Children's use of semantic cues in degraded listening environments

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Children 5 and 9 years of age and adults were required to identify the final words of low- and high-context sentences in background noise. Age-related differences in the audibility of speech signals were minimized by selecting signal-to-noise ratios (SNRs) that yielded 78% correct performance for low-context sentences. As expected, children required more favorable SNRs than adults to achieve comparable levels of performance. A more difficult listening condition was generated by adding 2 dB of noise. In general, 5-year-olds performed more poorly than did 9-year-olds and adults. Listeners of all ages, however, showed comparable gains from context in both levels of noise, indicating that noise does not impede children's use of contextual cues.
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I. INTRODUCTION

When identifying words in spoken utterances, listeners typically monitor contextual cues as well as acoustic-phonetic information. At times, acoustic-phonetic cues are insufficient for the identification of particular words because of limitations in the signal (e.g., poor articulation on the part of the speaker) or listening environment (e.g., the presence of competing sounds or reverberation). In such circumstances, contextual cues—lexical, semantic, and syntactic—can help listeners decode a message. For example, upon hearing the word ''eating,'' listeners expect a food-related noun to follow. Although adults derive considerable benefit from such contextual cues, especially in challenging listening environments (e.g., Kalikow *et al.*, 1977; Bilger *et al.*, 1984; Pichora-Fuller *et al.*, 1995; Dubno *et al.*, 2000), the extent to which children do so is unclear.

A number of investigators have examined children's use of semantic contextual cues to decode a degraded signal. For example, Cole and Perfetti (1980) presented mispronounced words in high-predictability and low-predictability sentences within a story. They found that 4-year-olds were better at detecting mispronounced words in high-predictability than in low-predictability sentences, indicating that very young children profit from such contextual cues. Craig *et al.* (1993) presented their target words in high-predictability contexts (e.g., ''The watchdog gave a warning growl'') or in low-predictability contexts (e.g., ''I had not thought about the growl''). They altered the to-be-identified word by eliminating the later portions of the word. In such ''gating'' tasks (Grosjean, 1980, 1985), participants engage in repeated attempts to identify the target word from successively longer portions, or gates. Craig *et al.* (1993) found that 8- to 10-year-old children required shorter gates (i.e., less acoustic information) to identify target words in high-predictability than in low-predictability sentences. By contrast, 5- to 7-year-olds required as much acoustic-phonetic information with high-predictability as with low-predictability contexts (Craig *et al.*, 1993). Because of young children's limitations in phonetic representation (Walley, 1988, 1993) and metalinguistic knowledge (Liu *et al.*, 1997), the gating task may underestimate their ability to use semantic contextual cues.

Tyler and Marslen-Wilson (1981) examined children's use of semantic contextual cues by altering the semantic adequacy of sentences. They presented target words in semantically appropriate (''John has to go back home'') or in anomalous (''John had to sit on the shop'') utterances. Children 5–10 years of age more readily detected the target words in semantically appropriate than in anomalous sentences, confirming their ability to profit from the semantic context. Liu *et al.* (1997) found that preschoolers repeat final target words more rapidly when they are presented in semantically appropriate contexts than in anomalous sentences. Even with compressed or filtered speech, 4-year-olds respond more quickly to semantically appropriate than to inappropriate sentences (Bates *et al.*, 2001).

There are recent indications that the ability to use semantic contextual cues emerges by 2 years of age. Fernald (2001) examined 2-year-olds' eye movements to two pictures as they listened to simple sentences with verbs that cued the target words (e.g., ''Drink the milk''). Eye movements toward the correct picture (i.e., the one cued by the semantic context) were initiated before the target word was presented. It is clear, then, that listening to speech engages predictive processing at relatively early stages of language development.

Despite evidence that young children benefit from semantic contextual cues in optimal listening conditions (e.g., Tyler and Marslen-Wilson, 1981; Fernald, 2001) or with compressed or filtered speech (e.g., Bates *et al.*, 2001), there are suggestions that background noise interferes with young children's use of such cues. Nittrouer and Boothroyd (1990) presented short sentences varying in semantic adequacy in a background of spectrally matched noise. The listener's task was to repeat the sentences verbatim. Although semantic cues facilitated performance, 4- to 6-year-old children did not benefit from such cues to the same extent as did young and elderly adults. Nittrouer and Boothroyd (1990) speculate

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that young children's limited knowledge of semantic constraints rather than the presence of noise was responsible for their lesser benefit from semantic cues. Elliott (1979) investigated children's use of semantic cues by means of the SPIN (speech perception in noise) task (Kalikow *et al.*, 1977; Bilger *et al.*, 1984). Participants in the SPIN task are required to repeat the final word of high- and low-predictability sentences presented in multitalker babble. Elliott (1979) found that children 9–13 years of age derived less benefit from contextual cues in high-predictability sentences than did older listeners. Interestingly, the ability to profit from semantic cues (as assessed by the SPIN task) continues to improve into older adulthood (Pichora-Fuller *et al.*, 1995; but see Dubno *et al.*, 2000). Pichora-Fuller *et al.* (1995) suggest that elderly adults may compensate for a declining perceptual system by relying on contextual cues to a greater extent than younger listeners do.

