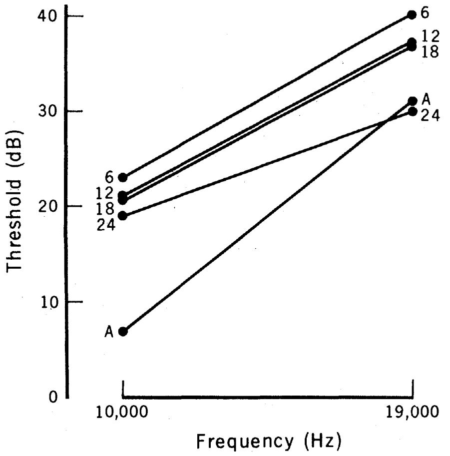
Fig. 2. Thresholds for half-octave band noises with center frequencies of 10,000 and 19,000 Hz for infants 6, 12, 18, and 24 months of age and for adults.



cent correct responses, even at higher intensities. This result is probably attributable to momentary lapses of attention. For the 10,000-Hz noise, the psychometric functions for the four infant groups are similar, but the adults were substantially more sensitive than the infants (*5*). In contrast, the psychometric functions for the children and adults exhibit more overlap at 19,000 Hz (*6*).

At 10,000 Hz, the thresholds for the four infant groups are similar and 12 to 16 dB higher than that for the adult group (Fig. 2). (Threshold was defined as the intensity at which the signal was detected 65 percent of the time.) At 19,000 Hz, however, this adult-infant difference is attenuated substantially. These results confirm a trend that we reported in our earlier study (*3*) on octave band noises, namely, a decrease in the disparity between infant and adult thresholds as the center frequency of the noise band increased. In that study, the disparity was 20 to 30 dB at the lower frequencies (200 to 400 Hz) and 10 dB at 10,000 Hz. In the present study the disparity disappears at about 19,000 Hz for the older infants (*7*).

It is difficult to determine the locus of these developmental changes in frequency sensitivity; in addition to possible maturational changes in the nervous system during the first few years of life, there are changes in the size of the infant's head and, in particular, in the size and shape of the external and middle ear structures (*8*). Age-related changes in these dimensional characteristics and changes in the impedance matching properties of the middle ear no doubt affect frequency sensitivity, but the precise nature of these effects is unknown (*8*).

The implications of such high-frequency sensitivity in infants are considerable. Presbycusis, the gradual loss of hearing with advancing age, is usually more pronounced in the high-frequency region (*9*). The onset of such high-frequency hearing loss may actually begin in infancy since there is morphological evidence of loss of hair cells in the extreme basal portion of the cochlea in infants ranging in age from 2 or 3 hours to several months (*10*). Furthermore, hair-cell loss with corresponding nerve degeneration slowly ascends from the basal end of the cochlea, involving an increasingly larger portion of the basal turn, over the first two decades of life (*10*). Since the basal end of the cochlea mediates high-frequency hearing, we would expect hearing losses associated with aging to manifest themselves first in the very high-frequency region, possibly at an early age. Furthermore, if the basal end of the cochlea is fragile and consequently susceptible to damage, losses in sensitivity due to environmental exposure, illness, or other trauma might first appear at the higher frequencies. In particular, since exposure to noisy environments affects the degree of high-frequency hearing loss in adults (*11*), the effects of noisy environments on young children might first manifest themselves in this high-frequency region. The course of auditory development from 6 months to 6 years of age should be mapped to answer questions such as these.

