value of the K_m/K_m' ratio, which is smaller than one in the first case and larger than one in the second. (For instance, in the experiment of Fig. 2, the K_m/K_m' ratio was calculated as 0.56.) This suggests that it might be possible to interpret in the same manner the activating effect of Na^+ on sugar and amino acid transport and the reciprocal effects of sugars and amino acids already discussed.
18. R. K. Crane, *Biochim. Biophys. Acta* **45**, 477 (1960).
19. F. Alvarado, *ibid.* **112**, 292 (1966).
20. The methylglucosides are not significantly hydrolyzed under the conditions of these experiments.
21. It appears that, for optimum interaction with the sugar carrier, sugars must possess a pyranose ring with as many substituent groups as possible in an equatorial position (*19*). Change of some of the groups to an axial position usually leads to a decrease in affinity. It seems possible that these changes in conformation of the sugars, although they still permit binding to the carrier, may induce on it the conformational shifts suggested in the text.
22. R. K. Crane, *Physiol. Rev.* **40**, 789 (1960).
23. Using rat intestine, B. G. Munck has also demonstrated counterflow between one of the neutral amino acids, leucine, and one of the basic amino acids, lysine [*Biochim. Biophys. Acta* **109**, 142 (1965)].
24. J. T. Wong, *Biochim. Biophys. Acta* **94**, 102 (1965).
25. R. K. Crane, Symposium on Intracellular Transport, sponsored by the International Society for Cell Biology, held at Frascati, Italy, 21–24 June 1965, J. F. Danielli, Ed., in press.
26. H. A. Krebs and K. Henseleit, *Z. Physiol. Chem.* **310**, 33 (1932).
27. H. Lineweaver and D. Burk, *J. Am. Chem. Soc.* **56**, 658 (1934).
28. Supported by the NSF grant No. GB-1894. Mary Lou Fowler has provided technical assistance.
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17 January 1966

Visually Evoked Potentials: Amplitude Changes with Age

Abstract. *Visually evoked potentials of 215 subjects, aged 1 month to 81 years, were studied. Amplitudes of waves in the first 250 milliseconds of the response changed markedly with age. In responses recorded from the occiput, there was a rapid increase in amplitude reaching a maximum in the 5- to 6-year-old group, with means of amplitudes at this age being about twice as large as means of some older age groups. With children 7 years and older there was a rapid decline in amplitude until ages 13 to 14, when an abrupt increase in amplitude appeared. Amplitude appeared to stabilize at about age 16. In older subjects, mean age 60 and beyond, significant changes were noted in the earlier components of the response.*

Shortly after his discovery of brain waves, Berger turned his attention to age differences in the electroencephalogram (EEG) and reported changes from infancy to adulthood (*1*). Others, notably Lindsley (*2*), Smith (*3*), Bernhard and Skoglund (*4*), and Henry (*5*) soon described changes in brain wave frequency and amplitude. Alpha frequency was found to increase steadily with age in a roughly exponential curve with its asymptote reached at 12 to 16 years. Amplitude, on the other hand, rapidly increased between the ages of 3 months and 3 years, then significantly decreased at the 4th year, probably because of final closing of the fontanels (*2*). After this there was a gradual decrement in amplitude until stabilization occurred in late childhood.

Recently, electronic computers have provided a means for the study of summed evoked potentials—electrical changes recorded from scalp, initiated by brief stimuli such as a click or a light pulse. These previously obscure cerebral electrical changes, when related to the time of a stimulus, emerge from the background brain "noise" and can be studied. Summed evoked potentials are receiving systematic attention in the adult (*6*), and in premature and full-term infants (*7*). Lacking, however, is a description of evoked potential changes in their relation to increasing age. If salient EEG changes occur during the formative years, leveling off at about 16, what changes might one expect in the evoked potential?

We now report on visually evoked potentials of 215 normal subjects, aged 1 month to 81 years, who were divided into 14 groups, with from 9 to 24 subjects in each group (Table 1).

The heads of subjects were measured and fitted with scalp electrodes that were then attached with bentonite paste. The electrodes were placed bilaterally, at O_1 and O_2 on the occiput and C_3 and C_4 in the central area, according to the "10–20" international system. The results from occipital leads only are reported here.