In principle, children whose perceptual system is not fully developed have much to gain from semantic contextual cues, especially in noisy backgrounds. The available evidence (e.g., Elliott, 1979; Nittrouer and Boothroyd, 1990) indicates, however, that they do not profit optimally from such cues. Why not? A number of factors may be implicated. Young children are likely to perform more poorly than adults on difficult listening tasks simply on the basis of their 5-dB difference in absolute and masked thresholds (e.g., Schneider *et al.*, 1986, 1989). For example, Fallon *et al.* (2000) found that 5-year-old children required signal-to-noise ratios (SNRs) that were 5 dB more favorable than those of adults to achieve comparable identification in simple low-context sentences (e.g., ''Touch the dog''). Failure to compensate for age-related sensory differences obscures the independent contributions of sensory and cognitive factors. Second, the test materials in Nittrouer and Boothroyd (1990) and Elliott (1979) were not designed for young children. As a result, some of Nittrouer and Boothroyd's (1990) high-predictability sentences (e.g., ''Tough guys sound mean;'' ''Dull paint won't shine'') may have confused many, if not all, young children. Third, the articulatory demands of repeating the final word of lengthy test sentences (Elliott, 1979) may have posed disproportionate difficulty for very young children (Elliott *et al.*, 1979). In short, meaningful comparisons of children's and adults' use of contextual cues in noise depend on comparable task demands and listening conditions across age.

In the present study, we evaluated the contribution of semantic contextual cues to word recognition in noise by 5- and 9-year-old children and adults. To this end, we devised age-appropriate high- and low-context sentences in which the target word was a familiar monosyllabic noun. Task difficulty was minimized by means of a four-alternative picture-pointing response (following Fallon *et al.*, 2000). To minimize age-related differences in stimulus audibility, we established SNRs that yielded comparable performance levels (78%) on low-context sentences (e.g., ''We looked at the bread''). Greater use of contextual cues by older children and adults than by younger children would yield a statistical interaction between age and context. A secondary goal was to evaluate the prevailing view that noise has more adverse perceptual consequences on young children than it does on older listeners (Mills, 1975; Elliott, 1979). Although Fallon *et al.* (2000) found that noise increments have comparable effects on 5-year-olds, 9-year-olds, and adults, their test sentences (e.g., ''Touch the X'') were structurally simpler than those in the current study. It is possible, then, that noise increments would reveal age differences in the processing of more complex sentences. Accordingly, separate groups of listeners were tested with different noise levels. Disproportionate consequences of noise increments on young listeners would result in an interaction between age and noise level.

We recorded latencies for correctly identified low- and high-context targets to complement the accuracy measures. Recall that semantically appropriate sentences promote faster word repetition than do semantically impoverished or anomalous sentences (Liu *et al.*, 1997). By extension, we expected faster word identification (i.e., pointing to the target picture) in high- than in low-context sentences. Such reductions in latency would indicate that listeners use semantic cues to predict forthcoming words. If 5-year-olds and adults use semantic context similarly, they should show comparable reductions in response latency to high-context sentences.

II. METHOD

A. Participants

The participants were 48 5-year-olds (range: 5;0–5;6, $M=5;3$ years), 48 9-year-olds (range: 9;0–9;6, $M=9;3$ years), and 48 adults (range: 19–25, $M=20.7$ years), with equal numbers of males and females in each age group. No child in the sample had experienced frequent ear infections or had ever required pressure-equalizing tubes. All children and adults were free of colds on the day of testing. Participants were monolingual speakers of English, with the exception of three adults, who had learned English by 6 years of age and attended elementary school in North America. Additional participants were excluded because of experimenter error (one 5-year-old, two 9-year-olds, one adult), failure to complete the test session (one 5-year-old), failure to meet the training criterion (four 5-year-olds), failure to follow instructions (one 5-year-old, one 9-year-old), inattentiveness (three 5-year-olds, one 9-year-old), or apprehensiveness (two 5-year-olds).

