of this design and all show the same sour-bitter responses to subadapting concentrations of sodium chloride.

The results of this study indicate that the taste of water and weak sodium chloride solutions depends on prior adaptation. Ordinarily the tongue is adapted to saliva, which in man contains relatively low concentrations of salt (*7*). Thus, when the tongue is adapted to saliva, it is near the lower limit of the adapting level at which it is possible to get the subadapting taste. This appears to be one reason for the fact that water usually tastes flat or nearly tasteless. It is likely that other salivary constituents contribute to the "normal" taste of water in the same manner as sodium chloride. Whether distilled water normally tastes bitter may be related to individual differences in salivary constituents or differences in sensitivity to change from saliva. In addition, if the electrophysiological data are representative of the neurophysiology of human taste, it would seem that a decrement in peripheral neural activity is sufficient to code a sensation. However, if neural activity is not completely abolished by water, the signal could be the decrement itself or it could be a change in the pattern across all fibers.

The sour-bitter taste of water after adaptation to sodium chloride may be a gustatory afterimage analogous to visual afterimages. Preliminary observations confirm reports in the older literature that, after adaptation to other chemicals, water has other very definite qualities of taste. After tasting citric acid or quinine hydrochloride, water tastes sweet and after sucrose it tastes sour-bitter (*8*). Although the possibility of an opponent taste theory seems attractive, the evidence thus far does not suggest immediately obvious complementary tastes.

LINDA M. BARTOSHUK
DONALD H. MCBURNEY
CARL PFAFFMANN
Psychology Department, Brown University, Providence, Rhode Island

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Behavior of Infant Monkeys: Differences Attributable to Mode of Birth

Abstract. *A comparison of behavior of infant monkeys shortly after birth reveals differences in reactivity which can be related to the route of delivery, whether vaginal or cesarean section. The depression of behavior in the surgically delivered infants persists through day 5 postpartum and ultimately appears as lowered conditionability. Anesthetics or other drugs are not causal factors.*

Although the conditions surrounding the event of human birth are not conducive to a delineation of causal relations, the impression prevails that the early behavior of the infant delivered by cesarean section differs from that of the infant born vaginally. The usual description of these differences (*1*) emphasizes greater lethargy, decreased reactivity, and less frequent crying in the surgically delivered infant.

This report describes the early behavior of two groups of infant monkeys (*Macaca mulatta*), one group of 13 born by spontaneous vaginal delivery and one group of 13 born by cesarean section. With the exception of three of the vaginally delivered and one of the surgically delivered infants, the gestational ages at birth were known accurately to within 48 hours (*2*). The gestational ages of the four conceived prior to the captivity of the mothers were estimated by palpation immediately before delivery.

Surgical delivery was accomplished with a paramedian incision under local anesthesia. The animal, supine on the operating table with arms and legs outstretched, was first prepared for aseptic surgery and then anesthetized by the infiltration of 10 to 12 ml of a 1-percent solution of lidocaine hydrochloride (*3*) around the site of the incision. Care was taken to keep the size of the incision very small, to infiltrate and section separately each of the layers of the abdominal wall, and to manipulate the uterus only to the extent of delimitation and avoidance of the placenta. Under these circumstances surgery proceeded as rapidly as possible and the infant was delivered 30 to 45 minutes after the start of the preparation of the mother. Although other experiments dictated the date of surgical delivery, these did not complicate the conditions of the birth or the measurements of behavior made thereafter. Pertinent data on the two groups of monkeys are given in Table 1.

The vaginally born infants were placed in the laboratory nursery immediately after the birth was detected. Thus there was in this group a varying period of contact with the mother. The infants delivered by cesarean section were transferred immediately after delivery to the nursery. No infant, delivered by either means, showed signs of physiological duress or any other dysfunction when first placed in the nursery. For the first 5 days of life (the period covered in this report), the infants were maintained in pediatric incubators with an air temperature of about 32°C and an oxygen concentration of about 40 percent for the first 24 hours. The infants were fed a 10-percent glucose solution for the first 24 hours, a diluted proprietary formula for the next 24 hours, and a concentrated formula thereafter. All feeding was at 2-hour intervals from 7 A.M. to 3 P.M. and at 4-hour intervals to 11 P.M. Testing of behavior began 2 to 10 hours after birth and lasted up to 2 hours.

