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Central Auditory Processing in an Adult with Congenital Absence of Left Temporal Lobe

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Abstract

A young adult subject with congenital absence of the left temporal lobe received extensive behavioral and electrophysiologic tests to identify deficits in central auditory processing. Tests included the dichotic digits, staggered spondaic words (SSW), synthetic sentence identification with ipsilateral (SSI-ICM) and contralateral (SSI-CCM) competing messages, pitch pattern, and duration pattern measures. Additional special tests included the precedence effect in sound localization, measurement of frequency difference limens for short (5 msec) and long (200 msec) duration tones, and the P300 event-related potential. The subject's performance on all measures was well within normal limits. These findings provide important new evidence that reinforces the belief of neuroscientists that the developing nervous system exhibits a remarkable degree of functional plasticity.

Key Words: Central auditory processing, congenital absence, dichotic listening, neural plasticity, P300 event-related potentials, temporal lobe

Considerable basic and clinical evidence has accumulated with both human and nonhuman animal species that documents the remarkable functional plasticity of the developing nervous system (Cotman, 1985; Bishop, 1982). Although the human brain appears to have less capacity for functional recovery or compensation following neural injury than is found with many lower species, in recent years, there has been growing evidence that this capacity may be far greater than previously believed (Marshall, 1985; Bach-Y-Rita, 1990; Timiras et al, 1991; Varon et al, 1991). This has encouraged researchers to begin investigating possible clinical means of assisting or facilitating recovery or compensation processes in the brain. In recent years, a wave of excitement has been triggered among audiologists and hearing scientists by discoveries (Girod and Rubel, 1991; Rubel et al, 1991; Forge et al, 1993; Lefebvre et al, 1993; Lambert, 1994; Robertson and Rubel, 1994) that suggest it might eventually be possible to stimulate the regrowth of cochlear hair cells in man.

While considerable evidence suggests that neural lesions in children may produce fewer or less severe behavioral deficits than is typically found in adults, newer research continues to question the extent to which the immature nervous system is resistant to the deleterious effects of all early insults. Jerger and Zeller (1989), for example, recently reported that childhood lesions may produce deficits in certain dichotic listening tasks that are similar to those found with adult lesion subjects. The present case report describes findings with a young adult male who apparently developed a subarachnoid cyst in early infancy. This resulted in the development of a brain that had much of the left hemisphere, including the temporal lobe, replaced by a large sac filled with cerebrospinal fluid. The present report describes the results of an extensive central auditory test battery performed with this subject, which suggest that this replacement may have been anatomical rather than functional in nature. Before describing these test findings, a brief overview will be presented of the effects that unilateral temporal lobe lesions have been reported to produce when such insults occur in the adult.

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Effects of Auditory Cortex Lesions on Central Auditory Processing

Unilateral lesions of the adult temporal lobe have been reported to impair a wide variety of hearing, language, learning, and memory functions, depending on various factors, including which hemisphere (dominant or nondominant) was involved, as well as the medial extent of the lesion (whether limbic structures such as the hippocampus, amygdala, etc. were damaged). With respect to nonlanguage auditory functions, which is the focus of the present report, perhaps the most well-documented effect of temporal lobe lesions involves various measures of binaural listening. Earlier studies (Sanchez-Longo et al, 1957; Sanchez-Longo and Forster, 1958) demonstrated that simpler forms of sound localization, involving unitary sound sources, were impaired by temporal lobe lesions. In recent years, a more complex form of sound localization task, involving tracking and localization of fused auditory images, has been found to possibly be even more sensitive to temporal lobe damage (Moore et al, 1990). Other clinical measures of binaural processing that have been found to effectively identify temporal lobe dysfunction include the staggered spondaic word (SSW) test (Katz, 1962; Katz et al, 1963; Katz and Pack, 1975; Cranford et al, 1982), the competing sentence test (Lynn and Gilroy, 1972; Williford, 1977; Cranford et al, 1982; Musiek, 1983b), dichotic digits (Musiek, 1983a), dichotic CVs (Berlin et al, 1972, 1975), and the synthetic sentence identification test (SSI) presented in the presence of a contralateral competing message (Jerger and Jerger, 1974, 1975).