B. Apparatus and stimuli

Testing occurred in a double-wall sound-attenuating booth, $3\ \mathrm{m}\times 2.8\ \mathrm{m}\times 2\ \mathrm{m}$ in size. Participants were seated facing a nonglare touch-screen monitor (Goldstar 1465DLs) 33×33 cm. Loudspeakers (KEF Model 101) were 45 degrees to the left and right of the participant (distance of 70 cm) at approximate ear level. Sentence files and babble files were converted to analog form by means of Tucker-Davis digital-to-analog converters under the control of a computer with a Pentium processor. Sentence and babble amplitudes were controlled separately by means of programmable attenuators. After mixing, the combined signals were amplified (SAE 2600) and presented over loudspeakers located inside the testing booth. Sound-field levels were determined in the absence of the listener by means of a Bruel and Kjaer $\frac{1}{2}$-in. microphone.

TABLE I. Fundamental frequency and duration of low- and high-context sentences.

	Frequency (Hz)		Duration (ms)	
	Sentence	Target	Sentence	Target
Low context				
Mean	231.24	233.28	1787.43	605.26
SD	13.39	15.71	155.94	87.84
Range	198.30–257.65	200.15–262.27	1453.60–2040.20	432.15–783.25
High context				
Mean	231.12	238.02	2147.68	556.62
SD	9.36	20.55	354.04	79.57
Range	206.92–251.59	180.88–286.69	1500.15–2883.60	414.60–726.30

We generated a large corpus ($n=188$) of high-context sentences with concrete, monosyllabic nouns in sentence-final position. Sentences were relatively simple and short (5 to 10 syllables in length), with content that was familiar to 5-year-olds. To assess the degree to which high-context stems primed the final target words, an independent sample of 361 adults (289 women, 72 men; mean age$=$22.3 years; range 18–54) completed subsets of high-context sentence stems (e.g., ''Mice like to eat ___ '') with the word that first came to mind. Each participant completed approximately 47 sentence stems by means of a paper-and-pencil task, yielding approximately 90 observations per sentence. The data from 19 additional adults were excluded for failing to complete over 90% of the stems (four women, one man), learning English after age 14 (ten women, two men), or providing blatantly foolish answers (two men). From the initial corpus, 60 sentences were selected to serve as practice ($n=20$) and test ($n=40$) items. The mean number of syllables in high-context sentences was 7.28. On average, adults completed each high-context stem with the target word 52.5% of the time (range 3%–95%). Low-context sentences ($n=60$, 40 test items, 20 practice items) were generated with these target words. Low-context sentences could take one of five forms: (1) ''[Pronoun] looked at the [target]''; (2) ''[Pronoun] talked about the [target]''; (3) ''[Pronoun] read about the [target]''; (4) ''[Pronoun] heard about the [target]''; and (5) ''[Pronoun] pointed at the [target].'' Thus, low-context sentences contained 5 or 6 syllables ($M=5.77$). High- and low-context sentences are listed in the Appendix.

We verified 5-year-olds' ability to predict the target words from the high-context stems by means of a four-alternative, forced-choice task. Subsets ($n=20$) of prerecorded high-context sentence stems were presented at 44 dB (A) in quiet to an additional sample of 29 5-year-olds (14 girls, 15 boys; $M=5;3$ years). Sentence stems were accompanied by four pictures that appeared in different corners of a touch screen. The four alternatives included the target and three foils depicting words that were semantically and phonologically dissimilar from the target word. Visual feedback in the form of a flashing picture was provided for correct responses. The experimenter explained to children that they would hear a lady talking, but that the computer would ''chop off'' her last word. Their task was to select the picture corresponding to what the lady wanted to say. To ensure that children understood the instructions, they received two practice trials with photocopied arrays of pictures from practice plates of the *Peabody Picture Vocabulary Test* (Dunn and Dunn, 1997). For example, the experimenter presented pictures of a table, doll, car, and man and said, ''We put dinner on the ___.'' If children responded incorrectly on the practice trials, the experimenter provided the correct answer. Children selected the target word on 98.8% of test trials, indicating that the high-context sentence stems effectively cued the target words with ideal listening conditions and a closed-response set.

