Perception & Psychophysics
1999, 61 (1), 80-86

Effect of masker level on infants' detection of tones in noise

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In adult listeners, the signal-to-noise ratio at masked threshold remains constant with increases in masker level over a wide range of stimulus conditions. This relationship was examined in 7-month-old infants by obtaining masked thresholds for .5- and 4-kHz tones presented in four levels of continuous masking noise. Adults were also tested for comparison. Masker spectrum levels ranged from 5 to 35 dB/Hz for .5-kHz tones, and from −5 to 25 dB/Hz for 4-kHz stimuli. Thresholds were determined for stimuli of both 10 and 100 msec in duration. The results indicated that infants' performance was more adultlike for 4-kHz stimuli. Although mean thresholds for both 10- and 100-msec, 4-kHz tones were approximately 7 dB higher in infants than in adults, E/N_0 at threshold remained essentially constant over the 30-dB range of maskers employed. By contrast, infants' thresholds for .5-kHz tones were exceptionally high at lower levels of the masker. Threshold E/N_0 decreased significantly as masker level increased from 5 to 35 dB/Hz, and this decrease was significantly greater for 10- than for 100-msec stimuli. Temporal summation of .5-kHz tones, measured as the difference between thresholds obtained at the two signal durations, was greater for infants than for adults at low levels of the masker. However, because infants' thresholds improved more rapidly with level for 10- than for 100-msec tones, age differences in temporal summation were no longer significant when masker spectrum level was 35 dB/Hz. These results suggest that the relationship between signal-to-noise ratio at masked threshold and level of the masker is dependent on both signal frequency and duration during infancy.

Studies of auditory development have demonstrated that the masked thresholds of infants and young children are significantly higher than those of adults. For both tone and noise stimuli, masked thresholds are typically elevated by about 5–15 dB in 6-month-old infants, gradually decreasing to adult levels by approximately 10 years of age (Allen & Wightman, 1994; Nozza & Wilson, 1984; Schneider & Trehub, 1992; Schneider, Trehub, Morrongiello, & Thorpe, 1989). Traditional models of the detection process hold that input to the auditory system is first subject to a filtering process, and that decisions about the presence or absence of a signal are based on the comparison of signal-plus-noise energy versus noise energy at the output of the auditory filter (e.g., Green & Swets, 1966). Thus, masked thresholds are determined by two factors: filter bandwidth, which limits the amount of noise passing through the auditory filter, and processing efficiency, the signal-to-noise ratio at the filter output that is required to detect the presence of the signal (Patterson, Nimmo-Smith, Weber, & Milroy, 1982). Because auditory filter width is believed to be mature by 6 months of age (Olsho, 1985; Schneider, Morrongiello, & Trehub, 1990; Spetner & Olsho, 1990), developmental differences in masked threshold have generally been ascribed to reduced auditory processing efficiency in young listeners (Werner & Marean, 1996).

Both sensory and nonsensory factors may contribute to the efficiency of the detection process. Werner and colleagues (Bargones & Werner, 1994; Bargones, Werner, & Marean, 1995; Werner & Bargones, 1991; Werner & Marean, 1996) have argued that a large portion of the age difference in masked thresholds may be attributable to immaturities in listening strategies and attention. The purpose of the present study was to examine the role of a sensory variable, intensity of the masking noise, to determine whether infants' ability to detect tones in a noise background might also depend on the level of the masker. In adult listeners, masking grows linearly with increases in masker level so that signal-to-noise ratio at threshold remains constant (Hawkins & Stevens, 1950). This invariance holds for all but extremely low level maskers (Hawkins & Stevens, 1950) and for signal frequencies ranging from at least 300 to 5000 Hz (Hawkins & Stevens, 1950; Moore, 1975). When maskers are continuous rather than gated, it also holds for shorter as well as longer duration stimuli (Carlyon & Moore, 1986).[1] Since traditional accounts of masking consider detection of a tone in noise to be equivalent to the discrimination of a difference in intensity (Miller, 1947), this relationship is frequently described as an instance of Weber's law. Although more recent studies have demonstrated that listeners detecting tones in noise are able to use cues other than those associated with a change in level, the data are generally consistent with the traditional model when intensity-based cues are reliable (Richards & Nekrich, 1993).