Various other test measures have also revealed temporal lobe deficits. Musiek and his colleagues reported evidence that temporal lobe damage impairs the subject's ability to identify the pattern of a triad of consecutive tone pulses when the tones differ with respect to either frequency (Pinheiro, 1976; Musiek and Pinheiro, 1987) or the temporal duration (Musiek et al, 1990) of individual pulses. In an earlier study, Cranford et al (1982) reported that temporal lobe lesions may impair the discrimination of short duration sounds. For ears located contralateral to unilateral temporal lobe lesions, subjects exhibited abnormally elevated frequency difference limens (DLFs) for tone pulses (1000 Hz) that were shorter than approximately 50 msec. The perception of longer duration tones was not impaired. For ears located ipsilateral to the damaged hemisphere, DLFs were normal at all tonal durations.

METHOD

Subject

The subject of this study is a 32-year-old Caucasian male who, in 1983, experienced a grand mal seizure while working as a nuclear reactor operator on board an aircraft carrier. A computed tomography (CT) scan revealed a large subarachnoid cyst occupying most of the left temporal and parietal lobes. The lesion measured approximately 11 cm in length and approximately 6 cm in width and, according to the neuroradiologist, "occupies primarily the location of the distribution of the left middle cerebral artery." This artery provides the major vascular supply to the auditory receptive and association areas of the suprasylvian and posterior temporal lobe regions. The patient has been followed by a neurologist at 6-month intervals, with subsequent CT scans indicating no change. Figure 1 shows findings from a recent magnetic resonance imaging (MRI) scan performed for the present study. The subject is on Dilantin to control seizures and amitriptyline to counteract headaches and drowsiness caused by the Dilantin. The subject has been seizure free since 1986, has no gross or fine motor dysfunction, and is employed as a biomedical technician.

Auditory Test Battery

The battery of tests administered included basic audiometric tests, as well as a series of tests for central auditory processing that have been relatively well documented clinically in terms of expected findings with temporal lobe lesion subjects. Additionally, three new experimental tests (brief tone, precedence effect, and P300), which have been evaluated less extensively with such patients, were administered.

1. Audiometric evaluation. This battery included measurement of pure-tone air- and bone-conduction thresholds from 250 to 8000 Hz (ASHA, 1978) and immittance testing. The audiometric and all subsequent behavioral tests were performed with the subject seated in a sound-treated room (Acoustic Systems). Tape recorded or digitally generated (brief tones) signals were passed through the speech circuit of a Grason Stadler 1710 audiometer to TDH-49 headphones.
2. Dichotic digits. The dichotic digits test was administered using Musiek's (1983a) published protocol. The test is composed of recordings of naturally spoken digits from

