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Time Compression and Release from Masking in Adults and Children

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Abstract

We studied the effect of speech time compression (TC), alone and in the presence of competing babble, in 24 adults and 24 children. Both adults and children showed significant decreases in speech recognition when speech was compressed at a rate of 60 percent, as compared with recognition of normal-rate speech. Listening to time-compressed speech in a binaural homophasic mode resulted in better speech recognition than in a monaural mode for both adults and children. When speech was antiphasic, both adults and children demonstrated a release from masking for normal-rate (0% compression) and 60 percent time-compressed speech. When both groups listened to speech that had been compressed and presented in a babble, their performance supported a multiplicative distortion theory. The results support the importance of binaural hearing for optimizing auditory performance in difficult listening situations.

Key Words: Binaural hearing, central auditory nervous system (CANS), children, release from masking, speech recognition, time compression (TC)

Two potentially useful processes in diagnostic and rehabilitative audiology are masking level differences (MLDs) and time-compressed speech.

Masking Level Difference

The MLD is the improvement in threshold or speech recognition that occurs when speech or noise presented simultaneously and binaurally is shifted 180 degrees out of phase between ears. This heterophasic or antiphasic relation between the signal and noise underlies the occurrence of the MLD. It has been postulated that correlation processes within the central auditory nervous system are responsible for MLDs (Jeffress, 1972). This view is supported by anatomic and physiologic evidence (Cranford, Stramler, and Igarashi, 1978). The MLD has been measured in adults for low-frequency signals (Hirsh, 1948; Quaranta, Cassano, and Cervellera, 1978) and speech or complex signals (Licklider, 1948; Goldstein and Stephens, 1975; Bocca and Antonelli, 1976; Olsen and Noffsinger, 1976; Olsen, Noffsinger, and Carhart, 1976; Lynn, Gilroy, Taylor, and Leiser, 1981). In addition, several studies have measured MLDs in children (Sweetow and Reddel, 1978; Roush and Tait, 1984; Nozza, 1987; Nozza, Wagner, and Crandell, 1988; Hall and Grose, 1990).

Summarizing these studies with children, it appears that there is a developmental trend, with MLDs becoming larger until the child reaches age 5 or 6 years. At this age, the MLDs reach adult values, ranging between 8 and 15 dB, depending on the experimental paradigm.

Measurement of MLDs may have diagnostic use in adults with central auditory nervous system (CANS) dysfunction (Bocca and Antonelli, 1976; Olsen and Noffsinger, 1976; Olsen et al, 1976; Quaranta and Cervellera, 1977; Lynn et al, 1981; Hannley, Jerger, and Rivera, 1983) and in children with CANS dysfunction (Sweetow and Reddel, 1978 versus Roush and Tait, 1984).

None of these studies of children and CANS assessment measured the effects of release from masking on improvement in speech-recognition ability at a fixed signal presentation level in terms of percentage correct. Also, none of

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these studies tested a large pool of subjects within a restricted age range in order to assess maturational effects more accurately and to provide normative data with which to compare deviations in performance. Because MLDs are dependent on binaural interaction, and because real-world listening demands require binaural abilities for maximum auditory function (Durlach, Thompson, and Colburn, 1981), abnormally low MLDs for age may have implications for children with CANS dysfunction (Bornstein and Musiek, 1992).

Time Compression

Time-compressed speech assesses a listener's ability to code rapid speech that has had nonphonemic acoustic elements removed. It has been used primarily as a monaural task. Normative data on adults have been presented for this task (Beasley, Schwimmer, and Rintelmann, 1972; Grimes, Mueller, and Williams, 1984; Beattie, 1986). Although some normative data for children have been presented (Beasley and Freeman, 1977; Ferre and Wilber, 1986), more extensive data within a restricted age range are needed to examine developmental effects and to define abnormal performance more reliably. Studies have shown that time-compressed speech tasks may have diagnostic significance in adults and children (Kurdziel, Rintelmann, and Beasley, 1976; Manning, Johnston, and Beasley, 1977). Performance on time-compressed speech tasks may also have rehabilitation implications. It has been observed clinically and educationally that faster speaking rates often reduce listening efficiency in children and in aging or aphasic adults. Several studies support this observation (Albert and Baer, 1973; McCroskey and Thompson, 1973; Konkle, Beasley, and Bess, 1977).

