a target monosyllabic word was followed by three additional words. Children were instructed to listen carefully to the beginning sound of each target word (e.g., soap) and say which of the additional three words had the same initial sound as the target (e.g., king, dime, salt). The *Phoneme-Deletion task* consisted of 32 monosyllabic nonsense words. Children were told that they would hear a nonsense word and were instructed to say the real word that would result if a specified segment of that word were removed (e.g. *bloot* without the /*t*/ becomes *blue*). Face-to-face instruction and practice were provided for each task prior to testing and an experimenter remained in the room with the child throughout the test session. For each task, the child responded orally and the experimenter recorded his/her response. A given task was discontinued if the child missed 6 consecutive items and the remaining items were counted as incorrect in the calculation of total percent correct.

Results

Means and standard deviations for raw scores on the Digit Span and PPVT tests are shown in Table 1. As expected, raw scores for both tests improved with increasing age.

Separate analyses were completed for speech perception-in-noise and phonological-awareness tasks. In addition, a potential influence of phonological awareness on speech perception in noise was examined. All percent correct scores were converted to Rationalized Arcsine Units (RAU; Studebaker 1985) prior to statistical analyses in order to equalize the variance across the range of scores.

Speech Perception in Noise

Figure 1 displays mean percent-correct performance for nonsense syllables, words and sentences as a function of SNR with age group as the parameter. In general, mean scores were higher for sentences than for nonsense syllables and words across all ages and SNRs. A somewhat unexpected finding was better overall performance for nonsense syllables in comparison to words. This finding may have been the result of the fact that the nonsense syllables all included the same vowel (/ɑ/) and required identification of only one consonant for a correct response, while multiple phonemes had to be identified for a correct word score (McCreery, et al. 2010). Thus, even though the nonsense syllables contained fewer linguistic cues, the task itself was less demanding. Differences across age groups were larger for words than for nonsense syllables and sentences.

To assess differences in speech recognition as a function of stimulus material, SNR and age group, a separate mixed model ANOVA was conducted for each set of speech materials with SNR as the within-subject factor and age group as the between-subject factor. A Bonferroni adjusted alpha level of. 016 (.05/3) was used for all pairwise comparisons of SNR. For nonsense syllables, there was a significant effect of SNR [F(2,66) = 37.69; p<.001; η_p^2=. 533], but no main effect of age group [F(2,33) =.508; p=.606; η_p^2 =.030)] and no SNR x age group interaction[F(4,66) = 1.8; p=.140; η_p^2=.098)]. Post hoc tests revealed significant differences between 0 dB and 5 dB SNR and between 0 dB and 10 dB SNR only. For words, a Greenhouse-Geisser correction was used to adjust the degrees of freedom due to a failure to meet the assumption of sphericity (Max and Onghena 1999). There was a significant main effect of SNR [F(1.58,52.3) = 11.79; p<.001; η_p^2=.263] and age group [F(2, 33) = 4.89; p <.02; η_p^2=.228], but no SNR x age group interaction [F(4, 52.3) = 1.59; p =.202; η_p^2=.088]. Post hoc tests revealed significant differences between 0 dB and 5 dB SNR and between 0 dB and 10 dB SNR only. The observed age effect was due to significant differences between 5-and 7-year olds. For sentences, there was a significant effect of SNR [F(2, 66) = 13.68; p<.001; η_p^2=.293], but no age group effects [F(2, 33) = 1.01; p=.373; η_p^2=.058] and no SNR x age group interactions [F(4, 66) = 1.13; p=.353; η_p^2=..064]. Significant differences were found between the 0 and 5 dB SNR and between the 0 and 10 dB SNR conditions only.

Phonological Awareness

Figure 2 displays mean percent correct scores and standard deviations for the three phonological awareness tasks as a function of age group. In general, there is a systematic increase in performance as a function of age for all three tasks. Mean scores for even the youngest age group were 50% or above for both Syllable-Counting and Initial-Consonant-Same tasks. However, scores for the Phoneme-Deletion task were much poorer for all age groups, with 5-year olds only averaging 14% correct on this task. Five 5-year olds and three 6-year olds were unable to perform the task at all, compared to only one 5-year old for the Initial-Consonant-Same task and no subjects for syllable counting. A mixed model ANOVA was conducted with phonological awareness task as the within-subject factor and age group as the between-subject factor. A Bonferroni adjusted alpha level of .008 (.05/6) was used for all pairwise comparisions of phonological awareness tasks. Results revealed a significant effect of task [F(2, 66) = 48.09; p<.001] and age group [F(2,33) = 8.56; p <.001], but no task x age group interaction [F(4, 66) = 1.6; p=.184; η_p^2=..089]. Post hoc tests revealed that the mean performance on the Phoneme-Deletion task was significantly poorer than performance on both Syllable-Counting and Initial-Consonant-Same tasks but there were no significant differences between performance on the Syllable-Counting and Initial-Consonant-Same tasks. The observed age effects were due to significant differences between 5-and 7-year olds.