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References and Notes

1. F. Galton, *Inquiries into Human Faculty and its Development* (Dutton, New York, 1907), pp. 26–27.
2. W. R. Wilson, in *Communicative and Cognitive Abilities—Early Behavioral Assessment*, F. D. Minifie and L. L. Lloyd, Eds. (University Park Press, Baltimore, 1978); B. A. Schneider, S. E. Trehub, D. Bull, *Can. J. Psychol.*, in press.
3. S. E. Trehub, B. A. Schneider, M. Endman, *J. Exp. Child Psychol.*, in press.
4. J. M. Moore, G. Thompson, M. Thompson, *J. Speech Hear. Disord.* **40**, 29 (1975).
5. An analysis of variance for 10,000 Hz showed a significant effect for stimulus level ($P < .0001$), age group ($P < .0001$), and interaction ($P < .025$). Post hoc comparisons among age groups according to Sheffe's method indicated that adults were significantly better than each infant group ($P < .0001$ for 6, 12, and 24 months and $P < .001$ for 18 months) but that there were no significant differences among infant groups. The interaction between stimulus level and age group reflects the fact that adults quickly reached the ceiling of 100 percent correct responding, whereas the infant groups continued to improve as stimulus intensity increased.
6. The analysis of variance for 19,000 Hz showed a significant effect for stimulus level ($P < .0001$) and age group ($P < .001$), but no significant interaction effect. Post hoc comparisons among age groups according to Scheffe's method indicated that adults were significantly better than the 6- ($P < .01$) and 12- ($P < .025$) month-old infants, but there were no significant differences in any of the other comparisons.
7. The same general pattern appears if a 75 percent rather than a 65 percent threshold criterion is chosen. With a 75 percent criterion, thresholds at 10,000 Hz for the four infant groups are still similar and 12 to 20 dB higher than those of adults. At 19,000 Hz, the adult-infant difference is attenuated an average of 8.75 dB for the 75 percent criterion as opposed to 8.9 dB for the 65 percent criterion. Furthermore, the thresholds for the adult and 24-month-old infants are within 2 dB of each other. Hence, our conclusions do not depend specifically on our choice of the 65 percent threshold criterion. Since our research has indicated that 6- and 12-month-old infants tend to reach asymptote at a lower level than older infants (*3*), threshold criteria in excess of 75 percent are likely to be affected by the rate of inattention.
8. K. Hecox, in *Infant Perception: From Sensation to Cognition*, L. B. Cohen and P. Salapatek, Eds. (Academic Press, New York, 1975), vol. 2, pp. 151–191.
9. R. H. Hull, in *Handbook of Clinical Audiology*, J. Katz, Ed. (Williams and Wilkins, Baltimore, 1978), p. 426.
10. L-G. Johnsson and J. E. Hawkins, *Ann. Otol.* **81**, 179 (1972).
11. A. Glorig and H. Davis, *Ann. Otol. Rhinol. Laryngol.* **70**, 556 (1961).
12. Supported by grants from the Medical Research Council of Canada and the Ontario Mental Health Foundation.

4 December 1979

Shark Skin and Locomotion

Wainwright *et al.* (*1*) report on stretching a piece of shark skin lengthwise while holding it stretched laterally with constant stress. (According to their description of their procedure it was not constant lateral stress that they applied, but constant lateral tension—that is, they kept the lateral tensioning force constant instead of making it proportional to the length of the specimen as the latter was stretched. The practical effect of the difference between the two procedures is small.) They say that the area under the longitudinal force-extension curve "is a measure of the energy required for and recovered from skin deformation," and note that this energy is higher when the lateral stress is higher. Because the hydrostatic pressure inside the shark is elevated wherever the body is curved, the elevation increasing with swimming speed, the circumferential stress in the skin will rise also and, with it, the apparent longitudinal stiffness of the skin. It might appear that shark skin is a spring of controllable stiffness that stores energy wherever the body is curved, in an amount that increases with swimming speed.

But because the experiment did not

hold the skin sample at constant width, it does not show that the skin stores any energy at all. Shark skin is oriented on the shark like cloth cut on the bias. Alternate layers of collagen fibers wind around the fish's body in helices of opposite hand. Stretching such a skin longitudinally will make it shrink laterally. Most of the energy put into the skin by stretching it lengthwise may be passed on by the skin to the lateral restraints as it pulls them together. The apparent rise in stiffness with lateral tension may mean only that more work is being done on the lateral restraints. To find the energy stored in the skin in this experiment the authors would have had to record the lateral force-extension curve and subtract the area under it from that under the longitudinal force-extension curve.

The ability of the skin to store energy should depend mostly on the compliance of its collagen fibers, which, as Wainwright *et al.* (*1*) state, are very stiff in tension. Experiments in which the skin was stretched parallel to one set of fibers confirm this high stiffness (*2*) and show that most of the energy represented by the area under the force-extension curves described in (*1*) could not have been stored in the skin.