Furthermore, in describing auditory behavior, it must be considered that acoustic redundancy in real-world listening situations is reduced, as compared with quiet, undistorted situations, and that processing of auditory information occurs in more than one dimension. There have been several published reports on the effects of multiple acoustic distortions in adults. (Lacroix, Harris, and Randolph, 1979; Hawkins and Yacullo, 1984; Bornstein and Randolph, 1985; Harris and Reitz, 1984; Irwin and McCauley, 1987; Loven and Collins, 1988; Helfer and Wilber, 1990), but few reports in children (Finitzo-Hieber and Tillman, 1978; Yacullo and Hawkins, 1987). Acoustic distortions are defined here as any alteration in the frequency, intensity, or temporal domain of a target speech signal or the target speech signal presented in some form of background competition. In the present study, the MLD task involves speech and a competing speech babble, both presented binaurally (i.e., homophasic condition). When the speech is shifted 180 degrees out of phase between ears (i.e., antiphasic or heterophasic condition), however, the effects of the distortion may be reduced, due to processing within the CANS. We have found no published reports directly comparing multiple-distortion effects between adults and children.

The purpose of the present investigation was twofold: (1) to determine whether there were differences between adults and children in MLDs for speech and time-compressed speech-recognition ability; and (2) to evaluate the multiplicative distortion effect of combining a time-compressed and MLD task in adults and children.

METHOD

Subjects

Twenty-four children and 24 adults served as subjects. The ages of the children ranged between 8 and 9 years, with a mean of 8.5 years; the ages of the adults ranged between 21 and 35 years, with a mean of 24.8 years. Both groups of adults and children were composed of 12 males and 12 females. Hearing sensitivity of all subjects was within normal limits (less than or equal to 10 dB HTL for the octave frequencies 250–4000 Hz, and 15 dB at 6000 Hz; ANSI, 1969). Middle ear pressure was more positive than –100 mm H_2O, and middle ear compliance was within the range of 0.25 to 1.6 cc. Speech reception thresholds (SRT) were less than or equal to 5 dB HTL for all subjects, using an ascending procedure in 5-dB steps (ASHA, 1979). Every subject had a negative otologic history, and no subject had symptoms of auditory dysfunction. All children were reported to be performing at grade level academically and had negative histories of psychological, psychoeducational, and speech-language difficulties.

Test Materials

Speech stimuli for adults were the Northwestern University Auditory Test Number 6 (NU-6) and for children the Word Intelligibility By Picture Identification (WIPI) lists 1–4. Lists were time-compressed at rates of 0 percent (i.e., unaltered) and 60 percent through a Varispeech II compressor. A competing signal consisting of a 12-speaker male and female babble (Kalikow, Stevens, and Elliot, 1977) was used with both NU-6 (Beasley et al, 1972) and WIPI word lists. Time-compressed versions of the Rintelmann NU-6 and Beasley WIPI recordings (Beasley, Maki, and Orchik, 1976) were played on a reel-to-reel recorder (Sony TC-377). The babble was played on a similar recorder. The intensity of the speech signal in each channel was adjusted and verified to be 6 dB greater than the babble (+6 dB S/N). Phase relations between the signals going to each channel were verified with a dual-beam oscilloscope (Tektronix 5410). This arrangement allowed for completion of all experimental conditions to be recorded on tape, which were then presented through a Grason/Stadler 1701 audiometer to all subjects through TDH-39 earphones. For all conditions and subjects, the speech presentation level was 50 dB SPL. There were ten conditions:

1. right ear 0 percent time compression (TC) in quiet;
2. left ear 0 percent TC in quiet;
3. right ear 60 percent TC in quiet;
4. left ear 60 percent TC in quiet;
5. binaural 0 percent TC in quiet;
6. binaural 60 percent TC in quiet;
7. binaural: babble in phase, speech in phase (N_0S_0), 0 percent TC;
8 binaural; babble in phase, speech 180 degrees out of phase (N_0S_π), 0 percent TC;
9. N_0S_0, 60 percent TC;
10. N_0S_π, 60 percent TC.

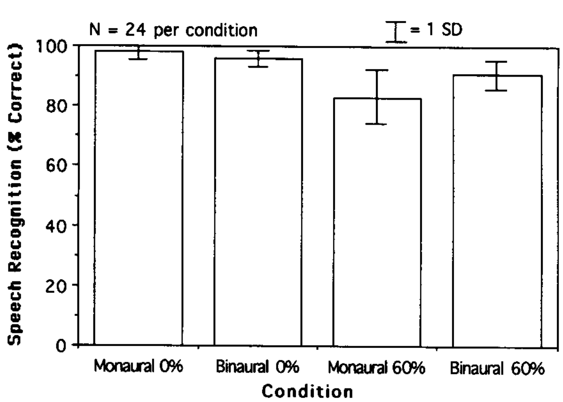

Figure 1 Mean speech-recognition scores and standard deviations for adults for four experimental conditions in quiet (0%:0% TC; 60%:60% TC).

Procedure

Testing was done in a sound-treated, double-walled IAC booth. Written responses were scored for adults. Pointing responses were scored for children. All word lists and experimental conditions were counterbalanced across subjects in this repeated-measures design. Subjects were given 15 practice items before testing in time-compressed and speech-in-babble conditions. Testing was generally completed in two sessions, each lasting approximately 40 minutes. Sessions were separated by at least 1 day and no longer than 2 weeks for all subjects. An effort was made to ensure that subjects were relaxed and alert during all phases of testing. Subjects were given a 5-minute break halfway through each session and were encouraged to report any fatigue or auditory symptoms.

RESULTS

A. Adults: Time Compression and Monaural/Binaural Listening

Speech-recognition scores for adults were expressed in percentage correct to examine the effects of time compression as a function of both monaural and binaural hearing in quiet. We first compared performance between right and left ears. A correlated t-test showed no significant difference between right and left ears for both time-compressed and normal-rate speech ($p > .05$), so the data were collapsed to comprise monaural conditions (Fig. 1). An analysis of variance performed for the four different listening conditions (monaural, 0% TC; monaural, 60% TC; binaural, 0% TC; binaural, 60% TC) showed significant differences ($F = 39.7$; $df = 5, 138$; $p < .0001$). Figure 1 shows speech-recognition scores as a function of the four experimental conditions. Comparisons between conditions were done with Fisher's protected t-test for correlated measures (Cohen and Cohen, 1975). It can be seen that there is no difference between monaural and binaural listening for normal-rate speech ($p > .05$). There was, however, a significant (8%) improvement for binaurally presented time-compressed speech ($t = 6.6$; $df = 23$; $p < .0001$). In addition, although the difference between time-compressed and normal-rate speech was significant for both monaural ($t = 7.9$; $df = 23$; $p < .0001$) and binaural ($t = 7.2$; $df = 23$; $p < .0001$) conditions, there was only a 5 percent decrease binaurally, but a 12 percent decrease monaurally.