Relation Between Speech Perception in Noise and Phonological Awareness

Given potential ceiling effects in speech perception measures at +5 and +10 dB SNR, any relation between speech perception in noise and phonological awareness may be difficult to assess under these conditions. Thus, the relationship was examined only at 0 dB SNR, where there was the greatest variability in scores. Figure 3 illustrates performance on the phonological awareness tasks as a function of performance on the speech perception tasks with age group as the parameter. The x-axis represents performance on the phonological awareness tasks (Syllable-Counting, Initial-Consonant-Same, Phoneme-Deletion) and the y-axis represents performance on the three speech perception tasks (nonsense syllables, words, sentences). As expected, the range of speech perception scores narrows with increases in stimulus redundancy. There also is a wide range of performance for the phonological awareness tasks (x-axis), but the range of scores does not diminish across tasks. Although some panels appear to show an association between speech perception and phonological awareness scores, it is clear that this is, at least in part, attributable to the fact that both tend to improve with age.

To examine the relationship between speech recognition in noise and phonological awareness skills further, separate multiple regressions were performed between nonsense-syllable, word, and sentence perception at 0 dB SNR as the dependent variables and age, raw score on the PPVT, raw score on the Digit Span Test, and scores on the syllable-counting, initial-consonant-same, and phoneme-deletion tasks as independent variables. Age was included as a continuous variable. Overall, no single variable accounted for a significant part of the variance in performance on nonsense syllables, words or sentences, with the exception the PPVT score and sentence perception. The combined variables accounted for only 1.8% of the variance in scores for nonsense syllables, 18% of the variance in scores for words and 19% of the variance in scores for sentence (Table 2).

These findings may have been influenced by the fact that, even at 0 dB SNR, many subjects demonstrated relatively high scores on both measures. While a greater spread of scores might have been observed if poorer SNRs had been used, recall that the SNRs in this study were selected to be representative of typical real-world listening conditions.

DISCUSSION

The primary purpose of the current study was to examine the relation between children's speech perception in noise and performance on a range of phonological awareness tasks. If a relationship existed between the phonological awareness tasks used in this study and speech perception in noise, children who demonstrated high performance on the phonological awareness tasks would also show better speech perception in noise. Current results did not support this hypothesis. Age effects existed for the phonological awareness tasks (7-year olds performing significantly better than 5-year olds) and for word recognition (7-year olds scoring significantly higher than 5-year olds). However, performance on the phonological awareness tasks did not account for a significant amount of variance in performance on the speech perception tasks.

It is possible that the failure to support a relationship between performance on the phonological awareness and speech perception tasks reflects differences in performance on phonological awareness tasks for this group of subjects when compared to other children. Performance for the phonological awareness tasks used in the current study can be compared to similar tasks from other studies (Figure 4). Although prior data were not available to compare all three tasks at each age, where comparisons were possible performance was similar across most measures. Notable differences were found for syllable counting, where results from Nittrouer and Burton (2005) were approximately 20% higher for 5-year olds than in the current study. Procedural and/or sample population differences across studies may account, at least partially, for these differences. Subjects in the Nittrouer and Burton study were selected from a specific population (mid-SES backgrounds with no history of otitis media). No such restrictions were placed on the subjects in the current study. If scores for all subject groups (i.e., including those from low-SES backgrounds and those with history of otitis media) in the Nittrouer and Burton study were combined, the differences between the two studies would be smaller. Similarly, for the Phoneme-Deletion task, results from the current study were approximately 15% higher for 6-year olds when compared to results from Stanovich et al. (1984). Stanovich et al. used fewer (10 vs. 24) words than in the current study and their words were real words both before and after phoneme deletion. However, it is unclear whether these differences could impact results. In general, despite differences in procedures, results across multiple studies support the phonological awareness results from the current study.