Results of the few developmental studies that have reported thresholds for more than one level of masking

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noise suggest that infants' masked thresholds increase with masker level in much the same way as adults'. However, only a limited range of masker levels in the vicinity of quiet threshold have been examined. Schneider et al. (1989) reported thresholds for octave-band noise stimuli with center frequencies ranging from .4 to 10 kHz, presented in 0- and 10-dB/Hz broadband masking noise. Although infant thresholds were 10–15 dB higher than those of adults at all frequencies, a 10-dB increase in masker level resulted in a threshold increase of approximately 10 dB in both infant and adult listeners. Similar results have been reported by Bull, Schneider, and Trehub (1981) and by Trehub, Bull, and Schneider (1981) for octave-band noise and speech stimuli presented in 0- and 18-dB/Hz broadband noise, and, more recently, by Nozza (1995) for 1-kHz tones presented in 0- and 10-dB/Hz maskers. A different pattern is suggested when studies employing more intense maskers are also considered. For masker spectrum levels in the range of 20 to 26 dB/Hz, infants' masked thresholds for midfrequency tones have been reported to be 6–8 dB above those of adults (Bargones et al., 1995; Nozza & Wilson, 1984), and for .5-kHz tones presented in 35-dB/Hz noise, Nozza (1987) found an infant–adult threshold difference of only 4 dB. These data raise the possibility that in young infants, unlike adults, the signal-to-noise ratio at threshold may decrease with increasing level of the masker. The present experiment was designed to clarify this issue by examining infants' masked thresholds for tones over a wider range of masker levels. In previous studies of auditory development, the absolute thresholds of 6- to 7-month-old infants have been found to be significantly less mature at low than at high frequencies (Olsho, Koch, Carter, Halpin, & Spetner, 1988; Trehub, Schneider, & Endman, 1980), especially for short-duration stimuli (Berg & Boswell, 1995). We therefore elected to obtain masked thresholds for both low- and high-frequency tones of 10 and 100 msec in duration. A question of particular interest was whether these previously demonstrated differences in maturity across stimulus conditions would also be evident in the masked thresholds of infant listeners.

METHOD

Participants

Sixty-four infants and 32 young adults participated in the study. Infants were tested when 30–35 weeks of age (mean age = 32.1 weeks). All were reported by their parents to be healthy and free of colds or ear infections on test days. An additional 76 infants were seen in the laboratory but were excluded from the final sample due to failure to meet training criteria (18), fussiness or loss of interest in visual reinforcers (47), refusal to wear headphones (10), and equipment problems (1). This exclusion rate is comparable to that of previous studies in which similar procedures were used (e.g., Berg & Boswell, 1995).

Adult listeners were students with no known history of hearing loss enrolled at the University of Florida. They were recruited from introductory psychology courses and received class credit for their participation.

Stimuli

Test stimuli were .5- and 4-kHz tones presented in four levels of continuous masking noise. They were gated by a programmable cosine switch with a rise/decay time of 3 msec and durations of 10 and 100 msec as measured at half-power points. For .5-kHz stimuli, the continuous masker was low-pass filtered at 2 kHz and presented at pressure spectrum levels ranging from 5 to 35 dB/Hz. For 4-kHz stimuli, the masker was bandpass filtered between 2 and 8 kHz and spectrum levels ranged from −5 to 25 dB/Hz. The tones were presented in trains consisting of up to seven repetitions per trial. Onset-to-onset interval between individual stimuli was 600 msec, resulting in a train approximately 4 sec in duration. All stimuli were delivered to the right ear using a pair of lightweight headphones (Sony MDR-CD6) held in place by an elastic headband.

Procedure

Infants were tested using a visually reinforced operant head turn procedure. They were seated on their parent's lap in a sound-treated chamber, with a loudspeaker and three battery-operated toys in Plexiglas boxes located 90° to the right. An experimenter seated in front of the infant manipulated quiet toys to direct his/her attention to midline and initiated trials when the infant's state and head position were judged appropriate. A second experimenter outside the chamber viewed the infant on a video monitor and made judgments on head turns. Both experimenters wore headphones and received a signal marking the observation interval on each trial, but did not hear stimuli delivered to the infant.