High- and low-context sentences were produced by a vocally trained woman and digitized at a rate of 20 kHz using a 16-bit Tucker Davis (DD1) analog-to-digital converter. The babble portion of SPIN forms used by Pichora-Fuller *et al.* (1995) was similarly digitized and stored. The sentences used in the main experiment (i.e., with target word included) had an average fundamental frequency of 231 Hz and an average duration of 1968 ms. As shown in Table I, the duration of high-context sentences exceeded that of low-context sentences, $t(78)=-5.56$, $p<0.001$, but the duration of target words in low-context sentences exceeded the duration of target words in high-context sentences, $t(78)=2.60$, $p=0.01$. The longer durations of low-context target words may reflect the speaker's intuitive compensation for low redundancy (Lieberman, 1963; Fowler, 1988). The mean fundamental frequency of target words did not differ as a function of contextual condition, $t(78)=-1.159$, $p=0.25$. Similarly, the mean fundamental frequency of low- and high-context sentences did not differ significantly, $t(78)=0.05$, $p=0.96$. Sentences were presented at approximately 44 dB(A), a level well above 5-year-olds' speech-identification threshold in forced-choice contexts. Pilot testing for a previous study (Fallon *et al.*, 2000) revealed that 5-year-olds identify monosyllabic target words in simple carrier phrases (e.g., ''Touch the X.'') with 99% accuracy. Root-mean-square (rms) values were calculated and adjusted such that each sentence was presented at equal intensity following the procedure of Schneider *et al.* (2000). SNR was varied by adjusting the level of babble (F_0: 185 Hz). Pilot-testing established the SNR at which each age group achieved approximately 78% correct performance on low-context sentences: -24 dB for 5-year-olds, -27 dB for 9-year-olds, and -30 dB for adults.[1] These levels were designated low-noise conditions. High-noise conditions were created for each age group by decreasing the SNR by 2 dB (by adding 2 dB of noise), resulting in SNRs of -26 dB for 5-year-olds, -29 dB for 9-year-olds, and -32 dB for adults. SNRs for the training phase were set 5 dB higher than those in the low-noise conditions: −19, −22, and −25 dB for 5-year-olds, 9-year-olds, and adults, respectively.

Visual stimuli consisted of 60 black-and-white line drawings of familiar, concrete objects corresponding to the target items. Images were gathered from various sources, including Snodgrass and Vanderwart (1980), Cycowicz *et al.* (1997), the *Peabody Picture Vocabulary Test* (Dunn and Dunn, 1997), and a local artist.

C. Procedure

All participants were tested individually. A trial, which was initiated by a button press, consisted of the simultaneous presentation of vocal stimuli (sentence and noise) and visual stimuli. Sentences in noise were accompanied by an array of four different images, one appearing in each corner of the touch screen. The multitalker babble began with the onset of the sentence and terminated when the sentence ended. The visual array included the target image and three designated foils that were phonetically and semantically dissimilar from the target. The locations of targets and foils were randomly selected on each trial. Reaction times accurate to the millisecond were recorded automatically from stimulus offset. Feedback for correct performance consisted of the target flashing in the middle of the screen. Incorrect selections resulted in the screen going blank. Unlike the usual situation in reaction-time experiments, listeners were not told to respond as quickly as possible.

The instructions were tailored to the age of participants. Listeners were told that the last word of the sentence would correspond to one of the pictures on the screen. The experimenter explained to 5-year-old children that they should choose the picture that matches the last word that the lady says. Moreover, 5-year-olds were told that if they only hear part of a word, they should choose the picture that sounds similar to what they hear (e.g., "If you hear 'irt' and there are pictures of a can, plate, shirt, and boat on the screen, you should pick the shirt because 'shirt' sounds the most like 'irt'."). Older children and adults were told that the pictures were identifiable by the most basic term. For example, a picture of a shirt would be identified by the word "shirt," not "button-down" or "clothing." No other strategies were suggested.

The test session consisted of a training phase and a test phase. All participants were required to meet a training criterion of 4 consecutive correct responses within a maximum of 20 trials consisting of randomly ordered high- and low-context sentences. On average, listeners achieved the training criterion in 7.4 trials. After reaching the criterion, participants proceeded to the test phase, which consisted of 40 randomly ordered sentences (20 low-context, 20 high-context) presented in either low or high noise. Target items could occur only once within a test session, necessitating two lists (A and B), each containing 40 sentences. High- and low-context sentences were presented at identical SNRs. Half of the participants were tested in low noise, the other half in high noise. In each noise condition, half of the listeners received list A, with the remaining listeners receiving list B. Equal numbers of males and females in each age group were tested in each noise condition, and equal numbers received list A or B.