I have not observed sharks much, but in other fish the pattern of swimming motion is nearly independent of speed. To go faster the fish uses the same pattern of motion, but does it faster. Kinetic energy involved in this motion goes as (speed)^2, and so should any potential energy stored in springs if the same pattern of forces and motion is to be maintained. Ordinary springs do not have this property (*3*). In the experiments of Wainwright *et al.* (*1*) the skin appears to be a modulatable spring, but, as shown above, this apparent property is most likely a wrong interpretation of the experiment.

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References

1. S. A. Wainwright, F. Vosburgh, J. H. Hebrank, *Science* **202**, 747 (1978).
2. S. A. Wainwright, personal communication.
3. C. W. McCutchen, *J. Biomech.* **3**, 271 (1970).

18 December 1978

If stiffness is considered to be the resistance to extension, then our figure 2 (*1*) shows that the stiffness of shark skin varies with stress in the skin due to restraining force. Since the pressure under the skin varies with the swimming speed, so therefore do the restraining force, skin stress, and stiffness of the skin in a swimming shark: we find no reason to alter our conclusions. We are unable to draw the same range of conclusions from McCutchen's comment and his work on trout that he has drawn.

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References

1. S. A. Wainwright, F. Vosburgh, J. H. Hebrank, *Science* **202**, 747 (1978).

31 December 1979

Lateralized Cognitive Processes and the Electroencephalogram

Many investigators have found differences in the balance of electroencephalographic (EEG) activity between the two hemispheres during tasks which differentially require verbal as opposed to spatial processing. Such results have been interpreted as reflecting differences in hemispheric utilization for particular cognitive processes. Gevins *et al.* (*1*) have challenged this interpretation by pointing out that putatively left- and right-hemisphere tasks often differ not only in their cognitive demands, but also in their "stimulus characteristics, efferent activities (limb and eye movements), and performance-related factors (task demands and a subject's ability and effort)."

We believe that this contention is not strongly supported by their data (*1*) and is seriously challenged by a large body of data, much of which they did not cite. At least nine studies have reported significant differences in relative hemispheric activation in the predicted direction when the EEG was recorded in response to verbal and nonverbal stimuli and the subjects were not required to make any overt motor response (*2*, *3*). Significant left and right differences have also been found in studies where response requirements for verbal and nonverbal tasks were equated (*4*–*6*). Asymmetries in EEG activity have also discriminated between purely covert verbal and nonverbal tasks (*6*, *7*) involving no stimulus or response (*6*), thus rigorously satisfying the criteria of Gevins *et al.* (*1*) for controlling the three essential noncognitive aspects of task performance: stimulus characteristics, efferent activities, and performance-related factors.

In support of their contention that measures of EEG asymmetry do not reflect lateralized cognitive processes, Gevins *et al.* present the results of two studies. The results of the first study indicated that tasks could be differentiated on the basis of EEG laterality measures. A second experiment was performed to match more carefully tasks on "efferent components, stimulus characteristics, and performance-related factors." These tasks were of shorter duration (6 to 15 seconds each) than those in the first study (1 minute). We believe that the tasks chosen for the two experiments and the methods used contributed significantly to the negative outcome of the experiments and that definitive conclusions cannot be drawn from them. Although Gevins *et al.* found that the first 15-second segment discriminated between writing versus the Koh's block design task in experiment 1, the subjects' set would probably be quite different in this situation compared to that in experiment 2. It is not clear from their report whether Gevins *et al.* randomized tasks in experiment 2. The methods used in their two experiments differed significantly. The rapidity and possibility of random task presentation in experiment 2 might have prevented the subjects from adopting a consistent cognitive set. Moreover, the spatial task used by Gevins *et al.* in experiment 2 was different from the one used in experiment 1. Recent evidence indicates that the mental rotation task used in experiment 2 is associated with relative left-hemisphere activation in comparison with other spatial tasks where stimulus-, motor-, and performance-related factors were equated (*8*). Thus, in effect, Gevins *et al.* (*1*) may have been comparing the effects of three different "left hemisphere" tasks in experiment 2.

In sum, the results reported by Gevins *et al.* do not convincingly support their contention that EEG asymmetry is unaffected by cognitive differences among tasks. In their experiment 2, it is unclear whether cognitive differences did indeed exist among the tasks. Moreover, their study must be viewed in the context of many other studies in which noncognitive sources of variance have been controlled and significant differences in EEG asymmetry between left and right hemisphere tasks have been found. As Gevins *et al.* have indicated, there is clearly a need to consider a variety of

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