METHODS & DESIGNS

A method for studying visually guided perception and learning in newborn macaques*

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A maintenance technique was developed in which neonatal monkeys obtain all liquid food by placing their heads in a face mask mounted on their cage wall. Complete self-feeding required only 3-6 days for animals started at birth. Once under a self-feeding schedule, operant responses were shaped to study visual perception, visually guided motor performance, and discrimination learning at ages much younger than those allowed by most alternative methods. Dark rearing, with the only source of visual input being through the face mask eyeholes, allowed the E to control completely the neonate's visual experiences and its opportunities for visual-motor responding. The method has proven useful in rhesus monkey newborns for studying adaptation to prismatic displacement at 30 days of age, and to performance on CRF, FI, and FR reinforcement schedules.

The developmental study of perception and learning in newborn and very young animals and humans has received intensive investigation only in recent years. This work relies primarily on reflexes, unlearned responses, and physiological indices to measure the reactions of very immature organisms in controlled stimulus situations. This may include the short-term or longitudinal investigation of suckling parameters, orientation toward stimulus sources, stimulus preferences, visual cliff or imprinting responses, or changes in heart rate, respiration, or evoked cortical potentials. In nonhuman primate newborns, even these techniques have rarely been employed; and studies using free behavior or instrumental learning response indices to measure perceptual and intellectual functioning are all but nonexistent. Exceptions include work by Fantz (1965), studying stimulus preferences to index perceptual ability, and by Zimmerman & Torrey (1965), utilizing approach to surrogate mothers to measure discrimination skills.

One reason for the relative lack of information on young primates is the obvious motor incoordination present for 2-4 weeks after birth. In part to circumvent this problem, several investigators (Held & Bauer, 1966; Riesen, 1960) have employed sensory deprivation techniques in studying perceptual development. Although this approach has generated valuable information, it has a major drawback in that sensory deprivation in infancy can produce neuroanatomical and biochemical abnormalities. The material in this paper provides a novel method for studying the normal development of visual perception and visually guided learning in macaque monkeys, without resort to sensory deprivation. The technique can generate reflex, unlearned, and preference reaction data as a function of controlled input from the first day of life; and it can generate visual-motor and learning response data under free behavior conditions by the third to sixth day of life.

BASIC TECHNIQUES

Apparatus

The apparatus is shown schematically in Fig. 1. It consists of a fiberglass or plastic mask of a baby monkey face, mounted on one wall of a standard nursery cage. For newborn rhesus monkeys *(Macaca mulatta)*, the "face" is 7.6 cm high and 5.1 cm wide.

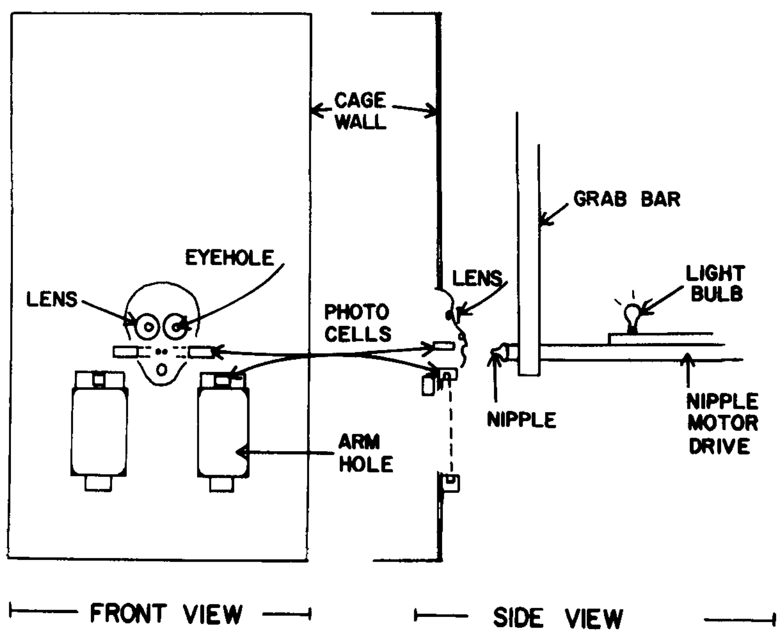

Fig. 1. The mask feeding apparatus, showing configuration used in the demonstration experiments on prism displacement reaction and operant learning of neonate rhesus monkeys.