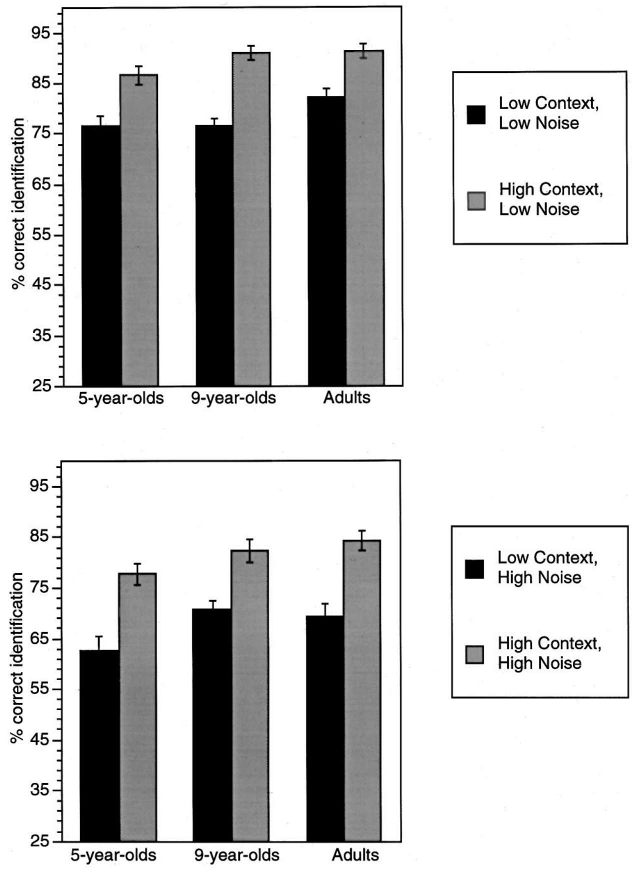

FIG. 1. Performance of 5-year-olds, 9-year-olds, and adults on low- and high-context sentences in both levels of noise. Error bars represent standard error of the mean.

Adults and 9-year-old children initiated trials at their preferred pace. The experimenter initiated trials for 5-year-olds when she judged them to be ready and attentive. The experimenter remained in the test booth during the entire session for children, offering periodic verbal reinforcement and encouragement that was unrelated to their performance. To maintain the interest of 5-year-olds, they received a colored sticker after every four trials, which they placed in an "incomplete" black-and-white picture. At the end of 40 trials, children had completed the picture.

III. RESULTS

Figure 1 illustrates performance at each noise level as a function of context and age. Because preliminary analyses revealed no difference in performance as a function of list (A or B), this factor was omitted from subsequent analyses. Despite our attempts to control for differences in stimulus audibility on low-context sentences, a one-way ANOVA with age as the independent variable revealed a marginal effect of age in the low-noise condition, $F(2,69)=2.78$, $p=0.07$. Post-hoc Tukey analyses, however, did not achieve conventional levels of significance ($p>0.1$ for all comparisons). A 2×3 ANOVA with context as a within-subject factor and age as a between-subject factor revealed that high-context sentences were identified more accurately than low-context sen-

TABLE II. Performance (percent correct) of 5-year-olds, 9-year-olds, and adults on low- and high-context sentences in both levels of noise.

	Low noise		High noise	
	Low context	High context	Low context	High context
5-year-olds	76.59 (9.51)	86.67 (9.17)	62.71 (13.90)	77.69 (10.30)
9-year-olds	76.46 (9.61)	91.04 (6.59)	70.83 (8.56)	82.29 (11.23)
Adults	82.08 (9.20)	91.25 (7.26)	69.38 (13.05)	84.17 (9.74)

Note: Standard deviations are in parentheses.

TABLE III. Average latencies in seconds for low- and high-context sentences as a function of age.

	Low context	High context
5-year-olds	1.883 (0.595)	1.623 (0.625)
9-year-olds	1.672 (0.639)	1.254 (0.512)
Adults	1.534 (0.420)	1.217 (0.500)

Note: Standard deviations are in parentheses.

tences, $F(1,69)=79.94$, $p<0.001$, and that 5-year-olds performed more poorly than 9-year-olds and adults, $F(2,69)=3.34$, $p=0.041$ (see Table II). As can be seen in Fig. 1, there was no interaction between age and context, $F(2,69)=1.76$, $p=0.18$. Note, however, that performance on high-context sentences was positively skewed, with several participants (four 5-year-olds, three 9-year-olds, and four adults) achieving perfect scores.

