bound form. However, contrary to our original assumption, an increase in fluorescence is not necessarily related to an accumulation of 5-HT. Although the elevation in brain 5-HT concentration induced by L-tryptophan is blocked by *p*-chlorophenylalanine, the intensity of fluorescence in raphe neurons is not reduced. These results are particularly surprising in view of the fact that after treatment with *p*-chlorophenylalanine the concentration of tryptophan in brain is reduced (*18*). It appears that changes in raphe fluorescence are, under some conditions, dissociated from changes in 5-HT content in brain. To account for this discrepancy one could postulate that 5-HT concentration in raphe neuronal perikarya does not decrease after injection of *p*-chlorophenylalanine despite a general lowering in the remainder of the brain. Another explanation for these paradoxical findings could be that *p*-chlorophenylalanine itself gives rise to a fluorescent product, but an initial report (*16*) to this effect has apparently not been confirmed (*19*).

Alternatively, it is possible that indole substances in addition to or instead of 5-HT can be concentrated or synthesized within raphe neurons. Conceivably, after injection of *p*-chlorophenylalanine abnormal metabolites of tryptophan could accumulate and give rise to fluorophores in raphe neurons. At least some tryptophan itself is likely to be present in raphe neurons and loading with tryptophan does increase its concentration in whole brain (*20*). However, regional assays show that the distribution of tryptophan in brain is homogeneous (*21*), and this pattern would not correspond to the anatomy of the raphe system (*22*). Tryptamine, the direct product of tryptophan decarboxylation, might also be present in raphe cells. However, in whole brain, even after tryptophan loading, amounts of tryptamine are too small to be accurately detected by present methods (*23*). No assays for tryptamine have been made specifically in raphe neurons. It remains to be determined experimentally whether 5-HT is normally the predominant amine metabolite of tryptophan present in raphe neurons. In addition, it will be necessary to see if drugs such as *p*-chlorophenylalanine can give rise to fluorophores not normally present in these neurons. Recently, Björklund *et al.* (*19*), on the basis of microspectrofluorometric analysis of fibers in the spinal cord, have also suggested that indoleamines other than 5-HT may be present in neurons within the central nervous system.

In conclusion, the increased fluorescence seen in raphe neurons after L-tryptophan loading is consistent with the fact that serotonin is also increased under these conditions. However, *p*-chlorophenylalanine does not block the increase in fluorescence, as would be predicted if serotonin is solely responsible for raphe fluorescence. Because of these uncertainties, the terms serotonin-containing or serotonergic can be applied only tentatively to raphe neurons, pending the acquisition of further data concerning the exact chemical identity of the fluorescent substance or substances in raphe cells. On the other hand, our results reveal a remarkable selectivity by which tryptophan, as the probable initial precursor of brain indoles, enhances the fluorescence of raphe neurons but not other neurons.

GEORGE K. AGHAJANIAN
IRVING M. ASHER
Departments of Psychiatry and
Pharmacology, Yale University School of Medicine and
Connecticut Mental Health Center, New Haven 06519