B. Adults: Time Compression and Babble

We next examined the effects of adding the babble binaurally as a competing signal with speech that was also presented binaurally, either in phase or out of phase, between ears. This was done for normal-rate and time-compressed speech. Figure 2 shows speech-recognition scores as a function of the four experimental conditions for adults (N_0S_0, 0%; N_0S_π, 0%; N_0S_0, 60%; N_0S_π, 60%). By comparing Figures 1 and 2, it is apparent that adding the babble to create a +6 dB S/N ratio significantly reduced speech recognition, regardless of the rate of time compression or the phase relationship of the signal between ears. An analysis of variance for the four different listening conditions showed significant differences ($F = 115$; df = 3, 92; $p < .0001$). Again, comparisons between conditions were accomplished through the use of Fisher's protected t-test for correlated measures. As with the quiet conditions, there was a significant decrease in speech recognition when the speech was time-compressed by 60 percent. This occurred with both N_0S_0 ($t = 23.9$; df = 23; $p < .0001$) and N_0S_π ($t = 16.4$; df = 23; $p < .0001$) babble conditions. Furthermore, there was a significant increase in speech-recognition scores for the N_0S_π condition as compared with the N_0S_0 condition for both normal-rate ($t = 11.3$; df = 23; $p < .0001$) and 60 percent time-compressed speech ($t = 20.3$; df = 23; $p < .0001$). For adults, however, the mean increase of 20 percent in speech recognition for the time-compressed condition was significantly better than the 15 percent increase in speech recognition for the normal-rate condition ($t = 3.2$; df = 23; $p < .0001$). Thus, in the N_0S_0 condition, recognition scores decreased by 28 percent, going from 0 percent to 60 percent time compression, but in the N_0S_π condition the scores decreased by a slightly lower amount of 23 percent.

C. Children: Time Compression and Monaural/Binaural Listening

Speech-recognition scores for children were also expressed in percentage correct, in order to examine the effects of time compression as a function of both monaural and binaural hearing in quiet. Similar statistical analyses were done for both children and adults. We first compared performance between right and left ears. As with adults, a correlated t-test showed no significant difference between right and left ears for both normal-rate and time-compressed speech ($p > .05$). The data, therefore, were collapsed to comprise monaural conditions. The analysis of variance for the four quiet listening conditions (monaural, 0% TC; monaural, 60% TC; binaural, 0% TC; binaural, 60% TC) was significant ($F = 65.8$; df = 5, 138; $p < .0001$). Figure 3 shows speech-recognition scores in children as a function of listening condition. Individual t-tests showed that monaural/binaural differences were present only in the time-compressed condition ($t = 6.8$; df = 23; $p < .0001$), which was the same pattern found with adults. Decreases in speech-recognition scores when speech was compressed were also significant monaurally ($t = 10.4$; df = 23; $p < .0001$) and binaurally ($t = 8.0$; df = 23; $p < .0001$). The binaural decrease (10%) was smaller than the monaural decrease (18%), which was also true for the adult group.

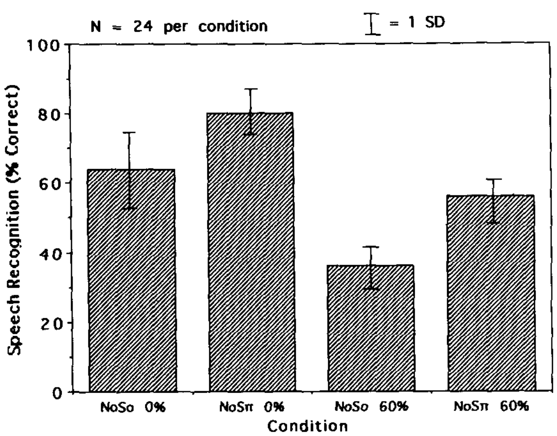

Figure 2 Mean speech-recognition scores and standard deviations for adults for four experimental conditions listening in noise.