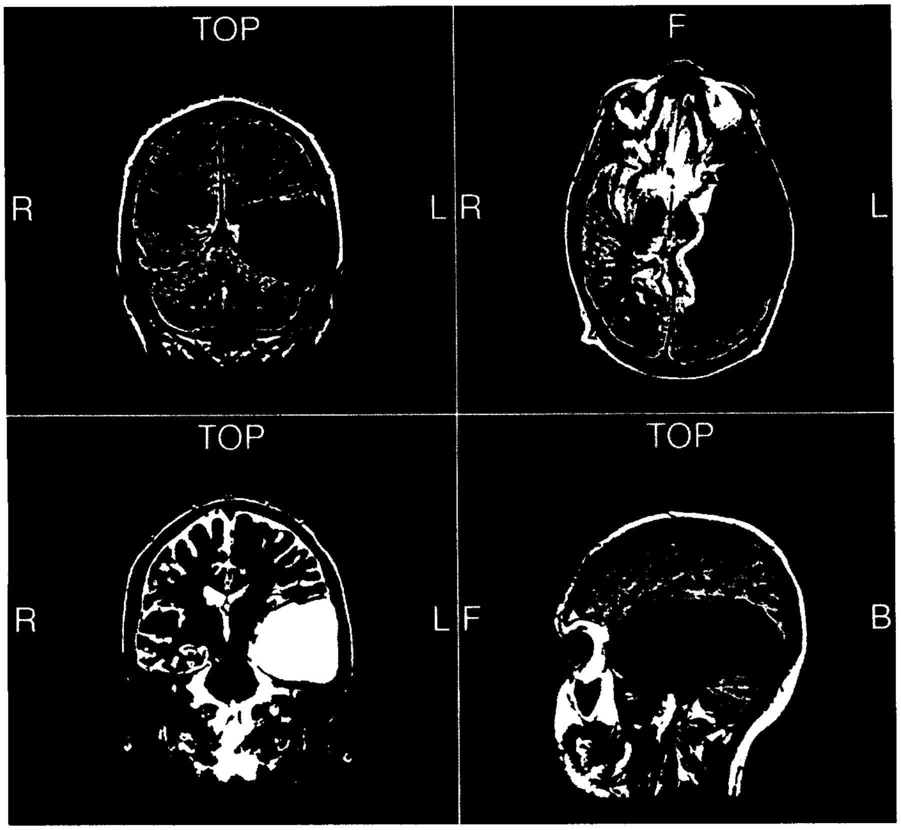

Figure 1 Magnetic resonance imaging (MRI) study showing location and extent of left hemisphere lesion in present research subject.

1 to 10, excluding the number 7. The early portion of the tape contains six practice items for each ear to familiarize subjects with the task requirements. The test consists of the presentation of 20 digit pairs for a total of 40 test items for each ear. The subject was asked to repeat all of the digits he heard and to guess if unsure of a response. Digits were presented dichotically at 50 dB SL (re: SRT). A percent correct response score was determined for each ear.

3. Pitch pattern and duration pattern. Using Auditec tapes, the pitch pattern test was presented according to the protocol of Musiek and Pinheiro (1987). The high pitch tones were 100 Hz, while the low tones were 600 Hz. Tone pulses were 150 msec in duration with 1000-msec interpulse intervals. Following a brief training/practice session, a 60 trial test session was given in which triads of tones were presented. Tones were presented at 50 dB SL (re: SRT). Each ear was tested separately. The subject's task was to verbally indicate the pattern of the pitch sequence (e.g., "high-low-high," "low-low-high," etc.). The duration pattern test was very similar (Musiek et al, 1990), except that the subject was required to discriminate a triad of 1000-Hz tones that differed with respect to the duration of individual components. The long tones were 500 msec in length while the short tones were 250 msec. The interpulse interval was 300 msec.
4. Synthetic sentence identification (SSI) with ipsilateral (ICM) and contralateral (CCM) competing message. Auditec-recorded SSI sentences were presented in a closed-set format. Each of 10 sentences appeared on a numbered, printed list. After each sentence had been presented, the subject reported the number of the sentence he believed was presented. The SSI score was based on the presentation of 10 sentences. SSI lists were the third-order sentences developed by Speaks and Jerger (1965). The sentences were presented at a level of 40 dB SL (re: SRT). For the SSI-ICM test, a competing signal of continuous speech discourse was presented at successive message-to-competition ratios (MCR) of +10, 0, –10, and –20. For the

SSI-CCM test, the speech was presented at MCRs of 0, –20, and –40.

5. Staggered spondaic words. The SSW test (list EC) was administered at 50 dB SL (re: SRT) according to the published guidelines of Katz (1962). In addition to the traditional scoring procedures, SSW performance was calculated as a percent correct score for right and left ear competing conditions.
6. Precedence effect in sound localization. Using procedures described by Moore et al (1990), the subject was required to track (using a laser pointer) the "movement" of fused auditory images (FAIs) on a semicircular screen. The moving FAI was simulated by varying the delay times incrementally between pairs of clicks presented from loudspeakers placed 45° to the left and right of the subject's head.
7. Brief tone discrimination. Frequency difference limens (DLFs) were measured for digitally generated 5- and 200-msec duration tones at the subject's left and right ears. An adaptive procedure, parameter estimation by sequential testing (PEST), was used in combination with a two-alternative forced-choice paradigm to measure DLFs. The subject was required to detect frequency increments relative to 1000-Hz standard tones. Tones were presented at 50 dB SL.
8. P300 event-related potential. Using a standard oddball paradigm (Squires and Hecox, 1983), P300 responses were recorded from C_z and F_z referenced to linked mastoids, with F_{pz} as common. Supraorbital electrodes were used to control for eye movement artifacts. The subject was required to count the number of occurrences of infrequent tones (2000-Hz tones, 40-msec duration) randomly interspersed among frequent tones (1000 Hz). The probability ratio of the frequent and rare tones was 80:20. Tones were presented at 70 dB nHL. Two repeated test runs were obtained in response to monaural stimulation at each ear. Other aspects of the stimulus and response acquisition procedures can be found in Cranford and Martin (1991).