The infant was placed in a small chamber (*4*) equipped with a stainless-steel grid for electroshock, house light for general illumination (0.126 lu/m^2), a loud speaker for the presentation of the conditioned stimulus (a tone of 3000 cy/sec at 75 db; 40 db ambient stimulation), a 50-ohm loudspeaker modified for the pickup of vocalizations, and two ceramic transducers for the creation of an ultrasonic field and the recording of general activity (*5*). The recording of general activity and vocalizations was begun immediately after the subject was introduced and the programming and filtering equipment was made ready. If the infant did not vocalize for 15 seconds, an interval timer was activated; if the infant did not vocalize within 45 seconds, the conditioned stimulus (CS) was presented for 5 seconds, followed by the onset of electroshock (US, 1.0 ma). If the subject vocalized after the initial 15 second-interval, during the 5 seconds of the CS, or during the interval when the CS and US were presented together, the stimulus sequence ceased and the programmer was interrupted for another 15-second interval. This sequence was repeated until 25 presentations of the CS had taken place (a minimum of about 19 minutes). In the initial session, the infant vocalized frequently, at 2- to 3-second intervals, and delayed the first CS presentation by as much as 45 minutes. When the CS did occur, the infant responded immediately. Later in the first session and throughout the last sessions, the infant vocalized only at the presentation of the CS (not necessarily at the onset) or at the onset of the electroshock. Clearly, the vocal response to the first presentations of the tone was one of sensitization; later in the last presentations and throughout the last sessions, the response was fully instrumental in nature, either escape or avoidance. The data recorded were: activity counts, number of vocalizations, number of presentations with the CS followed by the US (escape responses), and the number of trials with the CS not followed by the US (avoidance responses).

The behavioral differences between the 13 cesarean-born and the 13 vaginally born infants regarding total activity, number of vocalizations, and number of avoidance responses were all highly significant, as indicated in Table 1. The vaginally delivered infants were more active, more responsive to the situation, and more responsive to additional stimulation within that situation. (Further analysis of these data after logarithmic transformation to remove the obvious heteroscedasticity did not vitiate the significant differences between the groups.)

Additional data were collected on nine of the vaginally delivered and seven of the cesarean delivered monkeys on days 2 through 5 postpartum. Graphic presentations of the significant aspects of these data are given in Fig. 1. The differences in activity reported for the 1st day persisted over the next 4 days as well ($p < .025$). The increase in activity over this interval was not significant. Vocalization differences were evident over this period ($p < .05$) although, once again, progressive changes were not statistically significant. The most striking difference between the groups of vaginally and surgically born infants was in the number of avoidance responses ($p < .001$). Both groups, moreover, showed consistent changes over the 5 days of repeated testing ($p < .025$). In both groups responsiveness to the CS on the 2nd day was diminished but it increased sharply thereafter. As indicated by individual performances and trends within a given day, however, on only the 4th and 5th days did the vaginally born infants show what might be construed to be true conditioned avoidance responses, that is, the beginnings of a learning process. This phenomenon was not shown at this age by the infants born by cesarean section.