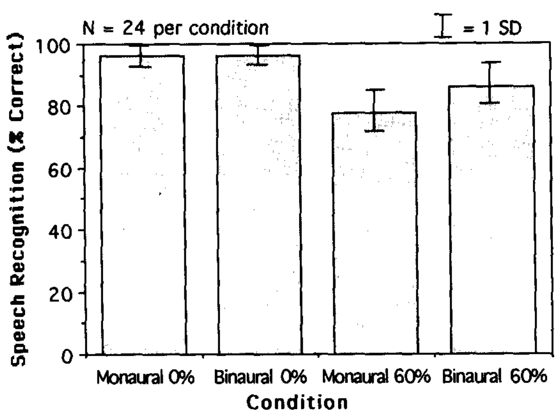

Figure 3 Mean speech-recognition scores and standard deviations for children for four experimental conditions listening in quiet (0%:0% TC; 60%:60% TC).

D. Children: Time Compression and Babble

As with the adult group, we examined the effects of adding the babble binaurally as a competing signal, with the speech also presented binaurally either in or out of phase between ears. This was done for time-compressed and normal-rate speech. Similar statistical analyses were done for these data as were done for the data from the adult group. Figure 4 shows speech-recognition scores as a function of the four experimental conditions for children (N_0S_0, 0%; N_0S_π, 0%; N_0S_0, 60%; N_0S_π, 60%). It is clear from comparing Figures 3 and 4 that, as with adults, adding a babble to produce a +6 dB S/N ratio interfered significantly with speech recognition for all conditions. An analysis of variance for the four different listening conditions was significant ($F = 173.4$; df = 3, 92; $p < .0001$). It is also apparent that regardless of whether the speech was in phase or out of phase at each ear, time compression caused speech recognition to decrease by 34 percent (for N_0S_0, $t = 27.5$; df = 23; $p < .01$; for N_0S_π, $t = 24.8$; df = 23; $p < .0001$). Also, for both time-compressed and normal-rate speech, shifting the speech out of phase resulted in a significant 12 percent increase in speech recognition (i.e., the MLD measured in percentage correct improvement) (for 0% TC, $t = 13.8$; df = 23; $p < .0001$; for 60% TC, $t = 11.4$; df = 23; $p < .0001$).

E. Comparison of Effects in Adults and Children

Absolute scores between adults and children cannot be directly compared, because different word lists and response modes were used. Although use of the same speech-recognition task for both groups would be ideal, it is known that a speech-recognition task must be within the vocabulary of children, uncontaminated by the examiner's interpretation of their responses. The differential effects of conditions, however, are probably less biased by the different word lists and response modes and hence were examined. To ignore these differential effects, despite the limitations, would be an oversight and would prevent addressing what appears to be an interesting phenomenon.

The differential effects of conditions are shown in Table 1. Adding time compression in quiet had a greater effect on performance in children. Monaurally, the children's performance decreased from 96 percent to 78 percent (18%), whereas the adults' performance decreased from 95 percent to 83 percent (12%). Binaurally, the children's performance decreased from 96 percent to 86 percent (10%), while the adults' performance decreased from 96 percent to 91 percent (5%). In adults listening binaurally, performance is almost the same for time-compressed and normal-rate speech, while for children this is not true. Figure 5 shows a comparison of release from masking in adults and children for time-compressed and normal-rate speech. Release from masking is defined here as the increase in speech-recognition scores when the speech signal is shifted out of phase between ears. Adults did not appear to show a greater release from masking than children for normal-rate speech (15% versus 12%). There was, however, a greater release from masking for time-compressed speech (20% versus 12%).

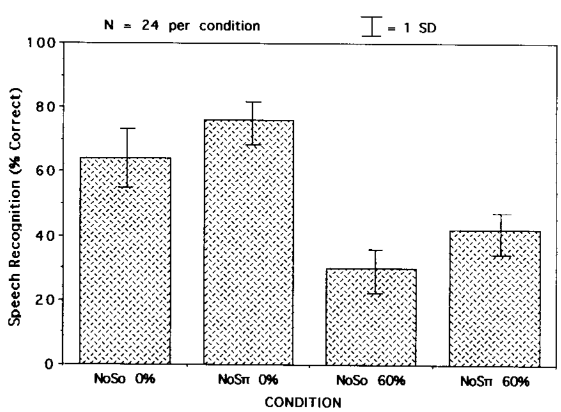

Figure 4 Mean speech-recognition scores and standard deviations for children for four experimental conditions listening in noise.