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The mask is prepared by molding a plaster cast from a full-term cadaver. This cast is then used to form fiberglass masks. Alternatively, a simple "Vacu-form" device can be purchased in toy stores, or can be constructed in the laboratory, to blow-mold the face masks. The procedure consists of making a negative face form slightly larger than the desired final product. Any type of plastic sheet material is heated in an oven, and quickly squeezed between the negative form and a plate with an air hole in the middle. Air pressure (30 lbs) is applied, which blows the plastic into the mold.

In our applications to date, the mask was mounted on runners, allowing adjustment of height above the floor. Photocells in the mask detected the presence of the neonate's face. Alternatively, electronic contact relays mounted on chin, forehead, and/or cheek areas can be used to detect entry into the mask. Armholes, cut below the mask, allow the neonate to reach outside the cage without taking its face from the mask. Photocells detect reaching by the neonate through the armholes.

A Pet Nurser nipple (Polynurser Products Corporation, Brooklyn, New York), connected by a polyethelene tube to a milk reservoir, was mounted on a motor-driven shaft. When activated, the motor drove the nipple through the mask mouthhole, allowing the neonate to suck. Other arrangements for retracting the nipple included a solenoid-operated lever, which displaced a nipple attached to the lever end through a distance of 1.3 cm, sufficient to gain entry into the mouthhole and to retract the nipple far enough so that feeding was not allowed. A final method for controlled feeding included fixing the nipple in the mouthhole and delivering milk under control of a fluid-flow solenoid. Any of these arrangements allows the E to deliver milk ad lib, under E-controlled schedules, or under control of responses made by the neonate. Such responses have included simple placement of the face in the mask, reaching through armholes, and reaching through the armholes and touching a stationary or moving target mounted in, or outside of, the visual field. It would also be possible to deliver milk as a function of other responses. These could include nipple-sucking parameters, eye position or eye movements detected by electronic devices or by an observer, or physiological parameters such as heart rate, respiration, or EEG.

Mask Training

During the first 3-5 days of life the neonate must be positioned in the mask by an attendant. For macaques, this is usually done every 2 h. Once positioned, the neonate usually supports itself by grasping handles that are mounted on the cage wall above the armholes. Experience with four neonates suggests that complete self-feeding can be reached 3-6 days after birth if the neonate is started on Day 1. Under usual nursery procedures (Blomquist & Harlow, 1961), complete self-feeding does not occur until 10-21 days of age. Therefore, the mask feeding technique is not only of value for behavioral studies, but also has the practical result of greatly easing problems of 24-h neonate care in a newborn nursery.

Testing Procedures

Although the specific stimulus characteristics of the cage environment will, of course, depend on the needs of the particular experiment, several procedures have been utilized in our laboratory. Complete control over visual and visual-motor input *during behavioral tests* has been achieved by completely enclosing the mask cage with opaque walls. During a test, the neonate sees no stimuli other than objects in the cage and those placed in the visual field of the mask eyeholes. All visual-motor experiences with E-controlled stimuli are attained by reaching responses through the armholes directed toward objects in, and outside, of the mask visual field.

Complete control over *all* visual and visual-motor input has been achieved by making the cage interior completely dark. The only visual stimulation occurs when the neonate's face is positioned in the mask, and the only visually guided responses available to the neonate occur when it reaches through the armholes for objects in the mask visual field. This procedure allows precise knowledge, and control over, all visual-motor input available to the monkey.