Ear-ground leads were used for reference. Each subject over 2 years of age reclined in a padded chair in a darkened room, with eyes open, facing a reflecting hemisphere 70 cm in diameter. Under 2 years, the subject sat on his mother's lap. The hemisphere was illuminated by a Grass PS-2B photostimulator lamp aimed at its center and positioned behind and to the left of the subject. The uniform flash that completely enveloped the subject's face, was of relatively low intensity (2 on the Grass PS intensity range of 1 to 16). The measured luminance of the hemisphere, 40 cm from the subject's eyes, was 2.2 millilamberts. One hundred flashes, 2 to 3 seconds apart, were delivered to each subject during a recording session. Every effort was made to insure comparable recording conditions. Attention was controlled by instructing the subject to fixate on a small black dot in the center of the hemisphere. As the recording sessions were short, generally 5 to 10 minutes, drowsiness was not a problem.

A Mnemotron computer of average transients was used to extract the cerebral responses to the flashes of light. These were plotted (by a Moseley X-Y Plotter) on paper (25 by 38 cm). The summed evoked responses from left occipital scalp were used for comparison and statistical evaluation. These responses (Fig. 1) were multiphasic with several recurring components in the first 250 msec of the response (*6*).

Three amplitude measures were made encompassing (i) 0 to 250 msec, (ii) 0 to 125 msec, and (iii) 126 to 250 msec of the evoked response of each subject. For each of the three time

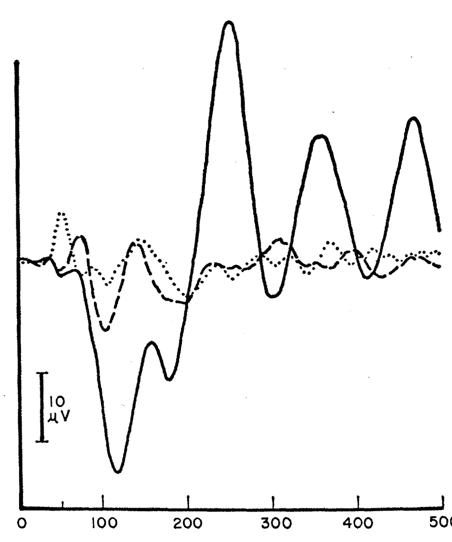

Fig. 1. Visually evoked potentials of three subjects of different ages. The high amplitude quality of the response during formative years and the potentiation of early components in later years are shown. A downward deflection indicates a positive change. Solid line, age 6; broken line, age 16; dotted line, age 60.

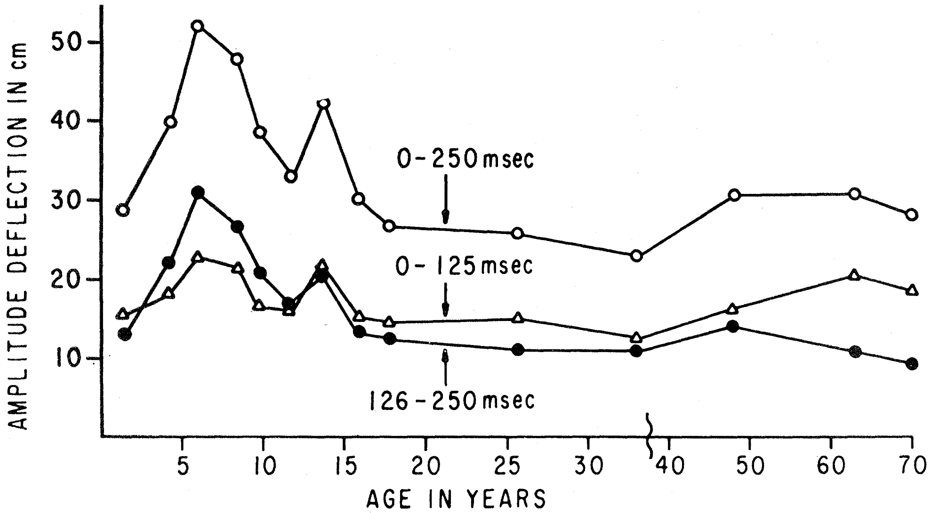

Fig. 2. Relationship of visually evoked response amplitude to age. A measure of amplitude excursion in centimeters of wave components occurring during the first 250 msec, first 125 msec, and 126 to 250 msec of responses recorded from occipital scalp.