Because of two aspects of this experiment the conclusions presented might require qualification. However, a review of the pertinent literature and a closer scrutiny of the data show that these qualifications are unnecessary. First, the nature of the surgical procedure, particularly the restraint of the gravid female, could impose a noxious condition on the fetus related to the stress on the female (*6*). Yet, when similar but more severe trauma has been imposed on other groups of infant macaques, techniques such as those used in this study have failed to differentiate them from appropriate controls. Second, although the mean gestational ages of the two groups do not differ significantly, the greater gestational age of the monkeys delivered spontaneously may contribute to the other significant differences between this and the surgically delivered group. A test of this possibility, perhaps the only one logically and logistically feasible, is the separate correlation of gestational age with performance for the vaginally delivered and surgically delivered infants. None of the rank-order correlations (*7*) so computed differed significantly from zero, nor did any of the like correlations of the two groups differ significantly from each other.

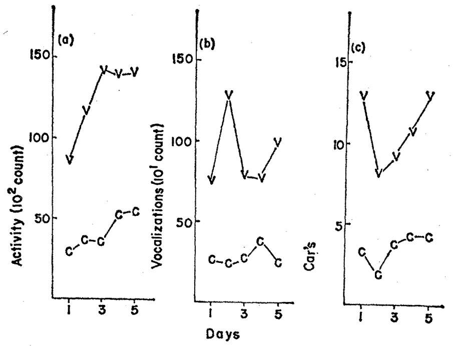

Fig. 1. *a*, Mean activity of the vaginally delivered ($N = 9$) and surgically delivered ($N = 7$) monkeys. *b*, Mean vocalizations of the two groups. *c*, Mean avoidance responses of the two groups. (All means are for the first 5 days of life.)

Several mechanisms may explain the behavioral differences indicated in this report. The first, deemed the most obvious, is the secretion of a chemical agent that acts in an excitatory fashion, either stimulating or arousing the infant. This agent is produced in the normal vaginal birth process. A second is a hormonal agent that has a generally depressing effect. It is naturally produced during pregnancy but it diminishes in amount with the approach of parturition. Whatever the mechanism may be, it will have to reflect the time factors of pregnancy at one extreme and of parturition at the other. The agent or composite of agents must be produced in quantity, effective at the time of birth and for some interval thereafter (much longer than the 5 days covered in this report).

Birth by surgical means induces such an effect on the behavior of the infant that the infant so born is much less active and much less readily aroused than an infant born vaginally. The mechanism by which such differences are induced is unknown, but it

Table 1. Biological and behavioral data of two groups of 13 monkeys each on the first day of life. The first value is the mean and the second is the range for the group.

Gestational age (days)	Wt. (g)	Activity (10^2 counts)	Vocalizations (10^2 counts)	Avoidance responses
Cesarean delivery				
156.1	488.9	31.2*	25.5†	4.5*
150–165	388–700	10.1–78.3	5.1–73.4	1–15
Vaginal delivery				
161.1	468.5	92.3	76.9	11.3
135–171	292–562	11.4–204.2	7.3–167.5	5–19

* $p < .001$. † $p < .005$.

may be maternal and endocrinal whereby a hormone having an effect on arousal varies predictably in quantity toward natural parturition. That the behavioral effect is later seen as a conditioning deficiency is noteworthy; the duration and long-range significance, however, are presently moot questions.

GILBERT W. MEIER
National Institute of Neurological Diseases and Blindness,
National Institutes of Health,
San Juan, Puerto Rico

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13 January 1964

Vigilance: The Importance of the Elicited Observing Rate

Abstract. *Observing may be elicited by regularly repeated events that occasionally become signals. Such events were presented at rates of either 5 per minute or 30 per minute, and signals averaged 15 per hour during an 80-minute vigil. Observers missed about 10 percent of the signals with the low event rate and about 70 percent of the signals with the high event rate. The experiment supports a decision-theory approach to observing behavior.*

A major problem in the experimental analysis of human vigilance is to account for the decline in the probability of detection of rare and weak signals during a prolonged vigil. This decrement is certainly due to failures of attention rather than to sensory changes. In the literature on vigilance (*1*) these failures of attention are usually considered as necessary effects of the passage of time. However, it is possible that failures of attention occur only if attending is elicited and then not reinforced, and the main role of the passage of time might be to permit unreinforced observing responses to occur (*2*).