Cage darkening has two secondary advantages. First, studies can be conducted on Ss who are functionally deprived of visual experience, but allowed sufficient diffuse or patterned input through the eyeholes to offset physiological abnormalities. And this can be done without having to affix materials to the animal's eyes or sewing the animal's lids closed. Secondly, the fact that mask responding provides the sole source of visual stimulation produces a high degree of exploratory-curiosity motivation. This, along with hunger, facilitates self-feeding at early ages and yields large time periods during the 24-h day when the baby has its face in the mask. One female, placed into the cage at 3 days of age, spent 4-8 h per day with her face in the mask by the sixth day of life. Only about 2 h of this time were actually spent ingesting milk. This means that many self-paced, perception, or learning trials can be run each day, rather than the relatively few daily trials that are available in most alternative methods that are easily confounded by activation state problems.

PILOT STUDY 1: RESPONSE TO PRISM DISPLACEMENT

An important problem in the study of visual-motor development concerns the ability of neonates to adapt to distortion or displacement of visual stimuli from their veridical position in space. This issue is central to questions about learned vs unlearned aspects of perceptual functioning (Held & Bossom, 1961). The present demonstration was addressed to this question. We asked if the mask technique could detect visual-motor "error" in responding to target displacement produced by prisms mounted in front of the mask eyeholes.

Procedure

A female rhesus monkey was put, on the third day of life, into the mask cage situation illustrated in Fig. 1. Throughout the experiment, the cage interior was completely dark. The nipple was always available during the first 24 h. A caretaker placed the neonate's face in the mask every 2 h during this time. The sole light source came from a 6-V bulb mounted 20.3 cm from the eyeholes, directly in back of the feeding nipple. The bulb was turned on whenever the S's face was in the mask. This allowed sight of a 7.6 x .6 cm stainless steel bar ("Grab Bar," Fig. 1), the nipple drive shaft and motor, the light bulb, and the ceramic bulb mounting fixture.

The 2-h caretaker assistance schedule continued until the S became self-feeding. The self-feeding criterion was ingestion of the same amount of milk from the mask feeder without caretaker aid, as the neonate had taken during bottle feedings prior to introduction into the apparatus. For this S, the criterion was reached on Day 4 of life, 19 h after introduction to the cage.

The nipple was no longer available ad lib when the neonate was 7 days old. To get the nipple, the S had to put her face in the mask for a 2-sec period. It took 2 h for the S to learn to do this. On Day 9 a new contingency was added. The baby had simultaneously to have her face in the mask and her arm through one of the armholes. Either a face-hand or a hand-face response was sufficient to produce the nipple. Two hours were required to learn this contingency.

At 30 days of age, the grab bar response was added. The baby had to have its face in the mask, arm through the armhole, and touch the grab bar. The grab bar was in a contact relay circuit, and was mounted 6.4 cm from the armhole, with the tip at eye level, at a 15-deg angle to the right of center in the visual field. The baby learned to feed under this contingency within 1 h of instigation of the procedure.

From the start of these procedures, on Day 3 through Day 30 of life, this neonate had weight gain within 1 SD of the mean for laboratory normative female data.

Nine days after initiating the grab bar response, two 0-deg prism lenses were placed over the mask eyeholes. This condition continued for 24 h. Next, two 18-deg, base right, prisms were placed over the eyeholes. This produced a 1-cm displacement of the grab bar to the left of the veridical position. This procedure continued for 6 days. Unfortunately, response to removal of the displacing lenses was not tested, as the infant had to be removed from the cage on immediate notice to a commitment in another study.

Throughout the experiment, mask, handhole, and grab bar responses were sampled once per minute every 15 min, 24 h per day. For the first and last hour of the 0-deg lens condition and the first hour of the 18-deg condition, the distribution of mask, armhole, and grab bar responses was measured continuously in real time.