References and Notes

1. M. Jouvet, *Science* **163**, 32 (1969).
2. M. H. Sheard and G. K. Aghajanian, *Life Sci.* **7**, 19 (1968).
3. G. K. Aghajanian, W. E. Foote, M. H. Sheard, *Science* **161**, 706 (1968); *J. Pharmacol. Exp. Ther.* **171**, 178 (1970).
4. A. Dahlström and K. Fuxe, *Acta Physiol. Scand.* **62** (Suppl. 232), 1 (1965).
5. A. Heller and R. Y. Moore, *J. Pharmacol. Exp. Ther.* **150**, 1 (1965); M. Jouvet, *Physiol. Rev.* **7**, 117 (1967); G. K. Aghajanian, J. A. Rosecrans, M. H. Sheard, *Science* **156**, 402 (1967); W. Kostowski, E. Giacalone, S. Garattini, L. Valzelli, *Eur. J. Pharmacol.* **4**, 371 (1968); J. A. Rosecrans and M. H. Sheard, *ibid.* **6**, 197 (1969); W. Kostowski, E. Giacalone, S. Garattini, L. Valzelli, *ibid.* **7**, 170 (1969).
6. S. Udenfriend, H. Weissback, D. F. Bodanski, *J. Biol. Chem.* **224**, 803 (1957); E. Costa and F. Rinaldi, *Amer. J. Physiol.* **194**, 214 (1958); M. K. Paasonen and N. J. Giarman, *Arch. Int. Pharmacodyn. Ther.* **114**, 189 (1958).
7. H. Corrodi, K. Fuxe, T. Hökfelt, *J. Pharm. Pharmacol.* **19**, 433 (1967).
8. L. J. Weber and A. Horita, *Biochem. Pharmacol.* **14**, 1141 (1965); G. W. Ashcroft, D. Eccleston, T. B. B. Crawford, *J. Neurochem.* **12**, 483 (1965).
9. E. Jéquier, W. Lovenberg, A. Sjoerdsma, *Mol. Pharmacol.* **3**, 274 (1967).
10. A. B. T. Moir and D. Eccleston, *J. Neurochem.* **15**, 1093 (1968).
11. A. Björklund and B. Falck, *J. Histochem. Cytochem.* **16**, 717 (1968).
12. B. Falck, N.-Å. Hillarp, G. Thieme, A. Torp, *ibid.* **10**, 348 (1962).
13. L. S. Van Orden III, *Biochem. Pharmacol.* **19**, 1105 (1970).
14. A. Coppen, D. M. Shaw, B. Herzberg, R. Maggs, *Lancet* **1967-II**, 1178 (1967).
15. B. K. Koe and A. Weissman, *J. Pharmacol. Exp. Ther.* **15**, 499 (1966).
16. R. E. Barrett, *Advan. Pharmacol.* **6A**, 252 (1968).
17. M. H. Sheard and G. K. Aghajanian, *J. Pharmacol. Exp. Ther.* **163**, 425 (1968).
18. A. Tagliamonte, P. Tagliamonte, V. Perez-Cruet, G. Gessa, *Pharmacologist* **12**, No. 2, 236 (1970).
19. A. Björklund, B. Falck, U. Stenevi, *J. Pharmacol. Exp. Ther.* **175**, 525 (1970).
20. S. M. Hess, B. G. Redfield, S. Udenfriend, *ibid.* **127**, 178 (1959).
21. D. A. V. Peters, P. L. McGeer, E. G. McGeer, *J. Neurochem.* **15**, 1431 (1968).
22. N. E. Andèn, A. Dahlström, K. Fuxe, K. Larsson, L. Olson, U. Ungerstedt, *Acta Physiol. Scand.* **67**, 313 (1966).
23. D. Eccleston, G. W. Ashcroft, T. B. B. Crawford, R. Loose, *J. Neurochem.* **13**, 93 (1966).
24. Supported by NIMH grants (MH 17871 and MH 14459) and the State of Connecticut.

5 February 1971; revised 7 April 1971

Space Perception in Early Infancy: Perception within a Common Auditory-Visual Space

Abstract. *Infants as young as 30 days become visibly distressed upon observing their mothers speak to them while the mother's voice is displaced in space. Their ability to perceive this discrepancy indicates that infant perception occurs within a space that is common to the visual and auditory modes.*

We perceive objects and events within a space that is common to all perceptual modes. This spatial coordination among the senses is a fundamental property of the perceptual system. When we see one object collide with another, we localize the sound of impact at the same spatial locus at which we visually locate the collision. The same perceptual capacity also enables us to perceive a spatial discrepancy, as when we view a speaker whose voice is broadcast through a public address system. Although it has been demonstrated that such spatial conflicts can be resolved, with vision dominating the percept, there is no question that auditory-visual discrepancies of sufficient magnitude can be objectively perceived by the adult observer (*1*).