The latter view is part of our present approach to vigilance (*3*), in which we consider attending to be the effect of an observer's decision about whether or not to observe. This approach implies that the demand on a subject's observing behavior is more important than the low rate at which the signals are presented or the mere passage of time as a cause of the decrement. The experiment described here tested this possibility.

Subjects were seated without restraint so that they viewed a recessed display from a distance of about 75 cm. They monitored it continuously for 80 minutes, and signals were presented at the average rate of 15 per hour. With these factors constant, the experimental variable—the elicited observing rate—was manipulated by working with two different rates of regularly recurring events that at rare intervals became the signals. The events were presented at the rate of either 5 or 30 per minute. The event-presentation rate was equivalent to an elicited observing rate because a subject was required to do no more than observe the regularly repeated events in order to detect signals. Observing was, therefore, elicited only when an event was presented.

An event was produced by the apparent movement of a bar of light, 2 mm wide by 18 mm high. The complete event was a pair of movements in which the bar moved 29 mm to the right, snapped back to its zero position, again moved to the right, and again returned to its zero position. The movement was generated by successively lighting small, and appropriately spaced, diffusing screens. The light bar was switched to the deflected position where it remained for 0.41 second, returned to the zero position for 0.38 second, moved again to the deflected position for 0.41 second, and again returned to the zero position where it remained during the ensuing "inter-event" interval. The times when no bar was illuminated were negligible and were associated with the rise and decay times of the 6-volt alternating-current (No. 47) tungsten bulbs that were the light sources.

A high event rate of 30 events per minute was produced by making the interval between events 0.8 second, and a low event rate of 5 events per minute was produced by making the interval 10.8 seconds.

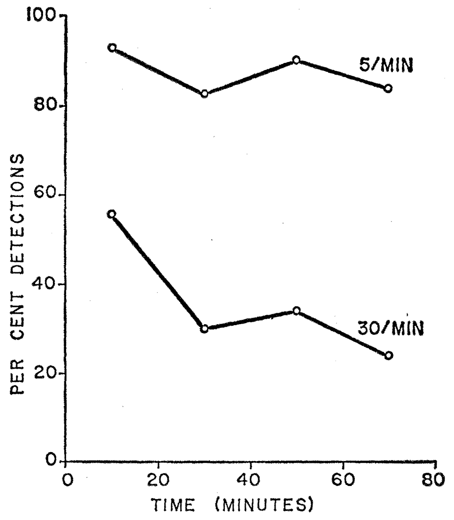

Fig. 1. Effect of event rate on detection of signals during successive 20-minute periods of an uninterrupted 80-minute vigil. Events to be judged as signal or nonsignal were repeated at the rate of either 5 or 30 per minute, and this variable differentiates the two curves. Average signal frequency was constant at 15 per hour. Each point is based on 60 signals.

The signal was an increase in the length of the second deflection within an event from 29 mm to 35 mm. This was an easy signal for an alert observer to detect. Under a two-alternative, forced-choice psychophysical procedure it was essentially always detected correctly. Subjects operated a switch to indicate that they saw a signal.

In the vigilance task, signals appeared at successive intervals of 4.4, 6.0, 5.6, 1.9, and 2.1 minutes during the first 20 minutes. The signal program was repeated four times to provide 20 signals during an uninterrupted 80-minute vigil. The signal schedule was identical for the high and low rates of event presentation. If an observer missed a signal it was repeated until detected in order to insure an equal number of reinforced observing responses for all subjects.

Twenty-four male student volunteers, working individually and alone, were used as subjects, 12 for each event rate. Instructions were presented by tape recording, and a short practice period with three or four signals was part of the procedure. The 80-minute vigil was begun after it was ascertained that the subject could identify the signal readily at its first appearance during the practice period. During both the practice period and the vigil a 73-db white noise was broadcast over a loudspeaker to mask cues from the automatic programming and recording