JOURNAL OF EXPERIMENTAL CHILD PSYCHOLOGY **64,** 175–198 (1997)
ARTICLE NO. CH962349

High-Amplitude Sucking and Newborns: The Quest for Underlying Mechanisms

CAROLINE FLOCCIA

CNRS-EHESS, Paris, France; and University of Geneva, Geneva, Switzerland

AND

ANNE CHRISTOPHE AND JOSIANE BERTONCINI

CNRS-EHESS, Paris, France

This study seeks to determine whether newborns are sensitive to an operant-conditioning task involving an unprepared relation between a response and a stimulus. The High-Amplitude Sucking procedure, which is based on such a relation by reinforcing nonnutritive sucking with auditory stimulation, was used. In order to verify that newborns learn the contingency between sucks and sounds in the HAS paradigm, three experiments were carried out. In Experiment 1, the effect of contingent versus noncontingent presentation of speech sounds on newborns' sucking activity was investigated during the minutes following a silent baseline. In contrast to what has been reported with 2-month-old infants in HAS, contingently stimulated newborns did not differ significantly from a nonstimulated control group. Experiment 2 showed that an increase in sucking rates could be obtained after a stimulus change, when sounds were presented contingently, but not when sounds were presented noncontingently. Experiment 3 demonstrated that newborns' sucking responses were reinforced by variation in the presented speech sounds. The results of these three experiments support the hypothesis that newborns tested under the HAS procedure are involved in an operant-learning situation. Implications for learning in neonates and possible differences with older infants are discussed.

Numerous studies have investigated primary learning abilities in newborns, including more sophisticated forms of learning such as operant conditioning.

The research described here was supported by grants from the Human Frontier Science Program (''Contrasting Language Phonologies'' project) and the Human Capital and Mobility Program. We thank Jacques Mehler, Stanislas Dehaene, Viviane Pouthas, Brit van Ooyen, Evelyn Hausslein, and the reviewers for helpful comments on earlier versions of the paper. We also thank Jean-Luc Manguin for technical assistance, and Christiane de Beaurepaire and Laure Legendre for their help with data collection. Finally, we are grateful to the staff at the Baudelocque Maternity in Paris for their kind cooperation. Correspondence and reprint requests should be addressed to Caroline Floccia at the Laboratoire de Psycholinguistique Expérimentale, FAPSE, route de Drize 9, 1227 Carouge, Switzerland, E-mail: floccia@fapse.unige.ch.

0022-0965/97 $25.00

The results of these studies suggest that newborns can indeed be operantly conditioned (e.g., Siqueland & Lipsitt, 1966; Lipsitt, Kaye, & Bosack, 1966; Siqueland, 1968; DeCasper & Fifer, 1980; DeCasper & Sigafoos, 1983). The majority of these studies, however, refer to specific situations involving a so-called ''prepared'' relation between the selected response and the reinforcer. As noted by Sameroff and Cavanagh (1979, p. 362): ''Successful results have generally been reported for those response systems that are connected with the biological survival of the newborn, that is, sucking and headturning.'' Examples include head-turning responses rewarded by sucking on a blind nipple (Siqueland, 1968) or by food (Siqueland & Lipsitt, 1966), and sucking on a tube rewarded by the delivery of a sucrose solution (Lipsitt et al., 1966). There are presently however few studies that have established that operant conditioning can be observed in newborns with less privileged response-stimulus associations. Of these few, it has been shown that neonates can react to a contingency between the duration of their intersucking burst intervals and the delivery of potent auditory reinforcers during bursts (e.g., DeCasper & Fifer, 1980). In another paradigm, newborns learned that triggering a burst during the presentation of one of two discriminative auditory stimuli yielded to the delivery of different reinforcers during sucking (e.g., Spence & DeCasper, 1987). It is noteworthy however that all of these studies used strongly positive reinforcers, such as the mother's voice (DeCasper & Fifer, 1980; Spence & DeCasper, 1987; Moon & Fifer, 1990) or the intrauterine heartbeat (DeCasper & Sigafoos, 1983).