Recall that the relationship between phonological awareness and speech perception in noise was suggested, at least in part, from studies in which children who demonstrated poorer phonological awareness (e.g., poor readers) also demonstrated poor speech perception in noise in comparison to peers (e.g., Brady et al. 1983). In the current study, performance was examined for typically developing children without suspected deficits in phonological awareness. the present findings provide no evidence of a systematic relationship between phonological awareness and speech perception in noise at moderate SNRs. This does not rule out the possibility of a relationship at poorer SNRs. Nor does it rule out the possibility of a relationship for children with known language and/or reading disorders. However, the presence of both poor phonological awareness and poor speech perception in noise does not imply correlation or causality. It is possible that there are underlying factors that are strongly related to deficits in both areas and/or that children may demonstrate deficits in numerous areas that are not causally related (Boets et al. 2007; Joanisse et al. 2000). Brady et al. (1989) found that, even in quiet conditions, poor readers performed similarly to peers with normal reading abilities when repeating monosyllabic words but experienced more difficulty when repeating multisyllabic and pseudo words. Speculating on the source of those differences they suggest that “the inferior performance of poor readers on repetition tasks may stem from problems perceiving the stimuli, from problems producing them quickly and accurately, or from difficulties in encoding that may be common to all phonological tasks” (p. 120).

Foy and Mann (2001) examined relations among between a number of spoken-language and phonological awareness tasks in preschool children who were beginning formal reading instruction. Included in their battery of tests were measures of reading, vocabulary, letter knowledge, phoneme awareness, and rhyme awareness as well as tests of articulation, naming speed, nonword repetition, phonological distinctness, and speech discrimination. Results revealed a relation between rhyme awareness and speech perception when controlling for age, vocabulary and letter knowledge. However, age, vocabulary and letter knowledge appeared to mediate the relation between phoneme awareness and speech perception/production. According to the investigators, their findings were “consistent with a view that phoneme and rhyme awareness skills represent separable components of phonological awareness” and “suggest that rhyme awareness tasks are better preschool measures of inherent differences in underlying phonological processing, and that phoneme awareness tasks are more determined by exposure to literacy” (p. 319).

Thus, while phonological awareness skills are strongly related to reading and some children with reading difficulties also demonstrate poor speech perception in noise, results of the current study fail to support a relationship between phonological awareness skills and speech perception in moderate levels of noise for typically developing five to seven year-old children with normal hearing. Differences in experimental design and subject characteristics make comparisons across studies difficult. For example, it is possible that stronger relationships may exist between speech perception in noise and other phonological awareness tasks (e.g., rhyme awareness, advanced tasks such as a pig-Latin task [as described by Nittrouer and Miller 1999]), especially at poorer SNRs. Subject age, the specific phonological awareness and speech perception tasks, as well as the presence of speech, language, and/or reading difficulties of some subjects are likely to influence interpretation of the data. For example, in addition to the fact that Brady et al. (1983) examined both good and poor readers, their subjects were older (third graders) than any of the subjects in the current study. Finally, the Brady et al. study used different speech and noise levels as well as a different phonological processing task. The relationships among variables in Brady et al. versus those in the current study could have differentially impacted findings in the two studies. Further research in this area is needed to examine possible relationships among the many factors that affect both speech perception in noise and the development of phonological awareness.

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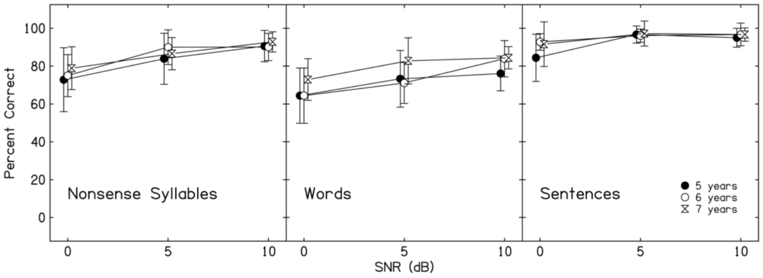

Figure 1.

Mean percent-correct performance and standard deviations for nonsense syllables, words, and sentences at 0, 5, and 10 dB signal-to-noise ratio (SNR) with age group as the parameter.