periods the amplitude excursion of the evoked response was measured to the nearest 0.5 cm by tracing with a map-reading wheel the response patterns scribed by the recording pen. The plotter was adjusted to scribe 125 and 250 msec over distances of 5 and 10 cm, respectively. Thus, response excursions greater than those figures reflected degrees of wave-form amplitude. The responses of all 215 subjects were measured twice by this method. That the mean error in measurement was 2.3 percent, was indication of the method's reliability. (This method has been used successfully in the laboratory in measuring overall amplitude changes with an increase in stimulus intensity.) The means of the totals were then computed for the 14 age groups.

The group mean amplitude increased markedly from infancy to ages 5 to 6 years (Table 1; Fig. 2). The mean amplitude of this age range was about twice that of adult group. Analyses of variance of the amplitude measures, 0 to 250 msec and 126 to 250 msec, of the 14 groups, indicated that the 5- to 6-year-old group differed significantly from all other groups except the group immediately following it, the 7- to 8-year-olds ($F = 6.30$, $P < .001$; $F = 10.06$, $P < .001$). An analysis of variance of the amplitude measures at 0 to 125 msec indicated that the mean amplitude of the 5- to 6-year-old group was significantly larger than the six smallest means ($F = 2.39$, $P < .01$). In each instance *df* (degrees of freedom) was 13/201.

Table 1. Mean amplitude of the visually evoked potential of 14 age groups.

Age range (yr)	Mean age (yr)	Group (No.)	Mean amplitude measures		
			Total of all components 0–250 msec excursion (cm)	Separated amplitudes	
				0 to 125 msec (cm)	126 to 250 msec (cm)
0- 2	1.5	9	28.9	15.8	13.1
3- 4	4.1	12	40.4	18.0	22.3
5- 6	5.9	13	54.5	23.0	31.5
7- 8	7.8	16	48.3	21.5	26.9
9-10	9.9	11	38.5	16.6	21.9
11-12	11.9	11	32.6	16.3	16.3
13-14	13.5	15	42.5	21.8	20.7
15-16	16.0	21	28.8	15.3	13.5
17-19	17.8	21	26.9	14.4	12.5
20-29	25.8	24	26.4	15.2	11.2
30-39	33.4	11	23.6	12.4	11.3
40-55	48.1	17	30.9	16.7	14.2
56-66	62.8	16	31.3	20.5	10.8
67-81	70.2	18	28.3	18.4	9.9

With older children a rapid decline in amplitude occurred until ages 13 to 14. At this time there was an abrupt increase, both in early, 0 to 125 msec and late, 126 to 250 msec components. The means of this age group were significantly larger ($P < .05$) than the means of the group immediately following it for the amplitude measures at 0 to 250 msec and 126 to 250 msec. From ages 15 to 81 there were no significant differences between mean amplitudes. However, in older groups, mean ages 62.8 and 70.2 years, a reciprocal change in amplitude of earlier and later components could be seen with an amplitude increase in earlier, and an amplitude decrease in later, components (Fig. 2).

To evaluate these changes, ratios of the amplitude excursion of early and late components, that is, from 0 to 125 msec to that at 126 to 250 msec, were computed for the subjects in the 14 groups.

Since group variances were markedly different and the ratios were not normally distributed, a Kruskal-Wallis analysis of variance for ranked data was computed. This analysis showed significant differences between group ratios ($H = 61.9$; 13 *df;* $P < .001$) and also showed that the two groups of older subjects had mean ratios which were significantly larger than those of the other 12 groups ($P < .02$).

To ascertain whether the findings with older subjects may have resulted from a slower pupillary reflex and hence an increased amount of light, evoked potentials to higher intensity flashes were studied with ten subjects. In these, amplitude increased concomitantly with intensity, but most significantly in later components. This finding is contrary to the changes seen with older subjects, where there is a decrease in amplitude of late components, and an increase in earlier ones.

