nuclei consistently elicited spindling waves on the cerebral cortex (Fig. 1*C*). The barbiturate by itself, that is, without any interruption of the postulated thalamoreticular connections, never induced this effect.

In our opinion, these latest results indicate that the unspecific thalamic system is mainly or solely concerned with the production of slow cortical activity. They also suggest that the thalamocortical mechanism of synchronization is not frequency-dependent with regard to the modalities of its activation. And finally, they give direct and further evidence that the recruiting and arousing systems of the brain are separated functional units, a fact which has already been postulated on other grounds (*5; 6*).

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Psychomotor Coordination of Auditory and Visual Space at Birth

Abstract. Before it was 10 minutes old, a human neonate was able to turn its eyes in the direction of an auditory stimulus. This demonstrates that learning is not essential for a crude form of auditory localization, directional oculomotor response, and coordination of auditory and visual functioning.

It has long been believed that space perception is dependent upon extensive learning experiences (*1*) although the results of some studies (*2*) do not appear consistent with such a belief. If it could be demonstrated that responses based upon space perception are present at birth, the nativist view of space perception would be greatly strengthened and serious doubt would be cast upon the empiricist view.

In 1952 I noticed that my child (born without anesthesia, by natural childbirth), about one-half hour after birth, turned her eyes in the direction of a soft click made near one ear or the other. This report describes a systematic attempt to replicate this observation.

The subject was born without pharmacologic anesthesia, by natural childbirth. Three minutes after birth, a series of trials were begun. On each trial a click was made (in predetermined order) with a toy "cricket" next to the right or left ear of the subject, who was lying on her back. Two observers independently recorded whether the eyes (whose movements were fully coordinated) moved to the infant's left, to the infant's right, or not at all, in response to each click.

As soon as the first click was made, the neonate, who had been crying with eyes closed, stopped crying, opened her eyes, and turned them in the direction of the click; it was clear to both observers that the movements occurred in response to the click. At about eight trials per minute, 52 successive trials were undertaken; the series was discontinued because the subject "lost interest," adapted, or satiated, in the sense that no further eye movements occurred in response to the clicks. When the experiment was over, the subject was only 10 minutes old.

The observers agreed substantially. On only one trial did they disagree on the direction of eye movement; on six trials, one observer recorded an eye movement while the other recorded none. There was perfect agreement on the remaining 45 trials; in 23 of these there was no eye movement. For 22 critical trials in which the observers both reported eye movement in the same direction, 18 were in the direction of the click and four in a direction opposite to the click. The difference between this distribution and chance (11 and 11) is significant at better than the .01 level by binomial expansion or by *t*-test based on the standard error of a proportion.

Although psychological experiments are usually performed on a fairly large number of subjects, the original informal observation, and the statistical results (as well as the unquestionable response in the first trial) in the present more systematic replication, appear sufficient to make the point. Within 10 minutes after birth, rudimentary directional auditory localization is possible; so is directional oculomotor (perhaps visual?) response. Moreover, at least on a reflex level, a rough coordination between auditory space and visual (motor) space can be observed. This finding is not compatible with the view that space perception, and particularly cross-modal spatial coordination, is based upon a long and arduous learning process (*3*).

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3. I am grateful to Miss Kathi Lorraine Guertin, the subject; Mr. Frank Guertin and Mrs. Carol Joyce Guertin, the subject's parents; Dr. Gerald W. Lockwood, the obstetrician who delivered the subject; Dr. Victor C. Raimy, who provided hypnotic anesthesia and served as second observer; and the staff of the Community Hospital in Boulder, Colo.

22 June 1961

Stimulus Generalization of Imprinting

Abstract. Chicks were imprinted with a bluish object, then tested with different spectral values ranging to yellow-green. A systematic decrement in following was related to the stimulus series, although there was considerable generalization to all test values, which increased during testing. These data lead us to question the "irreversibility" of imprinting.