In high noise, performance on low-context sentences varied significantly with age, $F(2,69)=3.09$, $p=0.052$. Post-hoc Tukey comparisons of 5- and 9-year-olds approached conventional levels of significance, $p=0.058$, as did those between 5-year-olds and adults, $p=0.087$ (see Table II). A 2×3 ANOVA with context as a within-subject factor and age as a between-subject factor revealed main effects of context, $F(1,69)=81.36$, $p<0.001$, and of age, $F(2,69)=3.92$, $p=0.024$, but no interaction between context and age, $F(2,69)=0.56$, $p=0.57$. Performance on high-context sentences in high noise was more normally distributed than was performance in low noise, minimizing the likelihood that interactions between age and context were obscured by ceiling effects.

To compare performance at the two noise levels, a $2\times2\times3$ repeated-measures ANOVA, with context as a within-subject factor and noise level and age as between-subject factors, revealed a main effect of context, $F(1,138)=160.01$, $p<0.0001$, and of age, $F(2,138)=6.59$, $p=0.002$, reflecting poorer performance by 5-year-olds ($M=75.83\%$, s.d. $=10.83$) than by adults ($M=81.72\%$, s.d. $=9.14$), Tukey HSD, $p=0.012$. As expected, listeners performed better in low noise ($M=83.99\%$, s.d. $=7.04$) than in high noise ($M=74.48\%$, s.d. $=9.62$), $F(1,138)=49.77$, $p<0.001$. There were no two-way or higher-order interactions. The same pattern of findings emerged from an analysis using rationalized arcsine transformations of the percent correct data (Studebaker, 1985), which indicates that ceiling effects were not responsible for obscuring an interaction between age and context.

To gain further perspective on context effects, we examined reaction times to words identified correctly in low- and high-context sentences across age. The means and standard deviations of individual listeners on low- and high-context sentences were calculated separately, excluding trials on which reaction times exceeded the individual's mean by 2 standard deviations. Discarded trials for low-context sentences represented 6.26% (s.d. $=3.87$), 5.32% (s.d. $=3.77$), and 5.23% (s.d. $=3.12$) of all correct trials for 5-year-olds, 9-year-olds, and adults, respectively. For high-context sentences, discarded trials represented 6.70% (s.d. $=3.34$), 6.33% (s.d. $=4.58$), and 5.88% (s.d. $=5.20$) of all correct trials for 5-year-olds, 9-year-olds, and adults, respectively. A repeated-measures ANOVA indicated that these discard rates did not differ across context, $F(1,138)=2.24$, $p>0.1$; age, $F(2,138)=1.28$, $p>0.2$; or noise, $F(1,138)=1.06$, $p>0.3$. No interactions between the factors reached conventional levels of significance. To achieve homogeneity of variance, two 5-year-old girls who exhibited very high latencies were excluded from the subsequent analysis. Table III reports average latencies in each age group as a function of context. A $2\times2\times2\times3$ repeated-measures ANOVA, with mean latency as the dependent variable, context as a within-subject factor, and age and noise as between-subject factors, revealed that word identification was faster in high-context sentences ($M=1.361$ s, s.d. $=0.573$) than in low-context sentences ($M=1.695$ s, s.d. $=0.573$), $F(1,130)=89.40$, $p<0.0001$. Moreover, word identification was faster in low noise ($M=1.449$ s, s.d. $=0.516$) than in high noise ($M=1.670$ s, s.d. $=0.544$), $F(1,130)=4.132$, $p=0.04$. As shown in Table III, 9-year-olds and adults responded more rapidly than 5-year-olds, $F(2,130)=7.84$, $p=0.001$, but there was no age $\times$context interaction.

IV. DISCUSSION

Children 5 and 9 years of age and adults listened to high- and low-context sentences in noise (multitalker babble) at levels that were adjusted to equalize signal audibility across age. Although 5-year-olds experienced more difficulty than would be expected on the basis of age differences in sensitivity, listeners of all ages identified the target words more accurately and more quickly in high-context sentences than in low-context sentences and at lower noise levels than at higher noise levels. Moreover, gains in identification accuracy and reductions in latency were comparable in magnitude for all age groups.

Favorable effects of context on auditory word recognition are consistent with previous research on speech identification in noise by children (Elliott, 1979; Nittrouer and Boothroyd, 1990) and adults (e.g., Kalikow *et al.*, 1977; Bilger *et al.*, 1984; Boothroyd and Nittrouer, 1988). Nevertheless, comparable gains in identification accuracy across age are at odds with the prevailing view that young children use contextual information less effectively than older children, who, in turn, use such information less effectively than adults (Elliott, 1979). Instead, our findings are consistent with the view that 5-year-olds have similar lexical organization to that of older listeners (Cirrin, 1984). Thus, there is every reason to believe that the contextual cues in the test sentences primed similar semantic networks in 5-year-olds, 9-year-olds, and adults.