While the source of amplitude changes of the evoked potential of older people remains debatable, the amplitude changes during the development periods in children become stabilized at about age 16 and are similar to those changes reported for brain wave frequency and amplitude (*2–5*). This suggests that differences in amplitudes of evoked potential at different age levels are of cerebral origin.

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References and Notes

1. H. Berger, *Arch. Psychiat. Nervenkr.* **97**, 6 (1932).
2. D. B. Lindsley, *Science* **84**, 354 (1936); *J. Genet. Psychol.* **55**, 197 (1939).
3. J. R. Smith, *ibid.* **53**, 431, 455, 471 (1938).
4. C. G. Bernhard and C. R. Skoglund, *Skand. Arch. Physiol.* **82**, 178 (1939).
5. C. E. Henry, *Monogr. Soc. Res. Child Development*, **9**, No. 39 (1949).
6. M. A. B. Brazier, in *The Henry Ford International Symposium, Reticular Formation of the Brain*, H. H. Jasper, L. D. Proctor, R. S. Knighton, W. C. Noshay, R. T. Costello, Eds. (Little Brown, Boston, 1958), pp. 151–168; W. A. Cobb and G. D. Dawson, *J. Physiol.* **152**, 108 (1960); M. L. Cigánek, *Electroencephalogr. Clin. Neurophysiol.* **13**, 165 (1961); *Sensory Evoked Response in Man*, H. E. Whipple and R. Katzman, Eds. [*Ann. N.Y. Acad. Sci.* **112**, 1–546 (1964)].
7. R. J. Ellingson, *Electroencephalogr. Clin. Neurophysiol.* **12**, 663 (1960); R. Engle and B. V. Butler, *J. Pediat.* **63**, 386 (1963); A. B. Barnet and R. S. Goodwin, *Electroencephalogr. Clin. Neurophysiol.* **18**, 441 (1965).
8. We thank Dr. H. R. Warner, University of Utah, for instructions and for the use of the Control Data 3200 Computer in his laboratories at the Latter Day Saints Hospital.

11 November 1965

Atmospheric Noble Gases from Extraterrestrial Dust

Schmidt recently discussed (*1*) the effect of varying one of the parameters—the influx rate of extraterrestrial dust—on the intensity of the proposed atmospheric-source mechanism (*2*). His discussion and table provide numerical support of my remark that "The source strength does depend directly on . . . the total influx of extraterrestrial material to the earth." (However, the numbers in the last line of his table 1 are not consistent with each other or with the rest of the table.) His comments further demonstrate the validity of my statement that "Estimates of accretion of extraterrestrial dust vary widely." In fact the papers on (possibly) extraterrestrial spherules that Schmidt himself has cited elsewhere (*3*) show an apparent spread of four orders of magnitude in the reported rate of influx of spherules (seven orders of magnitude if one extremely high value is included). The lowest values (*4*) are based on separations of magnetic spherules from marine sediments, and it is difficult both to evaluate the effects of weathering in the marine environment on the long-term preservation of these spherules and to be sure of the efficiency of experimental separation and identification.

The ratio of extraterrestrial to terrestrial spherules at any particular time and place on the surface of the earth is a matter of active investigation and considerable controversy (*5*), and the observations of Giovinetto and Schmidt that Schmidt cites are relevant. Among spherules of extraterrestrial origin, the relative abundances of atmospheric-ablation droplets from large meteorites, micrometeorites fused during atmospheric entry, and pre-atmospheric spherules also are not well determined.

I agree with Schmidt that rates of influx of identifiably extraterrestrial spherules may be much smaller than influx rates of other kinds of fine-grained material. In fact I noted in my paper that determinations of the number of dark magnetic spherules may have underestimated rates of influx because they did not include water-soluble compounds, silicates, or material volatilized during entry into the atmosphere. The magnetic-spherule estimates also of course do not include influx of nonmagnetic material or of particles sufficiently small, or with low-enough velocity, to have escaped complete melting during atmospheric entry.