Table 1 Audiometric Pure-Tone Thresholds (dB HL)

	Frequency (Hz)							
	250	*500*	*1000*	*2000*	*3000*	*4000*	*6000*	*8000*
Right	5	5	5	5	10	60	50	55
Left	10	5	5	10	10	70	60	89

Table 2 Dichotic Digits, Pitch Pattern, and Duration Pattern Test Results (%)

	Right Ear	*Left Ear*	*Normal Range*
Digits	97.5	97.5	80–100
Pitch	100	100	68–100
Duration	95	95	68–100

RESULTS AND DISCUSSION

The present subject's performance on all test measures met or exceeded expected levels of normalcy for his age and hearing status. Table 1 summarizes the subject's audiometric findings. The only abnormal finding was a sensorineural hearing loss at 4000, 6000, and 8000 Hz, which was moderate for the right ear, and moderate-to-severe for the left ear. Immitance testing revealed normal middle ear pressure and compliance bilaterally (peaks between ± 50 daPa).

Table 2 also shows that the subject's performance on the dichotic digits, pitch pattern, and duration pattern tests exceeded expected normal levels at both ears. With the SSW test, the subject had no errors for either ear with either the noncompeting or competing conditions. Finally, Table 3 shows findings with the SSI test administered with ipsilateral and contralateral competing messages at different MCRs. These results are also well within normal limits for young adult listeners.

The precedence effect test, while extensively investigated in cats with unilateral auditory cortex lesions (Cranford et al, 1971; Cranford and Oberholtzer, 1976), has not been thoroughly

Table 3 Findings with the Synthetic Sentence Identification Test (%)

	SSI-ICM		
MCR	*Right Ear*	*Left Ear*	*Normal Range*
–20	50	60	45–65
–10	80	90	70–90
0	100	100	95–100
+10	100	100	95–100
	SSI-CCM		
–40	100	100	90–100
–20	100	100	90–100
0	100	100	90–100

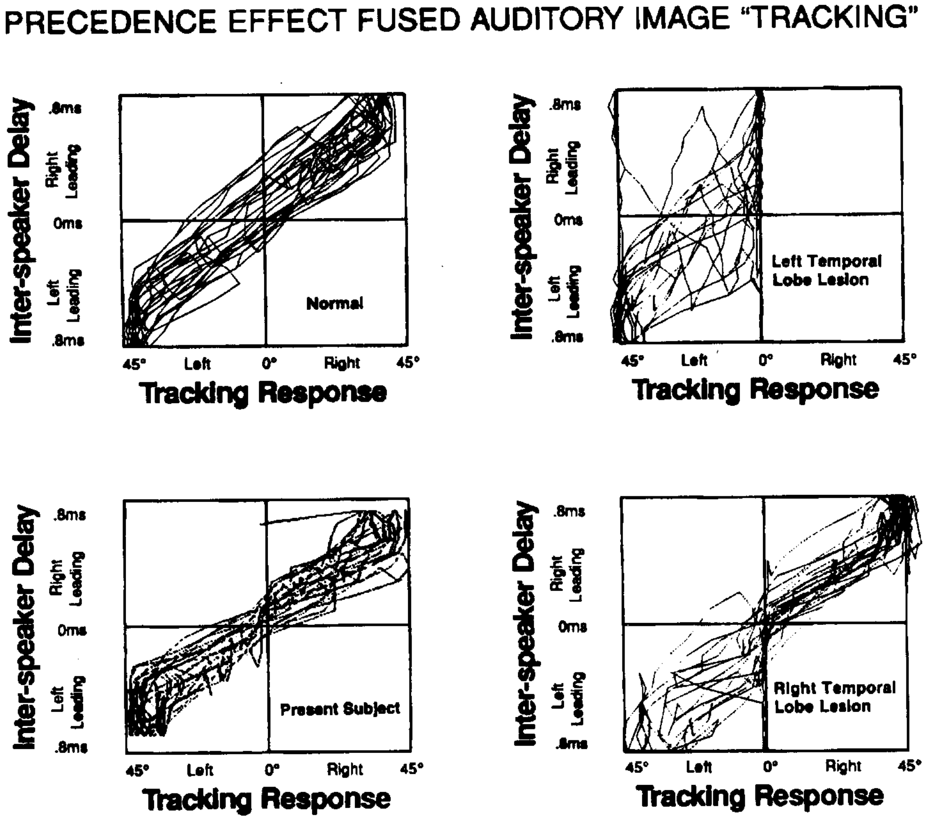

Figure 2 Contrasts performance of present subject on precedence effect test with that of two temporal lobe subjects and a typical young normal subject tested in the Moore et al (1990) study.