Lorenz (*1*) was the first to describe imprinting. He wrote of it as an "object-acquiring" process manifested by the behavior of an organism following the "acquired" object. The acquisition of this response occurs early in the life of the organism (typically, domesticated fowl) during a critical period, at which time the animal will follow the first moving object to which it is exposed. For Lorenz, the imprinting process is "irreversible" in that (i) the first object to elicit the following response becomes the only one capable of doing so, and (ii) this acquired behavior is never forgotten.

The first aspect of this "irreversibility" deals with response specificity, implying minimal generalization of the following response to stimuli other than the "acquired object." Moltz (*2*) points out that there is a lack of adequate research on this. In the relevant studies done by Jaynes (*3*) and by Hinde, Thorpe, and Vince (*4*), the training and test objects differed in several physical dimensions, and there was no systematic investigation of generalization with a series of values on a physical continuum.

The purpose of the present research was to investigate stimulus generalization of the following response on the spectral dimension in a manner similar to the study of generalization gradients for other kinds of acquired behavior. This continuum has been used extensively to study generalization of keypecking in the pigeon (see, for example, *5*).

Five domestic White Rock chicks were used. These were selected from a larger number; those that failed to imprint to the training stimulus were discarded. All chicks were hatched in the laboratory and raised in individual brooder compartments for the duration of the experiment. The training device was in the form of a circular runway, after Hess (*6*). The stimulus object was a glass porch globe 6 inches in diameter, which was suspended 2 inches above the floor of the runway and revolved with a 16-inch radius around a central post. The sphere was illuminated internally by a tungsten-filament bulb which was surrounded by a Kodak Wratten gelatin filter also placed inside the globe. Six different filters were used, having dominant wavelength values of 470, 486, 501, 520, 534, and 555 mμ. For the human observer, these values range from violet-blue to yellowish-green. The brightness of the stimuli were equated for a human observer by using lamps of different filaments and controlling the voltage. Immediately above the globe was a transistor radio speaker which played a tape recording of the experimenter's voice repeating "Come, chick, chick, chick, chick."

Approximately 16 hours after hatching, each chick was placed in the apparatus next to the globe, illuminated by light of 470-mμ wavelength, and was trained to follow the globe by a procedure analogous to successive approximations. The globe was moved by hand back and forth as the chick followed it around the runway for a 30-min session. On the three subsequent daily training sessions (17 min each), the globe was moved automatically in a timing sequence of 6 sec of movement alternating with 12 sec of rest. The globe traveled around the runway about five times at an approximate speed of 1 inch/sec.

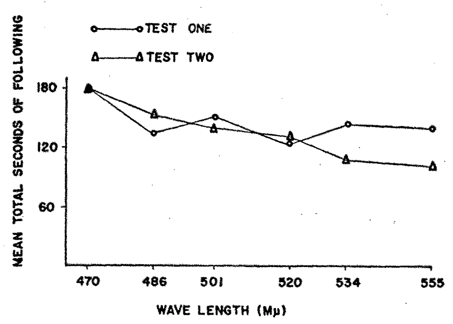

Fig. 1. Mean generalization gradients for subjects imprinted at wavelength 470 mμ.

Days 5 and 6 were generalization testing sessions. The chicks were first exposed to the 470-mμ light for 5 min of further training and then all six stimulus values were presented in a different random order for each bird for 3 min each. Day 6 was the same as day 5 except that the sound was turned off during testing. Following behavior was measured in terms of the number of seconds that the chick was within 1 foot of the sphere.

By the end of training, all subjects consistently followed the stimulus of 470-mμ wavelength. The generalization of following to other values on the test days is shown in Fig. 1, where the mean time (in seconds) of following (out of the possible 180 sec) is plotted against the wavelength of the test stimulus. Perfect following was obtained for the training stimulus. A decrement is observed for other values, and, particularly on test 1, this decrement is systematically related to the difference between training and test stimuli. In general, there was more following on test 2, which shows that the presence of the sound was not critical in eliciting following during testing. Both parametric and nonparametric analyses of variance (treatments × subjects design) indicated a significant generalization decrement at the .05 level of confidence for the combined data of the 2 days of testing and at the .10 level for the first day alone. The experimeter noted "distress cries" uttered at some time to all testing stimuli except the training value, which typically elicited "contented chirping."