When examining potential cases of operant conditioning therefore, particularly with neonates, one must take into account the preparedness of the response–stimulus association, as well as the species-specificity of the reinforcers. As Sameroff and Cavanagh (1979, pp. 362–363) aptly state: ''If indeed these response systems are already prepared for adaptation to specific stimuli, then the demonstration of these adaptations would not be the result of learning, but rather the result of developmental processes more fundamental than learning.''

Similar to the studies mentioned above, this study examines newborns' reactions to an unprepared relation between a behavioral response and a perceptual stimulus. Unlike the previous studies, however, the present study seeks to determine whether newborns can be operantly conditioned in a situation involving a reward with no particular biological relevance. The High-Amplitude Sucking procedure (HAS) offers such a situation. The HAS paradigm consists of presenting auditory stimuli as reinforcement for sucking above a certain amplitude on a blind nipple. Infants are thus considered to learn the contingency between their sucking and auditory reinforcements, and thus demonstrate operant conditioning. Indeed, previous studies have investigated the role of contingency in HAS in 2- to 3-month-old infants, and the authors have favored the operant-conditioning interpretation (Trehub & Chang, 1977; Williams & Golenski, 1978). Curiously, although there is less evidence of operant learning in newborns than in older infants, there have been no studies examining the HAS procedure in newborns. The aim of the present study therefore is to determine whether newborns' sucking behavior in the HAS paradigm is due to operant conditioning or whether it is due to a process that does not require any special kind of learning, namely, response elicitation. For that purpose, we examined the sucking behavior of neonates under a variety of conditions involving auditory stimulation, inspired by the procedures designed by Trehub and Chang (1977), Williams and Golenski (1978), and Cowan, Suomi and Morse (1982) for their experiments with older infants.

Description of the HAS Procedure and Interpretation of the Resulting Behavior

In the classic HAS paradigm, an auditory stimulus is presented contingent on the infant's high-amplitude sucks: each time the infant produces a suck above a predefined amplitude threshold, the infant receives an auditory stimulus. Typically, one observes an increase in the response rate relative to a baseline during which subjects receive no stimulation (Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Trehub & Chang, 1977). Once a preestablished satiation criterion has been reached (a decrease in the sucking rates), the stimulus is changed for the subjects in the Experimental group. The change of stimulus is known as the ''shift.'' To monitor for spontaneous changes in infants' sucking, a Control group undergoes similar conditions as the Experimental group, but the stimulus remains unchanged after the satiation criterion has been reached. A significant difference in the post-shift sucking rate between the Control group and the Experimental group is interpreted as evidence that the two stimuli were discriminated by the infants. This procedure has allowed great advances in understanding the auditory perceptual capacities in both the young infant (Eimas et al., 1971; for a review, see Jusczyk, 1985), and the newborn (e.g., Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987; Bijeljac-Babic, Bertoncini, & Mehler, 1993).

As previously mentioned, the classical and more widely cited interpretation of what happens in the HAS paradigm rests on the notion of operant conditioning (e.g. Jusczyk, 1985). The auditory stimulus (generally, speech) is assumed to act as a reinforcement for the infants. Because the delivery of the stimuli is made contingent on infants' sucking responses, this results in an increase in sucking rates. Furthermore, it is assumed that the reinforcing properties of the stimuli wear off with continued presentation, a phenomenon referred to as satiation. In terms of the infant's behavior, satiation leads to a decrease in the reinforced response rates. Replacing the known stimulus by a novel one is assumed to renew the reinforcing properties of the auditory stimuli, resulting in a new increase in sucking rates (Eimas et al., 1971).