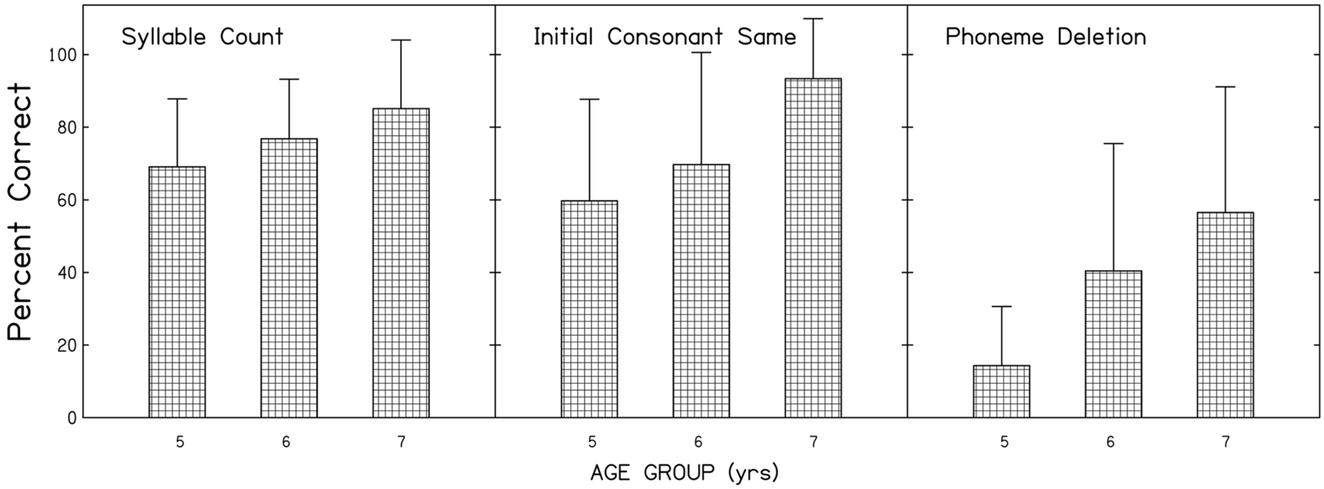

Figure 2.

Mean percent-correct scores and standard deviations for the three phonological awareness tasks (syllable count, initial consonant same, phoneme deletion) as a function of age group.