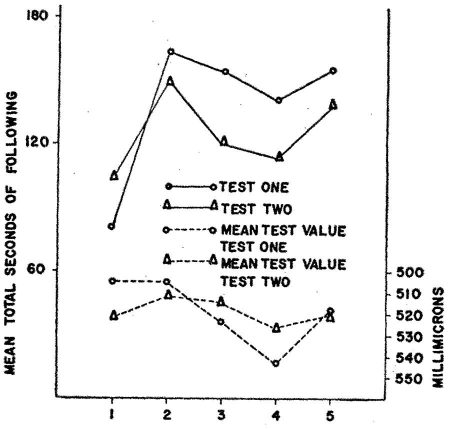

Fig. 2. Mean following scores and mean test stimulus values in order of stimulus presentation, excluding the training value (470-mμ wavelength).

In Fig. 2 the scores for following are analyzed with respect to order of presentation of test stimuli, disregarding stimulus values. The test trials on which the training stimulus was presented are omitted here. The lowest scores were obtained on both days during the first test period, after which there is an abrupt increase. There is generally more following on test 2. This increase in the amount of following over time, both within and between test days, indicates a loss of specificity of the following response to the "acquired" object. To determine whether the form of the curves in Fig. 2 is due to the test values randomly assigned to different test periods, the mean test values for each period are also presented. While there is some correspondence between the following scores and the mean test values for periods 2 through 5, the low scores obtained on the first periods are not accompanied by mean test values particularly remote from the training stimulus.

This study demonstrates that imprinting generalizes decrementally on a stimulus continuum. In this way it is similar to many other kinds of acquired behavior, and certainly no more specific. In fact, the obtained gradients are flatter than those obtained for the same continuum for key pecking in the pigeon (*5*), where the response rate falls to near zero over a similar range of stimulus values. In our case, the gradient appears to flatten out on test 1 at about 60 percent of the score obtained for the training stimulus. It may be, of course, that we have not isolated a crucial characteristic of the stimulus object, and that changes in shape, size, or speed of movement would lead to a greater decrement. On the other hand, it is known (Schaefer and Hess, *7*) that neonatal chicks can discriminate among colors. If the "object-acquiring" process was very specific, a steep generalization decrement would be expected for *any* discriminable aspect of the imprinted stimulus.

The over-all increase during the course of testing presents a difficulty for the assessment of generalization gradients, since this effect is confounded with stimulus difference to flatten the gradient. It would be advisable to use shorter testing periods and to balance test values systematically with regard to order of presentation. But the development of following behavior to other stimuli than the training value supports the evidence from the generalization gradient that leads us to question any extreme specificity of the "object-acquiring" process (*8*).

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4 August 1961

Identification of Small Animals by Proximity Sensing

Abstract. Individual deer mice are identified by magnetic proximity sensing. Approach of an animal wearing a small ferromagnetic collar unbalances an excited inductance bridge which triggers recording circuitry. In conjunction with conductance proximity sensing, the techniques can identify four individuals. Some results on the tendency of two females to follow one another are cited.

Studies of social interactions among small animals have been hampered by lack of techniques for automatic identification of individuals. Limitations are particularly serious for studies of nocturnal animals. Past work with these has hinged either on laborious direct observation or upon observation of end positions (*1*). The identification methods described herein depend upon the detection and differentiation of small metal collars by proximity switches. Since we have used ferromagnetic sensing most extensively, it has been selected for detailed illustration.