Results and Discussion

During the 45 days in the apparatus, the S spent a total of 10.38 sec/min, over all 15-min periods sampled, with her face in the mask. Statistically reliable ($p < .05$ by t tests) differences in mask time were found as a function of the mask lens conditions. The last hour of the no-lens conditions ($\overline{X}$ time with face in mask per minute = 12.69 sec, SE = 2.05) had higher mask time than either the 0-deg ($\overline{X}$ = 7.47 sec, SE = 1.63) or 18-deg ($\overline{X}$ = 6.97 sec, SE = 2.10) prism conditions. The latter two conditions did not differ reliably.

Latency measures for the mask-to-handhole and the handhole-to-grab bar responses were analyzed for trials sequenced mask-hand-bar. No differences appeared between Hour 1 of the 0-deg condition and the first hour of the 18-deg condition. The last hour at 0 deg compared with the first hour at 18 deg also revealed no reliable latency differences. However, trials sequenced mask-hand-bar were not evenly distributed over these 1-h blocks. With 18-deg prisms, almost all such trials occurred within the first ½ h. Therefore, 15-min blocks were compared. The mask-to-arm response was faster during the last 15 min of the first ½ h under 18 deg ($\overline{X}$ = .36 sec) than during the first 15 min ($\overline{X}$ = .79 sec), while the latency of the hand-to-bar response was also faster during the last ($\overline{X}$ = .66 sec) than during the first ($\overline{X}$ = 1.32 sec) 15 min (both $p < .15$).

When these 15-min periods during the first ½ h of prism displacement are contrasted with the last 15 min of the 0-deg condition, the prism effect becomes clear. The hand-to-bar latency increased significantly ($p < .005$) from the last 15 min under 0 deg ($\overline{X}$ = .28 sec) to the first 15 min under 18 deg ($\overline{X}$ = 1.32 sec). However, hand-to-bar latency differences were not reliable between the last 15 min under 0 deg and the second 15 min under 18 deg ($\overline{X}$ = .66 sec). Differences in mask-to-hand latencies between 15-min periods under 0- and 18-deg prisms were not significant.

The decrease in overall time spent in the mask when the 18-deg prisms were inserted could be due to a disrupting effect of the prisms on vision. However, since this drop also occurred when the 0-deg lenses were installed, it is likely that general adaptation to the view from the mask produced the decreased mask time under both lens conditions. The data did reveal, however, that introduction of the 18-deg prisms disrupted the smooth reaching response, although the infant did compensate for this disruption within 15 min. This very short time for compensation is accounted for in part by the small displacement produced by the prisms relative to response difficulty. Infant monkey arms are very short, and therefore the grab bar had to be placed very close to the armholes. This not only made the displacement under prisms slight (1 cm), but it also resulted in very fast reaching response latencies (.65 sec or less). Also, visual guidance contributed to fast compensation, as the infant had full view of her hand throughout the prism experience. Thus, given these problems, it is especially cogent that at least some evidence for prism disruption was obtained. Use of a more complex response and/or optical system, functionally increasing the hand-eye-target distance, should produce slower adaptation, yielding opportunity to study many of the adaptation phenomena identified for adults in visual-motor perception.

PILOT STUDY 2: OPERANT LEARNING

A male rhesus neonate was placed into the semidarkened (1 fc) mask cage on the second day of life. On the first 6 days, milk was available ad lib in the mouthhole nipple. The neonate was completely self-feeding by 5 days of age. Operant learning procedures were instituted at 9 days of age.

On the morning of Day 9, the nipple was inserted into the cage when the neonate placed his face in the mask for 2 sec. This resulted in 5 sec of nipple availability. At the end of 5 sec, the nipple retracted from the mouthhole. To obtain another 5 sec of milk, the neonate had to remove his face from the mask, then reinsert his face for 2 sec. Proficiency in these responses was attained within 30 min of the onset of the procedure.

A continuous reinforcement schedule was instituted on the afternoon of Day 9 of life. To gain nipple contact for 5 sec, the neonate had to reach through the armhole and touch a small metal plate. The plate was positioned in the visual field, 5.1 cm from the armhole. All milk was obtained by this plate-touching response until the end of Day 12 of life. On Days 13 and 14 ad lib access to the nonretracted nipple was available.