It is likely that the principal source of discrepancies between the present findings and previous findings (Elliott, 1979; Nittrouer and Boothroyd, 1990) is methodological. Open-set responding (e.g., repeating the final word of test sentences), which is known to pose disproportionate difficulty for young children (Elliott *et al.*, 1979; Geffner *et al.*, 1996), was used in previous studies (e.g., Elliott, 1979), unlike the closed-set responding (picture-pointing) in the present investigation. Moreover, some of the high-predictability sentences in previous research included semantic contextual cues that would be ambiguous or incomprehensible to young children. For example, metaphorical expressions (e.g., "He played a game of cat and mouse") such as those used by Elliott (1979) are not mastered until well into the school years (Winner, 1988). Few researchers have provided feedback, which is known to enhance children's performance (Smith and Hodgson, 1970). Most critical, however, is the typical failure to control for age-related differences in stimulus audibility. When all age groups are tested at the same signal-to-noise level, it is difficult to separate the contributions of bottom-up (i.e., sensory) and top-down (i.e., cognitive) factors.

In the present study, reduced latencies to identify words in high-context sentences imply that 5-year-olds, like adults, engage in interpretive processing as each message unfolds. Thus, words appearing early in a sentence constrain listeners' expectations of what words will follow, leading to faster identification of the final words of high-context sentences. Nevertheless, 5-year-olds' response latencies were higher than those of older listeners for low- as well as high-context sentences, a result that can be attributed to faster processing of speech in noise or to more efficient motor processing (i.e., touching the screen) on the part of 9-year-olds and adults.

The addition of 2 dB of noise had comparable effects on performance irrespective of age, disconfirming claims that young children are especially disadvantaged by increases in noise (Mills, 1975). Fallon *et al.* (2000) found that a 5-dB difference in SNR between 5-year-olds and adults—the difference in absolute and masked thresholds between these age groups (Schneider *et al.*, 1986, 1989)—led to comparable word identification accuracy with very simple test sentences (e.g., Touch the dog; Touch the key). Pilot testing with the more complex sentences in the present investigation (e.g., "Mom talked about the fish"; "I went to the pond and caught a fish") indicated that a 6-dB difference in SNR equalized 5-year-olds' and adults' performance in low noise. Ultimately, that SNR difference failed to equalize performance levels across age, especially at the higher noise level. What accounts for this difference between studies? All sentences in Fallon *et al.* (2000) were identical except for the final monosyllabic word, which means that they were equivalent in number of syllables and roughly equivalent in duration. By contrast, sentences in the present investigation varied in their non-target words, number of syllables, overall duration, syntactic structure ("At the soccer game, I waved my flag"), and availability of contextual cues. Such variability may pose differential difficulty for 5-year-olds, just as multiple talkers interfere with preschoolers' ability to identify words in noise (Ryalls and Pisoni, 1997). With increasing age and corresponding growth in cognitive and linguistic ability, children are likely to become more skilled at ignoring salient but irrelevant cues (Bialystock, 1993; Morton and Trehub, 2001).

In contrast to the 12% benefit from context that was evident in the present study, Kalikow *et al.* (1977) reported high-context gains as great as 60% in their adult sample. Note, however, that Kalikow *et al.* (1977) used open-set responding. For adults, Fallon *et al.* (2000) found that the SNR needed to maintain a particular performance level on an open-set task was 13 dB higher than that needed on a closed-set task. Even with low-context sentences, listeners can benefit from cues in the array of pictures. If they hear the sound /b/, for example, they can restrict their choices to the depicted words. Thus, closed-set responding may account for the modest but highly reliable performance gains from semantic cues in the test sentences.

In quiet conditions, 5-year-olds identify the missing target word for high-context sentence stems 99% of the time. Why, then, does performance drop to 75% to 85% when noise is added? The babble background masks the contextual information as well as the target word. Decreasing the perceptibility of semantic cues in the initial portion of the sentence undoubtedly reduces the likelihood that the final word (which is also perceptually degraded) will be identified accurately. What the present investigation indicates is that 5-year-olds are as skilled as older listeners at using perceptually degraded semantic cues within a sentence to enhance their decoding of other perceptual information in that sentence.