It is the rate of total influx of all extraterrestrial material, not the rate of spherule influx, that is the significant rate in determining the source intensity for atmospheric contributions. The spherule measurements were quoted in an attempt to give a lower limit for the rate of total influx. However, in view of the uncertainties mentioned in the original paper and here, some of which Schmidt has reemphasized, it would have been better to omit altogether any reference to studies of spherules.

For the calculation in my paper, I assumed an influx rate of 2×10^{-7}g cm^{-2} year^{-1}, corresponding to about 10^6 tons per year over the surface of the earth. This value is in fair agreement with several different types of experimental evidence for total annual mass influx from extraterrestrial sources. This evidence includes the following: (i) Microphones and other satellite-borne equipment (*6*) lead to estimated influx rates of 4×10^6 tons per year, (ii) The total abundance of nickel found in Antarctic ice by Brocas and Picciotto (*7*), most of which they think they can demonstrate to be extraterrestrial in origin, leads them to estimate an influx of cosmic dust of 3×10^6 tons per year. (iii) The Cl^{36} activity found in marine sediments by Schaeffer *et al.* (*8*) enables them to estimate a minimum influx of extraterrestrial dust of about 10^6 tons per year, assuming saturation values of Cl^{36}. (iv) The Al^{26} activity found in submarine sediments by Lal and Venkatavaradan (*9*) is consistent with an influx of 4×10^6 tons per year, assuming saturation values of Al^{26} and solar-flare fluxes of 20 protons cm^{-2} sec^{-1} of energy greater than 10 Mev, averaged over the dust-particle orbits.

None of these numbers is of high precision: the satellite estimates depend on assumptions about particle velocities; the other estimates depend on assumptions about the chemical composition of the dust; the estimates based on long-lived radioactivities directly depend on the average lifetimes of the dust grains in space, which may be much shorter than the mean life of Al^{26} or Cl^{36}; and the average flux and energy spectra of solar-flare particles throughout a solar cycle are uncertain. Nonetheless, the number that I used for a current rate of influx of extraterrestrial dust is not inconsistent with the available experimental data, and may even be conservatively low.

Regarding the several essential parameters necessary to calculate for specific gases an average input intensity for the atmospheric-source mechanism of "solar wind in dust," it seems probable that uncertainties in the contemporary rate of influx of dust will be greatly reduced in the next few years. The most difficult parameters to establish quantitatively may be the rate of gas loss from the grain surfaces, resulting from the combined effects of diffusion and sputtering, and the rate of influx of dust during the earth's early history.

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References and Notes

1. R. A. Schmidt, *Science* **151**, (1966).
2. D. Tilles, *ibid.* **148**, 1085 (1965).
3. R. A. Schmidt, *NASA Tech. Note TN D-2719* (March 1965); and T J. Cohen, *Science* **145**, 924 (1964).
4. H. Pettersson and K. Frederiksson, *Pacific Sci.* **12**, 71 (1958); T. Laevastu and O. Mellis, *Trans. AGU* **36**, 385 (1955).
5. F. W. Wright, P. W. Hodge, C. C. Langway, Jr., *J. Geophys. Res.* **68**, 5575 (1963); P. W. Hodge and F. W. Wright, *ibid.* **69**, 2449 (1964); ———, C. C. Langway, Jr., *ibid.*, p. 2919 (1964); F. W. Wright and P. W. Hodge, *ibid.* **70**, 3889 (1965); K. Frederiksson and L. R. Martin, *Geochim. Cosmochim.* **27**, 245 (1963); T. A. Mutch, *J. Geophys. Res.* **69**, 4735 (1964).
6. W. M. Alexander, C. W. McCracken, L. Secretan, O. E. Berg, in *Space Research III* (1963), p. 891.
7. J. Brocas and E. Picciotto, in *Abstr. Proc. Inter. Congr. Pure Appl. Chem. Moscow 20th* (1965).
8. O. A. Schaeffer, G. Megrue, S. O. Thompson, in "Proc. conf. meteors dust," *Smithsonian Contrib. Astrophys.*, in press.
9. D. Lal and V. S. Venkatavaradan, *Science*, in press.

27 January 1966