The test procedure employed a single-interval go/no–go paradigm in which signal and nonsignal trials occurred with equal probability. They were presented in random order with the constraint that no more than three trials of either type occur consecutively. Observation intervals were 4 sec in duration unless terminated by a response. Head turns to the right on signal trials were considered correct detections and were immediately reinforced by the 3-sec activation of an animated toy. Head turns on nonsignal trials were recorded as false alarms and were not reinforced.

Infants were randomly assigned to one of eight groups ($n = 8$ per group) and received both 10- and 100-msec tones at a single frequency and level of the masker. Order of duration conditions was counterbalanced across subjects within each group. Sessions began with a training phase in which the assigned test stimulus was first presented via the loudspeaker at a clearly audible level. After three consecutive correct turns to the right, headphones were applied, and training continued until a criterion of four additional consecutive turns had been met. During this phase, signal level was gradually reduced to within 10 dB of the initial level used in threshold tracking. Two consecutive head turns in response to signals 10 dB above starting level were required following within-session changes in stimulus duration.

Once training criteria had been met, an adaptive one-up, two-down tracking procedure was initiated, with signal level set 20 dB above comparable adult threshold for 4-kHz stimuli and 25–30 dB above adult threshold for .5-kHz stimuli. Step size began at 8 dB and decreased by half on subsequent up–down reversals until a minimum step of 2 dB had been reached. Only outcomes on signal trials contributed to alterations in signal level. After the first reversal, suprathreshold "probe" trials were presented every eighth trial to assess the infant's continued interest in the visual reinforcers. On these trials, the signal was set 10 dB above the current tracking level and the animated toy was activated at the end of the observation interval if the infant did not respond. Probe trials were also presented as "reminders" after two consecutive failures to turn on signal trials. Tracking was terminated after either five reversals or a maximum of 50 trials. Runs were also terminated if signal level exceeded a predetermined maximum, set at 10 dB above the starting level. Threshold estimates were computed only for those runs on which at least four reversals had been obtained. They were calculated as the mean signal level over the last three reversals and were therefore based on a minimum of four signal trials. Criteria for acceptance of threshold estimates were intended to minimize the contribution of nonsensory variables. Thresholds were considered acceptable if (1) false alarms occurred on no more than one third of the nonsignal trials, (2) the infant failed to respond on no more than two probe trials, and (3) the excursion of the adaptive track after the third reversal was less than 10 dB. Within a session, testing continued until one acceptable threshold estimate had been obtained for each of the two duration conditions or until the infant's state precluded further testing. Parents of infants successfully tested on only a single condition during the initial visit were asked to return for a second session. Twenty-nine percent of all threshold estimates computed did not meet the criteria for acceptance. Chi-square tests indicated that the incidence of rejected thresholds did not differ among experimental conditions. Of those infants excluded from the final sample due to loss of interest in the reinforcers, 8 provided acceptable thresholds for a single condition. With one exception, these were all within the range of threshold estimates obtained from infants completing the study.

Procedures for adult participants were intended to duplicate the infant test situation as closely as possible. Adults were provided with a response box and instructed to press a button whenever they heard the stimulus train. Observation intervals were unmarked, and intertrial intervals varied randomly from 1 to 15 sec to ensure that time of signal presentation was uncertain. Lights illuminating the visual reinforcers were briefly flashed as feedback for correct detections. Each adult listener received 10- and 100-msec tones at both .5 and 4 kHz at a single level of the masker. All other procedures were identical to those described for infants.

RESULTS

The mean number of trials required to estimate threshold was 34.4 for infants and 32.5 for adults, and did not differ significantly across age groups or stimulus conditions. Infants completing the study received an average of 2.4 probe trials per run. Analysis of responses on nonsignal trials indicated that false alarm rates were higher in infants than in adults [M = .18 *vs* .09; $F(1,112)$ = 47.58, $p < .001$]. For infants alone, false alarm rates were also significantly higher for 4-kHz than for .5-kHz tones [M = .20 vs .16; $F(1,56)$ = 5.08, $p < .05$], but did not differ among the remaining experimental conditions.[2]

Infant and adult masked thresholds for .5- and 4-kHz tones in four levels of masking noise are shown in Figure 1. Values plotted at points labeled "Q" are absolute thresholds previously reported in Berg (1991) and Berg and Boswell (1995), and were obtained using the same stimuli and experimental procedures. An initial test for equality of variances indicated that variances of infant and adult groups were not homogeneous. Significance of comparisons between age groups was therefore evaluated using the Brown-Forsythe statistic (Dixon, Brown, Engelman, & Jennrich, 1990), which compensates for the effect of unequal variances by reducing the degrees of freedom.