Although semantic cues had comparable facilitative effects on 5-year-olds', 9-year-olds', and adults' identification of words in noise, we cannot be sure that comparable processes were operative in each age group. In the real world as opposed to the laboratory, listening is invariably a constructive process. Listeners use their knowledge of the speaker, the topic of discussion, nonverbal cues, and other available information to enhance their decoding of speech. No doubt, constructive listening improves with increasing experience and cognitive sophistication, but the course of development is unknown. Moreover, it remains to be determined whether 5-year-olds would show comparable enhancement when open-set responses are required or when the contextual cues are embedded in more complex discourse.

Obviously, young children will be unable to achieve decoding accuracy comparable to adults in everyday listening situations that do not compensate for sensory differences between children and adults. Our findings indicate, however, that children are able to use strategic listening to their advantage in some situations, at least. One important challenge for future research is to map the developmental course of other aspects of constructive listening.

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APPENDIX

	Low context	High context
Practice	He read about the barn.	Farm animals stay in a barn.
	Mom talked about the belt.	I bought Dad a leather belt.
	We looked at the cage.	I put the bird back in its cage.
	He looked at the cheese.	Mice like to eat cheese.
	We pointed at the cloud.	Rain poured from the cloud.
	She read about the cow.	At the farm, I saw a cow.
	Mom pointed at the crown.	The king wore a gold crown.
	He talked about the deer.	In the forest, I saw a deer.
	Dad read about the drum.	Mike banged on a drum.
	She pointed at the fan.	I was hot, so I turned on the fan.
	She talked about the flag.	At the soccer game, I waved my flag.
	We read about the hose.	To water the lawn, Dad used the hose.
	Dad looked at the nose.	The bully punched my nose.
	Dad looked at the phone.	I answered the phone.
	Dad pointed at the pin.	To hold cloth together, we use a pin.
	He pointed at the rose.	I gave my mom a pretty rose.
	We talked about the shell.	At the beach, I found a shell.
	She looked at the snake.	I got bitten by a snake.
	Mom read about the soap.	We wash our hands with soap.
	Mom looked at the sock.	We put the shoe on after the sock.
Experiment	We pointed at the bag.	Mom packed my lunch in a bag.
	Mom pointed at the ball.	We played catch with the ball.
	We read about the bed.	I feel asleep on my bed.
	Dad pointed at the bee.	I got stung by a bee.
	Dad looked at the book.	I like to read a book.
	Mom looked at the boots.	When it snows, I put on my boots.
	We looked at the bread.	Sandwiches are made with bread.
	Mom read about the broom.	I cleaned the floor with a broom.
	Mom pointed at the brush.	To untangle my hair, I use a brush.
	Mom looked at the bus.	Dad rides to work on the bus.
	Mom read about the cake.	For dessert, we ate cake.
	She pointed at the car.	We drove to the store in our car.
	We pointed at the cat.	The dog chased the cat.
	She talked about the chair.	I sat down on the chair.
	She read about the clock.	I knew the time when I looked at the clock.
	He read about the clown.	We laughed at the funny clown.
	Dad pointed at the corn.	Farmers plant rows of corn.
	He talked about the cup.	I drink juice out of a cup.
	We read about the doll.	The girl played with her doll.
	He talked about the door.	Mom asked me to open the door.
	We talked about the dress.	She wore a pretty dress.
	Dad talked about the duck.	At the pond, I fed a duck.
	Mom talked about the fish.	I went to the pond and caught a fish.
	Dad read about the fork.	I eat spaghetti with a fork.
	She pointed at the horse.	I learned how to ride a horse.
	She looked at the house.	Ann’s family lives in a house.
	She talked about the key.	To open the door, Dad used a key.
	He looked at the kite.	I like to fly my kite.
	Dad read about the net.	Nick catches bugs with a net.
	Dad looked at the pail.	We carried the water in a pail.
	He read about the pants.	I fell and ripped my pants.
	She pointed at the pig.	The farmer fed the pig.
	He looked at the pot.	Mom cooks dinner in a pot.
	He pointed at the shoe.	I know how to tie a shoe.
	Dad talked about the skunk.	An animal that smells bad is a skunk.
	We looked at the snow.	I like to play in the snow.
	She read about the star.	In the sky, I saw a bright star.
	We talked about the tie.	When Dad gets dressed up, he wears a tie.
	Mom talked about the tree.	A bird built its nest in our tree.
	She looked at the wheel.	My wagon has a broken wheel.

[1]The SNRs yielding 78% performance for low-context sentences are low compared with previous research (e.g., Kalikow *et al.*, 1977; Elliott, 1979). We have demonstrated that the spectral characteristics of the speaker's voice and the closed-set response can account for these unusually low SNRs (Fallon *et al.*, 2000).

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