DISCUSSION

Time Compression and Monaural/Binaural Listening

The results of this investigation suggest that under ideal conditions, a binaural advan-

Table 1 Mean Differences between Experimental Conditions for Adults and Children

	Monaural 0–60%	Binaural 0–60%	N_0S_π-N_0S_0 0% TC	N_0S_π-N_0S_0 60% TC
Adults	12%	5%	15%	20%
Children	18%	10%	12%	12%

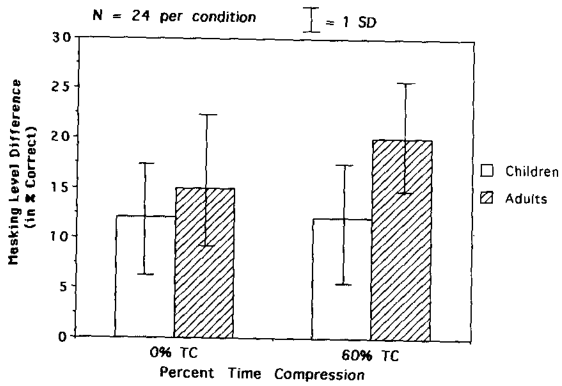

Figure 5 Release from masking measured as percentage in speech-recognition improvement as a function of time compression in children and adults for 0% TC and 60% TC.

tage may not be apparent in either children or adults. When a listening situation becomes more difficult, however, as when listening to "fast" speech, integration of information from two ears significantly improves speech perception. The improvement in binaural listening was 8 percent for both groups, demonstrating that by the age of 8 or 9 years, children have the ability to use binaural information in a way similar to adults. This improvement may be thought of as a diotic advantage, since the same signal is presented to each ear. Several authors have noted the relationship between the redundancy of auditory-neural pathways and speech (Calearo and Lazzaroni, 1957; Jerger, 1973; Beasley and Freeman, 1977). When speech is time-compressed, the redundancy of speech acoustics is reduced, because frequency, temporal, and intensity cues are all reduced. It becomes, therefore, more important for the auditory-neural system to preserve the coding in the remaining information as accurately as possible. It is reasonable to assume that by providing the same cues to an additional ear, there is a greater probability that the remaining speech cues will be coded more accurately, essentially by increasing another form of redundancy. One ear may not accurately code the cues, due to the stress of the rapidity of the signal. The other ear, however, may code the signal in a slightly different way, such that complementary information is provided. Alternatively, it may be that CANS processes use similar information coming from each ear to cross-correlate and resolve ambiguities that are present in rapid speech.

Children were more adversely affected by time-compressed speech than adults for both monaural and binaural conditions. This may be because cortical mechanisms in children 8 to 9 years old may not be as developed as in adults, as has been shown for late cortical evoked potentials (Musiek and Gollegly, 1988), and that coding time-compressed speech is partially dependent on these mechanisms. On a behavioral level, greater difficulty with time-compressed speech may reflect "auditory closure" abilities that are not as developed in children as in adults. A maturational trend on neuroauditory tests has been shown in children with learning disabilities (Musiek, Gollegly, and Baran, 1984, 1985) and is consistent with the course of language development until 11 or 12 years of age (Chomsky, 1967) and the myelination of auditory pathways that occurs between 11 and 14 years of age (Yakovlev and LeCours, 1967).

The amount of reduction in speech recognition for 60 percent time-compressed speech reported here is somewhat greater than that reported elsewhere (Grimes et al, 1984). This difference may be related to several experimental parameters, such as presentation level, stimulus material, and monaural versus binaural listening.