To verify the effectiveness of the masker, absolute and masked thresholds, collapsed across duration, were compared for both .5- and 4-kHz tones. These comparisons indicated that the masker produced a significant increase in thresholds for both stimuli. At the lowest masker level, infant thresholds were elevated approximately 7 dB above quiet threshold for .5-kHz tones [$F(1,14)$ = 12.24, $p < .01$] and 8–9 dB above quiet threshold for 4-kHz tones [$F(1,14)$ = 19.98, $p < .01$].

In general, masked thresholds were consistent with those previously reported in both infant and adult listeners. As spectrum level of the masker increased by 30 dB,

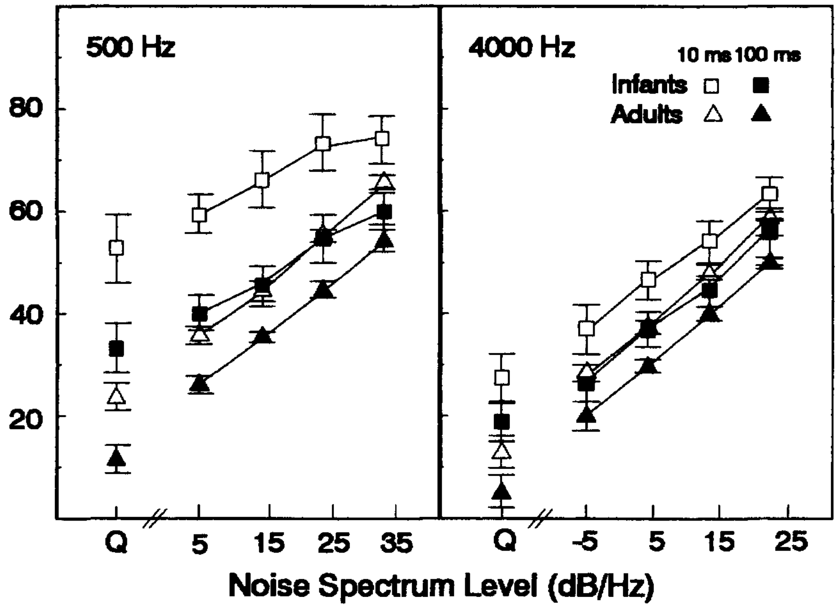

Figure 1. Mean infant and adult thresholds for .5- and 4-kHz tones presented in four levels of continuous masking noise. Tone durations were 10 and 100 msec. Values plotted at points labeled "Q" are absolute thresholds. Error bars represent ±1 *SD* from the mean.

increases in adult thresholds ranged from 28.4 dB for .5-kHz, 100-msec tones, to 30.7 dB for 4-kHz, 10-msec stimuli. Infant thresholds for 10- and 100-msec, 4-kHz tones also increased by a similar amount, but increases in thresholds for .5-kHz stimuli were considerably smaller. Differences between infant and adult thresholds for 4-kHz stimuli ranged from 5 to 9 dB across the various experimental conditions, in good agreement with age differences of 5–11 dB previously described for mid- and high-frequency tones (Bargones et al., 1995; Berg, 1991; Nozza, 1987; Nozza & Wilson, 1984). For .5-kHz, 100-msec tones, infant–adult differences in masked threshold ranged from 14 dB at a masker level of 5 dB/Hz to 6 dB at a masker level of 35 dB/Hz. These values are similar to infant–adult differences found by Schneider et al. (1989) for low-frequency octave-band noise, and by Nozza (1987) for .5-kHz tones at comparable levels of the masker. For .5-kHz, 10-msec tones, age differences decreased from 24 to 8 dB over the 30-dB range of masker levels employed. An analysis of variance confirmed that the slopes of infant and adult growth-of-masking functions were not reliably different for 4-kHz tones. For .5-kHz stimuli, infant functions were significantly more shallow than those of adults [age × level, $F(3,38) = 13.95, p < .001$]. A significant age × level × duration interaction [$F(3,38) = 6.13, p < .01$] indicated that infant functions were also more shallow for 10- than for 100-msec stimuli, whereas adult functions were not. As a consequence of these differences in slope, temporal summation of .5-kHz tones also varied with masker level in infant listeners: The difference between thresholds for 10- and 100-msec tones was significantly larger for infants than for adults when spectrum level of the masker was 5 dB/Hz [age × duration, $F(1,9) = 43.0, p < .001$], but not when masker spectrum level was 35 dB/Hz.