This, however, is not the only interpretation that can explain the infants' behavior during the HAS paradigm. The operant-conditioning explanation is not as clear-cut as one might think at first glance. Although nonnutritive sucking follows relatively stable rhythms, with intervals of sucking bursts and pauses, the durations of the sounds presented as well as the intervals between two sound presentations can vary widely. Thus the contingency between sounds and sucks is never as direct as one suck followed by one sound. Consequently, it is difficult to determine whether contingent presentation of short speech sounds such as syllables elicits sucking responses rather than reinforces them. In other words, in the case of sounds acting as reinforcers, the infant might **learn to suck in order to hear the stimuli;** in the case of sounds eliciting sucking responses, the **infant sucks spontaneaously upon hearing the stimuli.**

Keeping this in mind, the global variations of sucking behavior over time generally observed in HAS, that is, initial increase in sucking rates, decrease, and recovery when the stimulus is changed, are equally compatible with the hypothesis of response elicitation: an auditory stimulus elicits sucking responses, which habituate progressively as the stimulus is repeated, and then dishabituate if a novel stimulus is presented.

We attempted to clarify this ambiguity between elicitation and reinforcement in Experiment 1, by exploring the relation between initial increase in sucking rates and the contingency between sucks and sounds in neonates.

EXPERIMENT 1

The evolution of newborns' sucking activity was examined under three conditions: (1) sounds were presented contingent on HA sucks (Contingent group); (2) sounds were presented randomly (i.e., unrelated to sucking activity, Noncontingent group); (3) no sound was presented (Nonstimulated group). This design is inspired from a study by Trehub and Chang (1977) that compared groups of 5- to 15-week-old infants who were stimulated contingently, noncontingently, or not at all.

Following Trehub and Chang's hypothesis (1977) that infants learn by operant conditioning, if speech sounds act as reinforcements of HA sucking responses, only a contingent presentation of sounds should yield an increase in HA sucking rates. Therefore, whereas the HA sucking rates of the Contingent group are expected to increase, those of the Nonstimulated and Noncontingent groups are expected to remain at baseline level. Nevertheless, in order to conclude that contingency does have an effect on newborns' behavior, it would be sufficient to observe a significant elevated difference between the Contingent and other groups, regardless of whether the Contingent group increases its sucking rates above baseline or not (Bloom, 1984, p. 95).

If, on the other hand, the newborns follow the elicitation hypothesis, the speech sounds eliciting HA sucks, then both the Contingent and Noncontingent groups should demonstrate an increase in HA sucks as compared to the Nonstimulated group.

Trehub and Chang's study with older infants followed patterns consistent with the operant conditioning hypothesis. The Contingent group exhibited a significant and consistent linear increase in HA sucking rates, while the Noncontingent and Nonstimulated groups exhibited no increase in HA sucking rate, but remained at their baseline level. These two groups also did not differ significantly from each other.

These results however could also be explained by the elicitation hypothesis. If elicitation was playing a role in the infants' sucking rates, it would not necessarily be reflected through the overall sucks per minute, but instead could be reflected through the sucking pattern **within** each minute. Indeed, Sameroff (1967) demonstrated that brief sounds presented to newborns during a pause resulted in longer pauses, whereas sounds presented during sucking bursts resulted in longer bursts, but these effects could not be evidenced by analyses on sucking rates per minute. Thus, in the Trehub and Chang's study, the overall sucking rate per minute would not have increased in a noncontingent situation where sound was presented randomly. In contrast, because sounds in the contingent situation were always presented at the beginning of sucking bursts, the same effect would have led to a consistent increase in burst duration, which would surface as an increase in mean sucking rates per minute.

To control for such effects in the present study, pauses and burst durations were analyzed. In summary, two main analyses were conducted:

(1) HA sucking rates of the Contingent and the Noncontingent groups were compared to that of the Nonstimulated group. The operant-conditioning hypothesis would be supported by a significant difference between the Contingent group and the Nonstimulated group, and by no difference between the Noncontingent group and the Nonstimulated group. The elicitation hypothesis would be supported by a significant difference between both the Contingent and the Noncontingent group and the Nonstimulated group.