The origin of this perceptual capacity has been a major point of debate among perceptual nativists and empiricists. Yet we have little evidence with which to resolve the issue. The gradual appearance of head and eye orientations to a sound source in the peripheral visual field has been interpreted to mean that auditory and visual space become coordinated during the first few months of development (*2*). Some psychomotor coordination does seem to

be present at birth, however. Directionally appropriate eye movements to a sound source have been observed in the infant within minutes after delivery (*3*). Yet, direct perceptual evidence concerning this question is totally lacking, for the obvious reason that there is an apparent lack of a meaningful behavioral indicator of perception in infants.

Our purpose in this investigation was to determine whether human infants do perceive within a common auditory-visual space. If the capacity is functional in infants, they ought to notice a discrepancy in spatial information. On the assumption that infants have no explanation for the rearrangement of their perceptual world, we would expect them to show signs of confusion or upset on being confronted with a spatial discrepancy. In our experiment, the discrepancy was created by displacing the voice of the infant's mother as she spoke to him.

We observed eight infants whose age range was 30 to 55 days, with a median of 41 days. All infants were full term and delivered without the aid of medication. We did not begin the experimental procedure unless the infant appeared to be alert and relaxed.

The infant was seated in a chair designed to provide maximum support for the head and torso, while allowing free movement of the arms and legs. He was seated directly facing a 30 by 40 inch (76 by 101 cm) window, through which he viewed the mother in an adjoining room. The mother's voice was transmitted to the infant's room by means of a stereo amplifier system. The two loudspeakers were set 40 inches (101 cm) apart, 90° to each side of the infant and equidistant from him. One experimenter stood directly behind the infant. The second experimenter was in the mother's room, where he controlled the loudness balance between the stereo loudspeakers. The mother stood directly in front of the infant, separated from him by the window, at a distance of approximately 2 feet (60 cm), measured from face to face. The mother remained at this position throughout the experiment. The sound intensity level of the amplification system was set to approximate normal loudness of speech at that distance. Speech in the normal speech intensity range was inaudible between rooms when the amplification system was disconnected. A white curtain served as a background to the mother, who was illuminated by means of a flood lamp placed directly overhead.

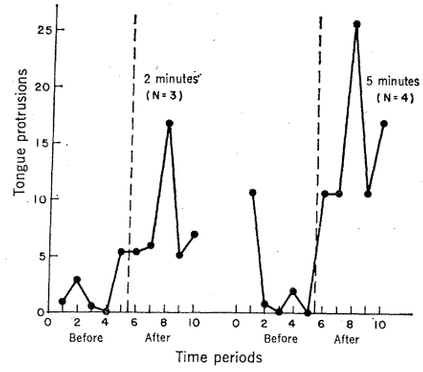

Fig. 1. Mean tonguing scores from film frames for each 9-second period. Films were shot at 12 frames per second.

The experiment was conducted in two immediately successive stages. In stage 1, the mother spoke to her infant with the loudspeakers in balance, so that her voice would appear to the infant to emanate from her position at the center of the window. During stage 2, the balance of the stereo system was set so that one of the loudspeakers was completely dominant. The mother's voice would thus appear to emanate from 90° right ($N = 4$) or 90° left ($N = 4$) of the infant's midplane. It was confirmed with four adult observers that the stage 1 setting did result in a straight-ahead localization of the amplified voice and that the stage 2 settings resulted in 90° left or right localizations. These pointing judgments were obtained with the observers' eyes closed and with their heads in the position that the infant's head would occupy.