Figure 2 shows masked thresholds replotted as the ratio of signal energy to spectrum level of the masker (E/N_0). For adult listeners, signal-to-noise ratios remained constant across levels of the masker for both .5- and 4-kHz tones and were in good agreement with values reported in the adult literature for similar stimulus conditions (Wier, Green, Hafter, & Burkhardt, 1977). Infants required significantly larger signal-to-noise ratios than adults for detection of both .5-kHz tones [$F(1,38) = 391.58, p < .001$] and 4-kHz tones [$F(1,31) = 111.0, p < .001$]. Further analyses for infants alone confirmed that the relationship between criterion E/N_0 and masker level was different for the two frequencies [frequency × level, $F(3,56) = 6.19, p < .01$]. At 4 kHz, E/N_0 for infant listeners was generally invariant with level. Although mean signal-to-noise ratios decreased slightly as masker level increased from −5 to 25 dB/Hz, this trend was not statistically significant for either 10- or 100-msec stimuli. At .5 kHz, infants' signal-to-noise ratios at threshold decreased significantly across the four levels of the masker. This decrease was significant for 100-msec tones alone [level, $F(3,28) = 12.28, p < .001$], and was significantly greater for 10- than for 100-msec stimuli [level × duration, $F(3,28) = 4.81, p < .01$]. As a result of this improvement in performance, infant–adult differences in E/N_0 at the highest masker level were comparable for both .5- and 4-kHz stimuli: Infants' thresholds ranged from approximately 5 to 8 dB above those of adults, but there was no evidence of an age × frequency interaction.

In normal adult listeners, E/N_0 increases with signal frequency at a rate of approximately 2 dB/oct (Green,

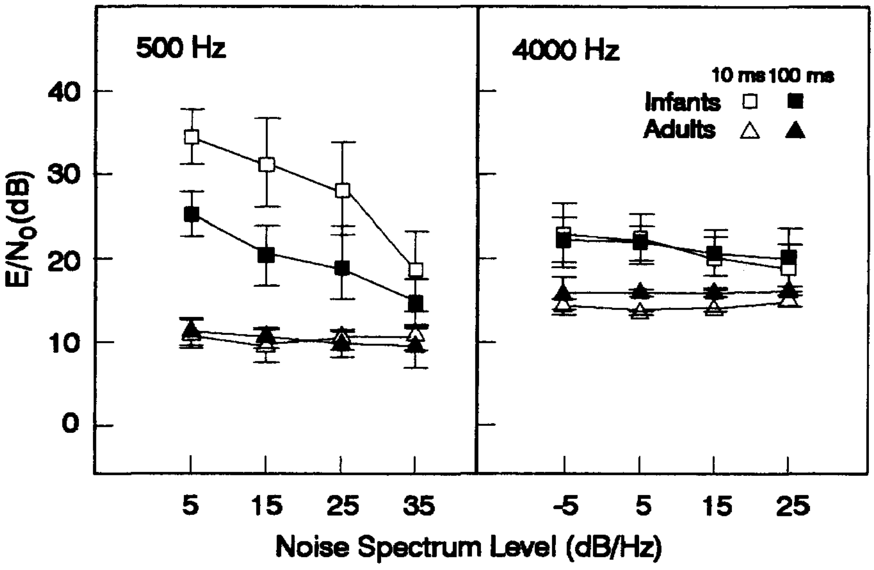

Figure 2. Mean infant and adult masked thresholds for .5- and 4-kHz tones presented in four levels of masking noise, expressed as the ratio of signal energy to spectrum level of the masker. Tone durations were 10 and 100 msec. Error bars represent ±1 *SD* from the mean.