(2) If no difference was found between the Noncontingent and the Nonstimulated groups, as in Trehub and Chang (1977), burst and pause durations of the two groups would be compared. Evidence for elicitation would be provided by modifications in the duration of bursts and pauses (related to sound presentation) in the Noncontingent group as compared to the Nonstimulated one (Sameroff, 1967).

Method

Subjects

Subjects were recruited among healthy, full-term newborns at the Baudelocque Maternity Hospital in Paris, France. They had suffered no complications during pregnancy or delivery, and they were classified as ''normal'' after neurological evaluations on their first and third day of life. All subjects weighed more than 2700 g at birth and had 5-min Apgar scores of 10.

One hundred seventy-seven newborns were tested. Sixty-four subjects were excluded for the following reasons: falling asleep (16), ceasing to suck during the experiment (7), crying or becoming fussy (14), showing irregular sucking patterns (11), rejecting the nipple (7), and technical reasons (6).

The remaining 113 newborns (50 females and 63 males) completed the experimental session. Their mean age was 3.3 days. Their mean gestational age was 39.5 weeks (from 37 to 41 weeks), and their mean birth weight was 3375 g (from 2775 to 4220). Each subject was assigned to one of three conditions: Contingent (50 subjects), Noncontingent (20 subjects), and Nonstimulated (43 infants). The group sizes are unequal because infants' data were recorded not only for the present experiment, but also for discrimination tests (see Experiment 2).

Apparatus

A standard pacifier was connected to a Gould P23 pressure transducer. An electronic custom-designed device served as an interface between the pressure transducer, an IBM-PC compatible computer, and two tape recorders. This electronic device detected the sucking responses and transformed them into digital output. It also ensured the uninterrupted presentation of each stimulus. The items were delivered by two TASCAM Porta 05 tape recorders, a ROTEL RA 820B stereo amplifier, and two MARTIN DB92 loudspeakers.

Stimuli

The stimuli were two French syllables, /ba/ and /ʃu/, spoken by a native female speaker and presented at about 70 dB. The duration of both stimuli was 350 ms. Half of the infants (in the Contingent and Noncontingent groups) received the stimulus /ba/, while the other half received the stimulus /ʃu/. For the Contingent condition, one token of each stimulus was repeated every 800 ms to obtain 20 min of sound tokens on each tape. For the Non-Contingent condition, one token of each stimulus was repeated on a tape at a rate corresponding to the responses produced during 5 min by a neonate of the Contingent group who displayed stable sucking activity, and who produced sucking rates close to the mean of the Contingent group. The series was repeated four times to produce a 20-min tape that corresponded to a mean reinforcing rate of 30 stimulations per minute. Finally, for the Nonstimulated group, no stimuli were used.

Procedure

Infants were tested individually in a sound-attenuated chamber. They were awakened approximately 2.5 hr after feeding and were aroused until a quiet, active state was obtained. They were then placed in a reclining position in a special ''baby-bath chair'' that reduces head movements. To avoid intervention by the experimenter, the pacifier was held by an adjustable mechanical arm, and the experimenter was out of the infant's sight during testing.

The session began with a baseline of at least 2 min, during which no stimuli were presented. To participate in the test, infants were required to satisfy two conditions to ensure that sucking activity be stable before the onset of the experiment: (1) producing a minimum of 30 sucks per min, thus providing a sample large enough for setting the reinforcement threshold for the Contingent condition, and (2) producing a minimum of 20% of sucks in the last minute of baseline above the High-Amplitude threshold. If these two conditions were not met, the baseline was extended to up to 5 min until both criteria had been reached. During the baseline, the computer calculated an amplitude threshold for HA sucks equivalent to the top 50% of the sucks.