investigated with large numbers of human temporal lobe patients. Figure 2, however, contrasts the present subject's findings with two adult male patients (ages 41 and 53) who were tested approximately 3 to 8 years following lesions (due to middle cerebral artery infarct or closed head trauma, respectively) involving the posterior temporal lobe (Brodmann's areas 41 and 42). Whereas both temporal lobe subjects had difficulty tracking the fused auditory image when it "moved" into the hemifield located opposite the damaged hemisphere, the present subject exhibited tracking skills equivalent to that of normal young listeners tested in previous studies (Moore et al, 1990).

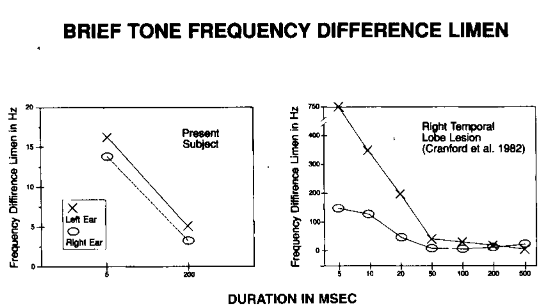

Figure 3 Compares brief tone frequency difference limens of present subject with those of a temporal lobe patient tested by Cranford et al (1982).

Cranford et al (1982) reported that temporal lobe patients exhibit elevated DLFs for brief duration tones at ears located contralateral to the damaged hemisphere. Figure 3 contrasts findings of a patient tested in this earlier study with findings from the present subject. The pre-

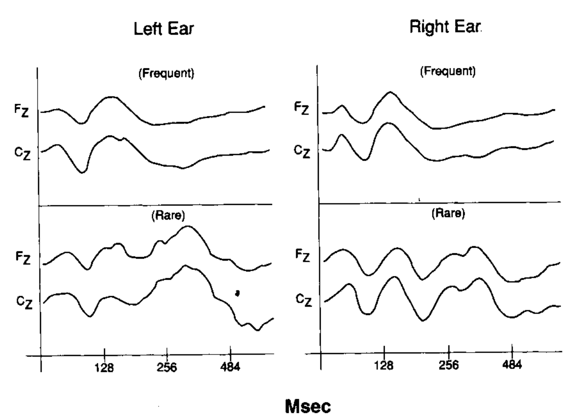

Figure 4 P300 event-related potentials recorded from present subject.

sent subject, while having elevated DLFs for the 5-msec duration tones, did not exhibit any ear differences in the magnitude of this effect. The smaller size of the present DLFs reflects the fact that the earlier investigation used analog means (Grason Stadler 1200 series equipment) to shape tone pulses. The present subject listened to digitally generated tones that had considerably less spectral splatter.

Previous findings with the P300 event-related potential in patients with lesions involving the temporal lobe have been mixed. Whereas some studies (Knight et al, 1989; Obert and Cranford, 1990; Kibbe-Michal et al, 1986; Musiek et al, 1992) have found abnormal or absent responses in temporal lobe patients, other studies (Wood et al, 1982; Stepleton et al, 1987; Johnson, 1988, 1989) have found normal P300s. Thus, at present, the critical area(s) of the lateral or medial cerebrum that is necessary for elicitation of the P300 is not known. The present subject, in spite of having significant portions of the left hemisphere missing (including portions of the parietal, occipital, and prefrontal, as well as temporal lobes), exhibited normal-appearing P300s with monaural stimulation of the two ears. Figure 4 shows these results.

SUMMARY

The present research subject exhibited no evidence of impaired performance with a battery of nine special behavioral and electrophysiologic tests that have been shown to be sensitive to temporal lobe dysfunction. The neurologic events that prevented the development of a left temporal lobe in this individual are presumed to have occurred in early infancy. It appears, therefore, that the right hemisphere of this subject may have assumed most or all of the critical monaural and binaural functions that normally would be shared by two hemispheres. An alternate possibility is that the remaining intact areas of the left hemisphere have assumed the functions of the missing portions. In either case, this study provides additional evidence that the developing human nervous system is capable of a remarkable degree of functional compensation in response to early insults.

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