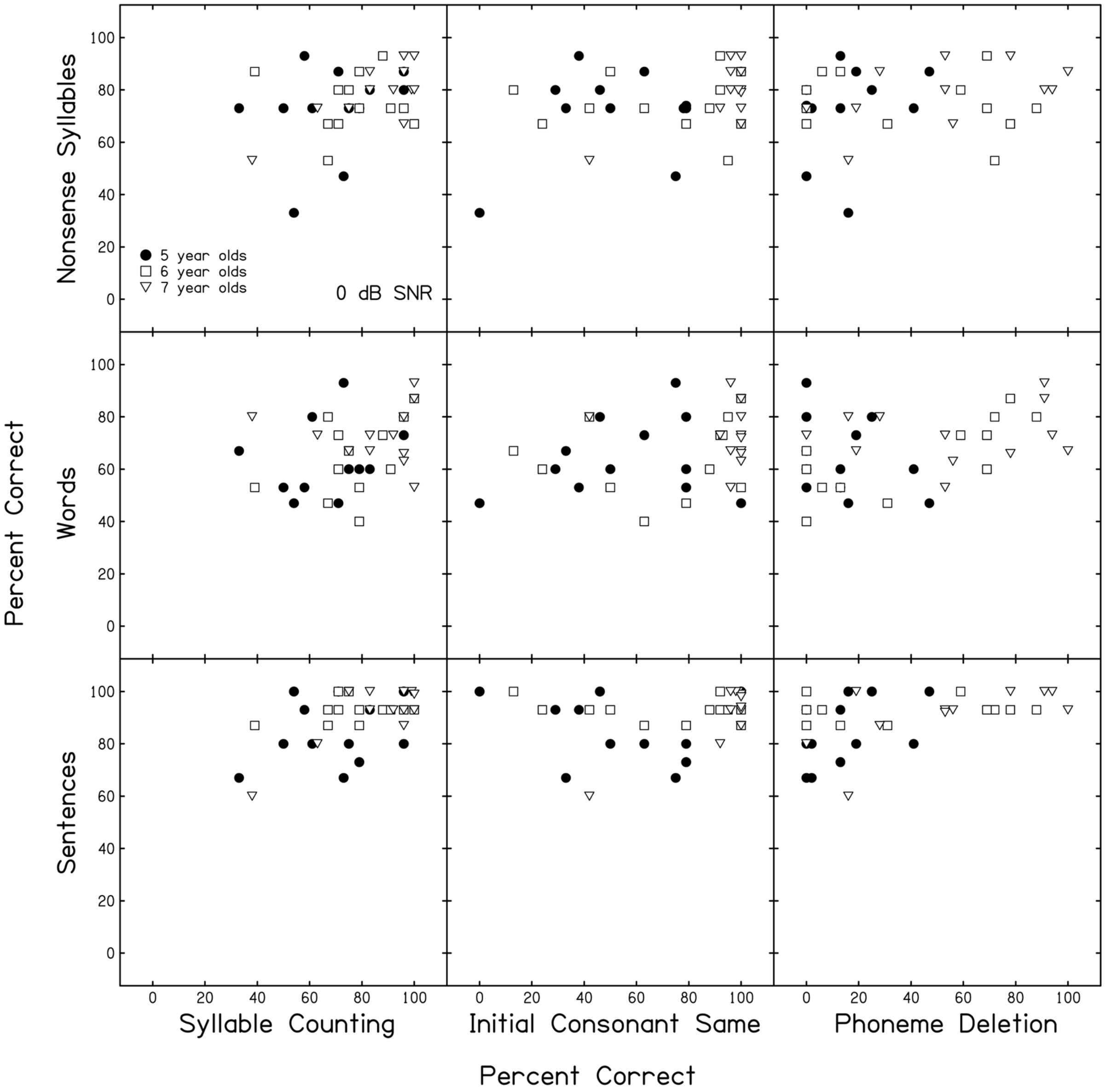

Figure 3.
Individual percent-correct performance at 0 dB SNR for the phonological awareness tasks (x-axis) as a function of speech perception (y-axis) for 5-, 6-, and 7-year olds (filled circles, open squares, open triangles, respectively).

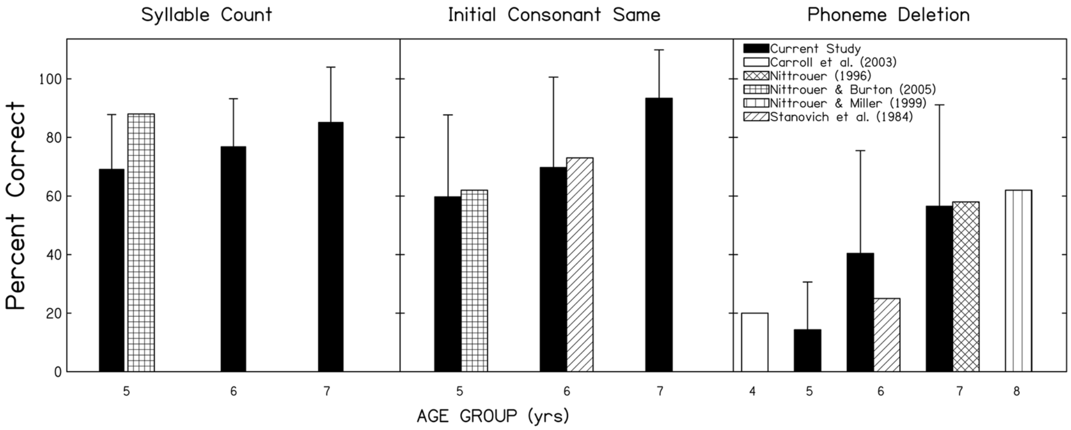

Figure 4.
Performance for the syllable count, initial consonant same, and phoneme deletion tasks from the current study as compared to similar tasks from other studies.

Table 1

Mean (standard deviation) raw scores for the Digit Span and Peabody Picture Vocabulary (PPVT) tests.

Age (years)	Digit Span	PPVT
5	9.7 (2.8)	91.0 (17.9)
6	10.6 (1.5)	95.9 (19.3)
7	13.1 (2.0)	118.1 (21.6)

Table 2

Multiple regression: amount of variance in speech perception scores at 0 dB SNR accounted for by age, raw score on the PPVT, raw score on the Digit Span Test, and scores on the syllable-counting (SC), initial-consonant-same (ICS), and phoneme-deletion (PD) tasks.

	Beta	***p***	**R^2**	**Adjusted R^2**
Nonsense Syllables			.202	.018
Age	−.172	.504		
PPVT (raw)	.177	.462		
Digit Span (raw)	.155	.537		
SC	.275	.246		
ICS	.208	.449		
PD	−.164	.524		
Words			.334	.181
Age	.221	.351		
PPVT (raw)	−.351	.118		
Digit Span (raw)	.139	.543		
SC	.288	.185		
ICS	−.227	.365		
PD	.334	.161		
Sentences			.342	.190
Age	−.160	.495		
PPVT (raw)	.451	**.046**		
Digit Span (raw)	.090	.693		
SC	.121	.571		
ICS	−.088	.723		
PD	.262	.266		