McKey, & Licklider, 1959). This relationship has traditionally been explained in terms of critical band mechanisms and is believed to reflect the increase in bandwidth of the auditory filter at higher center frequencies. A comparison of thresholds for .5- and 4-kHz tones at the highest masker level indicated that the relationship between detectability and signal frequency was similar for the two age groups. For 100-msec stimuli, thresholds obtained for the two frequencies differed by 5.5 dB in adults and by 4.3 dB in infants, corresponding to slopes of 1.8 and 1.4 dB/oct. Comparable differences for 10-msec stimuli were smaller in both infants and adults, in agreement with recent evidence indicating that E/N_0 is nearly independent of frequency at short signal durations (Dai & Wright, 1996).

DISCUSSION

In adult listeners, the signal-to-noise ratio at masked threshold remains constant with increases in masker level over a wide range of stimulus conditions. Results of the present study suggest that this is not true early in development. In 7-month-old infants, the relationship between E/N_0 at masked threshold and level of the masker was dependent on both signal frequency and duration. Infants' performance was most adultlike for 4-kHz stimuli. Although mean thresholds for both 10- and 100-msec 4-kHz tones were approximately 7 dB higher in infants than in adults, E/N_0 at threshold remained essentially constant for maskers ranging from −5 to 25 dB/Hz in both age groups. By contrast, threshold signal-to-noise ratios for infants detecting .5-kHz tones were exceptionally large at lower levels of the masker and decreased significantly as masker level increased from 5 to 35 dB/Hz. Assuming that auditory filter bandwidths are comparable in 7-month-old infants and adults, these data are consistent with previous reports indicating that auditory processing efficiency is reduced in young listeners. They also suggest that, at least at low masker levels, the processing efficiency of 7-month-olds is significantly poorer for .5- than for 4-kHz tones. Thus, the frequency gradient described for infants' thresholds in quiet is also apparent when stimuli are presented in masking noise. The present results suggest that infants' masked thresholds for .5-kHz tones must be elevated 25–30 dB above absolute threshold before processing efficiency is comparable for the two signal frequencies.

Also notable is the effect of masker level on temporal summation of low-frequency tones during infancy. In agreement with previous work (Berg & Boswell, 1995), temporal summation of .5-kHz tones, measured as the difference between thresholds for 10- and 100-msec stimuli, was significantly greater for infants than for adults at low levels of the masker. However, because infants' thresholds improved more rapidly with level for 10- than for 100-msec tones, age differences in temporal summation were no longer significant when masker spectrum level was increased to 35 dB/Hz. The absence of an age difference for temporal summation of 4-kHz tones is also consistent with results reported previously. At 4 kHz, infants' temporal summation varies with stimulus bandwidth: It is adultlike for 4-kHz tones, but not for octave-band noise bursts centered at 4 kHz (Berg, 1991). However, the exceptionally steep slope of infants' temporal summation functions for 4-kHz noise bursts is significantly reduced when stimuli are presented in 10-dB/Hz masking noise (Berg, 1991). Thus, it appears that infants' immature temporal summation functions for both low- and high-frequency signals become adultlike in masking noise, but that higher levels of masking are required at low frequencies.

Several possible mechanisms have been advanced to account for age-related differences in masked thresholds. Nonauditory factors such as attention and motivation are widely recognized as variables that may contribute to differences in performance across age groups (Werner & Marean, 1996; Wightman & Allen, 1992). Although such variables undoubtedly play an important role in studies of auditory development, it is unlikely that nonsensory factors alone could account for the frequency-specific differences in threshold observed here. One possible alternative is suggested by the finding that processing efficiency also decreases at low frequencies in adult listeners (Moore, Peters, & Glasberg, 1990; Peters & Moore, 1992). Noting that the random fluctuations in a noise masker become slower and more prominent as its bandwidth becomes more narrow, Moore et al. (1990) proposed that this reduction in efficiency may be due to the narrowing of auditory filter bandwidths with decreasing center frequency. As a result, random fluctuations at the filter output may be more perceptible and thus interfere more with performance at low than at high frequencies. Data reported by Grose, Hall, and Gibbs (1993) indicate that 4- to 5-year-old children have particular difficulty detecting tones presented in narrowband, modulated masking noise. Thus, it seems possible that detrimental effects of fluctuations in filter output at low frequencies may be more marked in infants than adults, especially when durations are short and relatively few cycles of the signal are available.