A general program of our laboratory has been to develop techniques that enable a broad spectrum of behavior of small animals to be monitored automatically for long periods (*2*). The behavior of a pair of female deer mice, *Peromyscus maniculatus*, has been studied in detail, first the behavior of each animal individually, and then the behavior of both in consort. Ferromagnetic proximity sensing enabled a large fraction of the combined activity to be assigned to one individual or the other.

The chief prerequisite of an identification station (Fig. 1*A*) is that the animals must approach to within about ¼ inch of the sensor face (*a* in Fig. 1*A*). The station illustrated penetrates the sidewall (*b*) of an experimental enclosure and dovetails into the cut-out area of a partition (*c*) which divides the enclosure into two compartments. Animals are identified during passage between these compartments, one of which contains the nest, and the other an activity wheel and food and water. This single station gives a high degree of individual activity assignment.

The ferromagnetic method utilizes a magnetic proximity sensor (Honeywell #SB84A), the pick-off element of which is a two-pole excited inductance bridge. Near approach of ferromagnetic material reduces the reluctance of the flux paths linking the coils of the bridge, thereby unbalancing it. The resulting signal triggers recording circuitry. Ferromagnetic collars each consist of two open 0.3-g rings of 0.035-inch soft iron wire closed snugly about the animals' necks. Nonferromagnetic dummy collars are made of soft copper wire.

The magnetic proximity sensor (*d*) comprises a portion of the wall of a circular passageway (*e*) counterbored into two matched ¼-inch-thick Plexiglas plates (*f*). A shutter (*g*) of 0.045-inch stainless steel rotates upon a ball bearing (*h*) press-fitted into its arm. This bearing fits lightly upon a ⅛-inch shaft (*i*) through the plates (*f*). A recess milled into the plates' inner surfaces provides pivoting freedom for the shutter, which occludes all but a semilenticular area of the passageway adjacent to the sensor. To effect passage, the animals simply brush aside the shutter (which gives way easily), necessarily apposing their collars to the sensor face (*a*).

Self-cutoff circuitry is employed to reduce any possible disturbance of the animal that might be caused by magnetic attraction of the collar in the field of the sensor coils. Thus, the sensor and amplifier (Honeywell, No. R7107A or R7110A) are not energized until the shutter is lifted, which closes the shutter microswitch (*j*) by cam action (*k*). The transistorized amplifier and sensor are armed instantaneously (see Fig. 1*B*) through the normally open terminal of this microswitch (microswitch No. BZ-RW8435). Upon being triggered, the amplifier disarms itself and the sensor within 35 to 50 msec by negative feedback involving a rocker-arm impulse relay (Potter & Brumfield, No. PC11A). Upon firing of this relay, a first pathway in series with the normally open terminal of the microswitch is opened, with concomitant closing of a second pathway in series with the normally closed terminal. When the shutter closes, after the amplifier relay has been triggered, a potential is applied through the normally closed terminal of the microswitch (in series with the now closed second pathway) to the coil of the impulse relay. Refiring of this relay reestablishes the normal series pathways. Thus, field effects are limited to a small fraction of a second, which turns out to be negligible in practice.

Each opening of the shutter is recorded by one channel of an Esterline-Angus 20-channel event recorder and counted by a parallel Veeder-Root magnetic counter. Each triggering of the sensor is recorded on an adjacent channel and counted on a second counter (Fig. 1*C*). Thus, scoring of a passage by both channels and counters identifies the animal with the ferromagnetic collar; scoring by only one channel and counter identifies the other occupant. Passages are sufficiently frequent that strip-chart recording without auxiliary digital printout should be at a chart speed of not less than 1 foot per hour.

An illustrative record of passages of two mature female deer mice between enclosure compartments is reconstructed in Fig. 1*C*. As an example of information obtained by using this identification technique, some findings on the tendency of these animals to follow one another to and from the nest are cited.

During a 1-week period, animal A (iron collar) entered the empty nest 60 times; animal B (copper collar), 189 times; unidentified, 14 times. In the same period, A left the nest when both