There was no break in the procedure between stages 1 and 2. The shift in loudspeaker dominance was executed during a speech pause, in order to avoid sound-motion effects. The duration of stage 1 was either 2 or 5 minutes. Four infants were randomly assigned to each duration condition. If during the first minute of stage 1 the infant appeared to be particularly inattentive, uncomfortable, or distressed, we terminated the procedure. After the first minute, the entire session was filmed for subsequent analysis. Filming was done at 12 frames per second. The mother's speech throughout the experiment was casual and unrehearsed. She was instructed to talk to her infant in her normal fashion. The mothers were not aware of the nature of the experiment.

Throughout stage 1, the infants typically appeared calm and relaxed, with little apparent reaction to the communication of the mother other than visually orienting to her. Our elimination procedure of course reduced the potential range of behavior that we might have observed during stage 1. After 15 to 25 seconds of the onset of stage 2, however, behavioral changes emerged, often dramatically. The infants began to exhibit signs of agitation and discomfort, including struggling movements of the arms, legs, and torso, vigorous mouthing of the tongue, and facial grimacing. Often infants would kick forward at the window; in three cases, they pushed themselves forward in the chair, so that it was necessary for the experimenter momentarily to restrain them and return them to their upright position. Three of the infants eventually cried, and whining vocalizations were noted in three others. Without exception, the infants became calm immediately upon being turned away from the window and distracted with a rattle. Attempts to return the infants to their position facing the mother were unsuccessful, despite a resumption of the stage 1 condition. The distress reaction quickly became evident again.

Although the distress reactions tend to be idiosyncratic, particularly with regard to activity changes, one behavioral distress indicator has been in evidence in all but one of the infants observed in this experiment, and in almost all pilot observations. This is the sudden appearance of mouthing of the tongue. This activity might occur with the tongue in the mouth, but there were usually intermittent periods in which the tongue would protrude between the lips, occasionally making lateral movements and curling upward, usually with the lips pursed. Typically, infants would continue to visually orient to the mother while engaging in this activity. We scored this tongue activity frame by frame from the film records, scoring one for each frame in which the tongue protruded between the lips. The 45-second periods before and after the switch from stage 1 to stage 2 were scored in this manner. One infant, whose agitation resulted in extreme lateral head movements that caused his mouth to be occasionally occluded from view, had to be omitted from this analysis. The results for the remaining seven infants are shown in Fig. 1. Note that the reaction is most evident within the 20- to 30-second period after the onset of stage 2. The mean tonguing scores for the 45-second periods before and after

the switch in stages were 12.3 and 60.1, respectively. This is a statistically significant difference ($P < .025$).

To be certain that the reaction was in fact due to the auditory-visual discrepancy and not to the shift in voice locus per se, we observed four additional infants. These infants, whose age range was from 28 to 56 days, received the experimental procedure as described above, except that the mother was not visible to the infant. She stood behind the curtain backdrop, completely hidden from the infant as she spoke to him. Voice locus and intensity were the same as in our original procedure. Two infants served at each of the 2-minute and 5-minute periods of stage 1. The sessions were filmed and scored for tonguing.

These infants remained calm throughout the procedure. There was almost no visible reaction to the lateral displacement of the mother's voice. The mean tonguing scores for the 45-second periods before and after the switch in stages were 15.5 and 20.8, respectively.

We observed three additional infants in order to determine whether the effect is dependent upon a speaker who is familiar to the infant. We thus repeated the experimental procedure but substituted a female laboratory assistant for the mother. Two infants served in the 2-minute condition of stage 1, and one infant in the 5-minute condition.

All three infants reacted with distress after the shift in voice locus. The mean tonguing scores for the 45-second periods before and after the switch in stages were 8.1 and 50.6, respectively.

We interpret our results as indicating that infants as young as 30 days are perceiving auditory and visual information within a common space. Perceived discrepancies within this space produce agitation and upset. The spatial dislocation thus is apparently a violation of the young infant's perceptual world, in which speaker and voice share the same spatial position. Further experiments will be required to determine which stimulus factors control the perception of spatial discrepancies. Communicative movements of the speaker, notably movements of the mouth and lips, are one obvious potential source of stimulus control. Michotte's (*4*) psychophysical investigations of causality perception in adults suggest that the perceptual unit is temporally defined; that is, the infants register the synchrony between lip movements and vocalizations, at least to the extent of differentiating the gaps between speech segments.