Time Compression and Masking Level Differences

Both adults and children showed a significant release from masking when listening to normal-rate and time-compressed speech. This may be thought of as a dichotic advantage, in that a different signal is presented to each ear. However, whereas adults showed an average release of 20 percent in speech-recognition scores for time-compressed speech, performance in children improved only by 12 percent. For normal-rate speech, significant differences in the release from masking between adults and children were not found. These results suggest that although binaural integration mechanisms are present in children between 8 and 9 years of age, they are not as developed as in adults, at least for some forms of speech. These results also agree with those of Sweetow and Reddell (1978), Roush and Tait (1984), and Hall and Grose (1990). Summarizing these investigations, MLDs did not change significantly between the ages of 6 and 12 years and were similar to those of adults. The results of the present investigation, however, provide a different perspective when one considers the use of time-compressed speech. One must question, therefore, the interpretation made by previous investigators that the same mechanisms present in 8- and 9-year-old children are the same as those in adults.

The use of time compression is most likely the main factor that accounts for the differences found between adults and children that were not found in other studies of MLDs. Other factors must be considered, however, such as the measurement tool used to quantify MLDs. Most other investigations used a threshold search under conditions of noise both in phase and out of phase. The procedure used in the present investigation measured speech-recognition performance at a fixed presentation level and signal-to-noise ratio, which may have resulted in a higher sensitivity to detecting differences in signal phase between ears. A second possibility for differences may be the competing stimulus used. The present investigation used a 12-speaker babble, whereas other investigations used noise. The ability to suppress speech-like competition is probably dependent upon more complex auditory-neural processes than the ability to suppress broad or narrow-band noise (Treisman, 1964), and these processes may not be as well developed in 8- to 9-year-old children.

Applying this concept to the target signal, Roush and Tait (1984) and Hall and Grose (1990) used low-frequency signals as targets, whereas the present study used speech. It is known that processing of speech at rostral levels is different from "elemental" stimuli (Musiek and Baran, 1987). This explanation would be consistent with the theory that MLDs probably involve low brainstem as well as higher binaural interactions. Myelination of auditory pathways is developed by 11 to 14 years of age, with low brainstem structures maturing earlier (Yakovlev and LeCours, 1967), and thus myelination alone cannot explain the differences found in this investigation. Unknown anatomic or physiologic differences in low brainstem structures, however, may also play a role. Pathologic changes in the CANS, primarily in low brainstem structures, have been found to reduce MLDs for normal-rate speech in adults (Lynn et al, 1981). Pathology of higher centers in adults, however, has also been shown to reduce MLDs for normal-rate speech (Quaranta and Cervellera, 1974; Bocca and Antonelli, 1976; Quaranta et al, 1978; Lynn et al, 1981), suggesting that differences in development of higher CANS structures between adults and children 8 to 9 years of age may also account for the differences found in the present investigation (Musiek and Baran, 1987).

The observation that the difference between adults and children in the magnitude of the MLD occurred with time-compressed speech and not normal-rate speech suggests that to identify subtle maturational differences, the redundancy of speech must be decreased, as several authors have noted (Calearo and Lazzaroni, 1957; Jerger, 1973; Beasley and Freeman, 1977). When this is done, both diotic and dichotic advantages may be seen. It also suggests that for cortical mechanisms or "auditory closure" to code time-compressed speech with maximum efficiency, they must be enhanced by more sophisticated processing at lower auditory levels.