On Day 15 a fixed-interval 30-sec schedule was introduced. The baby gained 5 sec of access to the normally retracted nipple by touching the metal plate after 30 or more seconds had elapsed since the last rewarded plate response. This procedure continued until Day 20, with all milk delivered in this manner. On Days 21 and 22 ad lib feeding from the nonretracted nipple was given. On Days 23-27 milk was available only on a fixed ratio 15 schedule. Every 15th plate-contact response was rewarded by 5 sec of nipple contact.

On CRF, FI, and FR schedules, all plate contacts producing milk had to be made with the face in the mask. Those plate contacts that occurred with the face not in the mask were not reinforced. During the 25 days in the apparatus, weight gain for this neonate was within 1 SD of male laboratory norms.

Results and Discussion

The results of this demonstration are shown in Fig. 2. Response frequency on the CRF schedule doubled from the first to the second day, with the second day's value being asymptotic. On the FI 30 schedule, response frequency increased dramatically over the CRF values. The number of reinforcements also increased slightly from Day 1 to later days on this schedule, although the very high ratio of rewards to total number of responses suggests that this neonate did not learn to anticipate the end of the 30-sec interval. Thus, this male monkey, at 15-20 days of age,

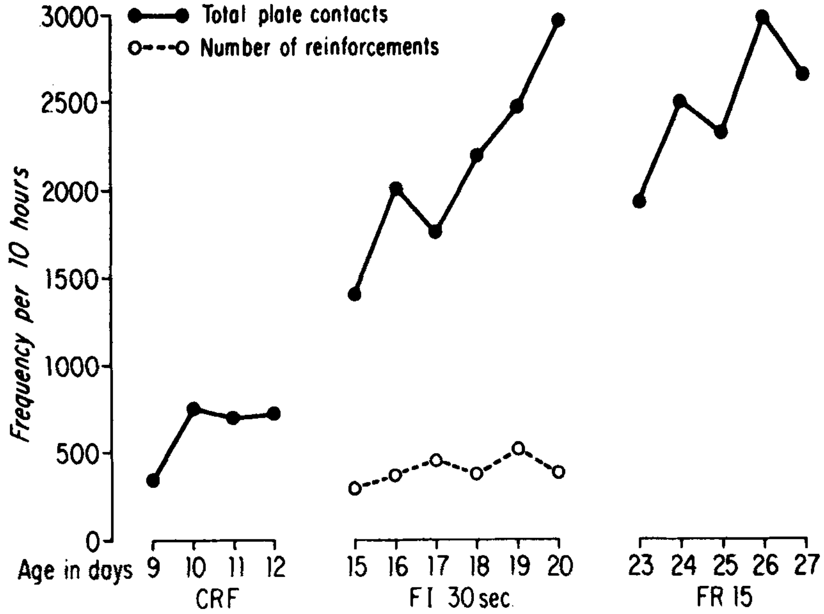

Fig. 2. Operant performance of a neonate male on CRF, FI, and FR reinforcement schedules.

did not show temporal learning characteristics of older animals on FI schedules.

Response on the FR 15 schedule started at a frequency much higher than the original CRF values, but this FR initial frequency was lower than the terminal response level on the FI schedule. FR frequency did, however, increase markedly over days, although it did not exceed the maximal value obtained on the FI schedule.

CONCLUSION

These demonstration data suggest that the mask-feeding technique provides a valuable tool for studying perceptual and learning functions using voluntary response indices—and that such studies can start very early in the neonatal primate's life. The data for these two neonates, and for two others studied in the basic procedure, suggest that coordinated responses, dependent only on the self-feeding ability of the neonate, can be obtained as early as the third day of life. Further, the persistence of neonate behavior in this situation suggests that rapid automated collection of large amounts of data on critical early days of life can be gathered. This data collection, because it occurs in the neonate's home cage, can proceed without major confounding or limitation due to the baby's activity level or state, as trials are numerous even when using self-paced schedules involving only ad lib motivational conditions.

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