Additional explanations proposed to account for age differences in masking have focused on possible immaturities in the coding of intensity. Schneider et al. (1989) considered two potential explanations: (1) that neural excitation grows more slowly with increasing intensity in infants and young children than in adults, and (2) that there is greater variability in the neural representation of intensity in young listeners. Although neural mechanisms involved in the coding of intensity are not well understood, it is generally agreed that variability in the stimulus representation limits the ability to detect changes in intensity, whereas the overall level of excitation is related to the perception of loudness (Plack & Carlyon, 1995). Zeng and Shannon (1994) have recently reported evidence suggesting that different neural mechanisms may be involved in the coding of loudness at low and high frequencies. On the basis of loudness judgments obtained from auditory implant patients, they concluded that the compression of auditory input evident in the loudness function is mediated primarily by mechanical processes in the cochlea for high frequencies and by neural mechanisms located in the cochlear nucleus for low-frequency stimuli. Thus, infant's poorer performance at .5 kHz may reflect a difference in the maturity of these two frequency-specific systems.

A second major result requiring explanation is the decrease in infants' criterion E/N_0 with increasing level of the masker at .5 kHz. One plausible hypothesis is based on the growth of loudness under partial masking: The loudness of a tone presented in masking noise is very low at masked threshold, but with further increases in level, its loudness grows more rapidly than the loudness of a tone in quiet (Scharf, 1978). Hall and Grose (1991) have argued that young listeners may require a greater level of loudness or excitation to detect the presence of a signal than do adults. As a result of this higher loudness criterion, their performance should be poorer under masking conditions in which loudness grows more slowly. They tested this hypothesis by comparing children's thresholds for tones in notched and unnotched maskers using two experimental paradigms. When subjects were tested using the standard fixed-masker-level paradigm, the difference in thresholds for adults and 4-year-olds was significantly larger for notched than for unnotched maskers, and the subsequent loudness judgments of adult listeners confirmed that the growth of loudness was more shallow in notched noise. However, when loudness growth was equalized across masking conditions by holding the level of the tone constant and varying the level of the masker, age differences in threshold as a function of notch width were no longer apparent. A number of studies have established that the loudness of a partially masked tone grows more rapidly the more intense the masking noise (Scharf, 1978; Stevens & Guirao, 1967). Thus, the improvement in infants' thresholds for .5-kHz tones in the present study may have resulted from a progressive steepening in the growth of loudness with increasing masker level. Presumably, threshold E/N_0 did not decrease with masker level for high-frequency tones because the loudness criterion is lower at 4 kHz in infant listeners.

Arguing against this explanation is our recent finding (Berg & Boswell, 1998) that a similar improvement in performance with increasing intensity is also seen for infants' detection of increments in low-frequency noise. In this paradigm, exaggerated loudness growth does not occur, at least in normally hearing adults. However, these results do not rule out the possibility that the growth of excitation steepens at higher intensities in young infants. It may be that the neural representation of low-frequency stimuli in the immature auditory system becomes more adultlike with increasing intensity level. To what extent this might involve an increase in the rate of growth of excitation or a decrease in variability remains unclear.

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NOTES

1. An exception to this generalization has recently been reported by Oxenham, Moore, and Vickers (1997), who found a nonlinear relationship between masker level and threshold of a 6.5-kHz tone for signal durations between 2 and 10 msec. No significant effect of masker level was found when the duration of the signal was 20 msec or longer.

2. The use of a tracking algorithm in which changes in level were based only upon outcomes on signal trials served to minimize the effect of false alarms on estimated threshold. Computer simulations indicated that, as false alarm rate increased from 0 to the maximum accepted rate of .33, estimated threshold decreased by approximately 2.5 dB. For the mean false alarm rate of .18 obtained for infant listeners in the present study, the decrease in computed threshold was less than 1.5 dB.

(Manuscript received April 28, 1997;
revision accepted for publication January 16, 1998.)