The lower age limit of our sample leaves open the possibility that the infants could have developed this capacity for spatial coordination during the first few weeks of postnatal life. The consistency with which our procedure produced visible distress in the infants does not, however, lend support to this interpretation. The expectation that voice and speaker are a spatial unit is presumably learned, but the learning would require the prior existence of a perceptual system that has access to and reliably coordinates information from separate modes. If the infant does not initially perceive the spatial integrity of such information, he must at least register the temporal correspondence between modes and, somehow, must begin to spatially coordinate the intermodal temporal unit. He must do so at a time in his life when his processing capacities are decidedly underdeveloped (*5*). If learning is to account for the auditory-visual spatial coordination, the learning process must necessarily be an extremely rapid and efficient one.

ERIC ARONSON*
SHELLEY ROSENBLOOM
Department of Psychology,
Center for Cognitive Studies,
Harvard University,
Cambridge, Massachusetts 02138

References and Notes

1. H. A. Witkin, S. Wapner, T. Leventhal, *J. Exp. Psychol.* **43**, 58 (1952); C. V. Jackson, *Q. J. Exp. Psychol.* **5**, 52 (1953).
2. J. Piaget, *The Origins of Intelligence in Children* (International Universities Press, New York, 1953).
3. M. Wertheimer, *Science* **134**, 1692 (1961).
4. A. Michotte, *The Perception of Causality* (Basic Books, New York, 1960).
5. T. G. R. Bower, *Percept. Psychophys.* **2**, 411 (1967); A. Peiper, *Cerebral Function in Infancy and Childhood* (International Universities Press, New York, 1952).

* Present address: Department of Psychology, University of Edinburgh, Edinburgh, Scotland.

11 January 1971; revised 22 March 1971

Attention-Related Increases in Cortical Responsivity Dissociated from the Contingent Negative Variation

Abstract. *Certain tasks which increase attention to stimuli also elicit the contingent negative variation and increase the amplitude of the P300 component of the sensory evoked response. Therefore it appeared possible that the contingent negative variation and attention-related increases in P300 are either confounded by artifact or generated by common neural mechanisms. The fact that we have recorded attention-related increases in P300 amplitude independent of corresponding systematic changes in contingent negative variation indicates that neither of these possibilities is correct. The two phenomena are independently variable modulations of cortical activity.*

When a sensory stimulus is made sufficiently interesting or relevant to the performance of a task, the cortical response (but not the peripheral nerve response) evoked by that stimulus is larger than it is when the stimulus has no significance for the subject (*1*). This increase in amplitude is particularly large and reliable in the so-called P300 wave, a late positive evoked response component best recorded slightly anterior to the vertex in man and having a maximum between 230 and 360 msec after the stimulus (*1–3*). We shall refer to attention-related increases in the amplitude of this component as the P300 effect. Recently several authors (*4–6*) have pointed out the similarity between conditions used to demonstrate the P300 effect and those conditions which produce a surface-negative baseline shift in the human electroencephalograph (EEG), commonly called the contingent negative variation (CNV) (*7–8*). The P300 effect appears to occur when there is either a preparatory increase in concentration immediately before the task stimulus, a condition which also elicits CNV, or a reactive decrease in concentration after a response to the stimulus, which occasions a positive-going shift in the CNV back to the EEG baseline before the trial.

The probable covariance of CNV with the P300 effect has suggested two hypotheses about the possible relationship of these phenomena. One hypothesis stated by Karlin (*4*) proposes that the P300 effect is an artifact of averaging the evoked potential at the same time that the CNV is returning to pretrial baseline, which thereby causes summation of the resulting positive-going baseline shift into the sensory response. This type of artifact was demonstrated by Donchin and Smith