Multiplicative Effects

This investigation identified other differences between adults and children. For example, the deleterious effect of time compression was greater in a babble than in quiet and was more pronounced in children than in adults (Figs. 3, 4). In the N_0S_0 babble condition, time compression resulted in a 28 percent performance decrease in adults and a 34 percent decrease in children. In the N_0S_π babble condition, the performance decrement was 24 percent for adults and 34 percent for children. When two acoustic distortions are present, their combined effect will be greater than predicted by simply adding their individual effects. This is the "multiplicative" effect that was described in detail by Harris (1960) and by Lacroix et al (1979). Figure 6 shows a comparison of an additive and a multiplicative effect for adults and children. In the present investigation, the two distortions were time compression and a competing speech babble. It is plausible that multiple distortions may interact with reduced neural redundancy when there is pathology affecting the auditory system. Hence, a test using multiple distortions may be a more sensitive diagnostic indicator of CANS dysfunction and may have greater validity for real-world listening demands.

Figure 6 shows that children demonstrated a greater multiplicative effect than adults when the speech was either in phase or out of phase. The right side of Figure 6 shows that the multiplicative effect was reduced by providing a phase difference between ears for the speech. This multiplicative effect, however, was reduced more in adults than in children, who did not have as great a release from masking. This may help explain the listening differences fre-

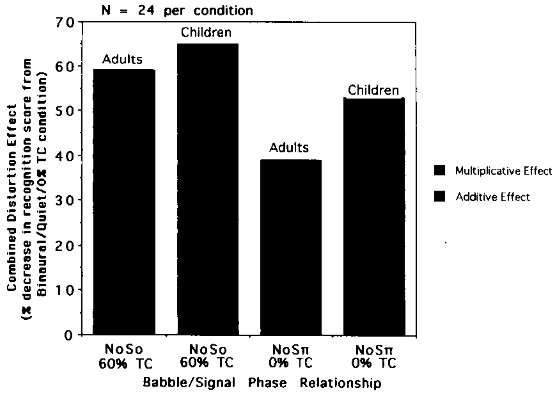

Figure 6 The multiplicative effect: mean decrease in speech-recognition scores for the babble conditions (either N_0S_0 or N_0S_π) from speech-recognition scores for normal-rate speech presented binaurally in quiet for adults and children, measured in percent.

quently noted between elementary school-aged children and adults. It appears that children may not have the sophisticated mechanisms necessary to handle the multiple distortions that are present in a classroom setting.

The relationship between maturation and auditory behavior has been shown by Musiek and Gollegly (1988). They noted that the underlying mechanisms of the CANS are probably governed by myelination, dendritic branching, and synaptogenesis, maturational processes that are not complete in children 8 or 9 years old (Conel, 1963; Yakovlev and LeCours, 1967). This may be related to the frequent observation that in classrooms with less than ideal acoustics, children appear to have more listening difficulties than adults believe they should. Multiplicative distortion effects, such as reverberation in the classroom, various forms of background noise and competition, loss of higher speech frequencies when a teacher is facing a blackboard, and fast rates of speaking may contribute to children's listening difficulties. These effects reduce or smear the important temporal cues of speech (Bornstein and Musiek, 1984) and may be related to temporal ordering problems. Children have not realized their full auditory closure or language abilities and, therefore, cannot handle these multiplicative distortions as well as adults.

SUMMARY

Both adults and children demonstrated reduced speech-recognition scores when listening to 60 percent time-compressed speech, as compared with normal-rate speech, in quiet and in noise. Performance, however, was more negatively affected in children than in adults. In addition, a binaural advantage was demonstrated for both adults and children listening to time-compressed speech in quiet. This advantage was not present when speech was presented at a normal rate. Adults and children both demonstrated a release from masking, with adults showing a greater release from masking than children for time-compressed speech. Binaural processing also appeared to reduce multiplicative distortion effects and to be present by 8 or 9 years of age. Binaural processing, however, was not as established as in adults. These results support the usefulness of binaural hearing, particularly when listening to real-world acoustic events, and, as such, support the general principle of binaural amplification. In addition, release from masking and the ability to comprehend time-compressed speech appear to be dependent on adequate temporal processing. Since speech perception is dependent on temporal cues, these tasks may be sensitive and useful in assessing children with central auditory processing difficulties.

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