For all groups, sucking rates were recorded for at least 10 min after the initial baseline minutes. For the first time in the use of HAS, we had the technical possibility to register not only HA sucks, but also global sucks irrespective of their amplitude. In the Contingent condition, the stimuli were triggered by the infants' High-Amplitude sucks. Each time the electronic device detected a HA suck, the tape channel was switched on for a minimum duration of 800 ms. The switch occurred only during a silent period on the tape, to avoid the possibility that infants be presented with an incomplete stimulus. If another HA suck was detected during this time frame, the channel remained on for another 800 ms. The tapes for the Noncontingent group were uninterrupted during the entire session; there was thus no correlation between infants' sucking activity and the stimulus presentation. Newborns in the Nonstimulated group received no stimulation, but the testing equipment was switched on, so that the background noise was the same as the other conditions.

Results

HA Sucking Rate Evolution

The initial plan of analysis included 3 factors: Group (Contingent, Noncontingent and Nonstimulated), Time as a repeated measure (the 8 first minutes after baseline), and subjects' sex. A significant main effect of sex was found on the last 2 min of baseline for HA sucks only ($F(1, 107) = 4.18$, $p = .043$): girls produced a mean of 3.0 HA sucks more than boys. During the post-baseline minutes, no further main effect of sex nor interaction of sex with other factors was observed. Moreover, none of the sources of variance (other than sex) that were significant when sex was included became nonsignificant when it was excluded. As a consequence, this factor was not included in the final plan of analyses.

The same conclusions can be drawn concerning the effect of sex throughout the paper: sex did not interact with any of the other factors, and its omission from the analyses did not affect the significance of the other findings. Thus it will not be included in the plans of analyses any more, unless a main effect of sex emerges.

The effect of stimulus presentation on infants' sucking activity was exam-

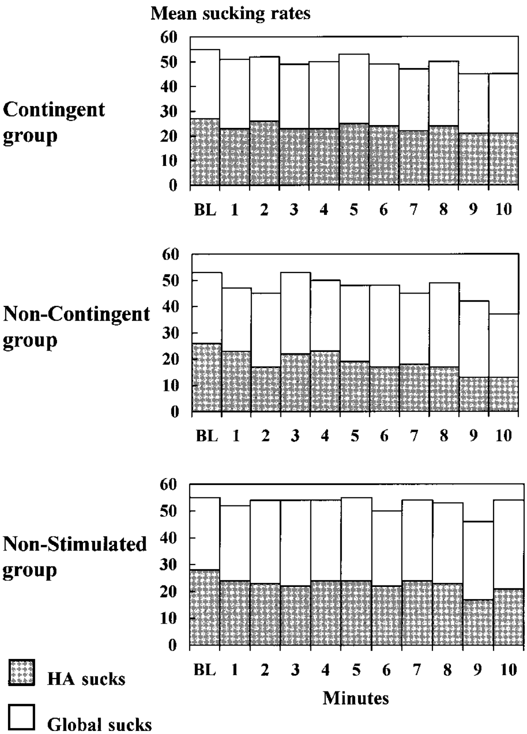

FIG. 1. Experiment 1: Mean high-amplitude and global sucking rates of newborns tested in the Contingent condition (above), in the Noncontingent condition (middle), and in the Nonstimulated condition (below), plotted minute by minute, including baseline (BL: average of sucking rates in the last 2 min).

ined using a linear trend analysis (unweighted LIN ANOVA) of HA sucking rates over the 8 min of the testing session. This analysis indicates whether there is a significant increase or decrease of mean HA sucking rates over time for each group (Cowan, Suomi, & Morse, 1982; Trehub & Chang, 1977).

Histograms of HA and global sucks per minute (including baseline minutes) are given in Fig. 1 for each group.

Preliminary analyses. We verified that there was no significant effect of group on the last 2 minutes of baseline ($F(2, 110) < 1$).

Comparison between the Contingent group and the Nonstimulated group. As could be predicted from Fig. 1, the comparison on the linear trend of HA sucking rates between the two groups was not significant ($F(1, 91) < 1$). For both groups, HA sucking rates remained around baseline level.

Comparison between the Noncontingent group and the Nonstimulated group. The comparison on the linear trend of HA sucking rates between the two groups was also not significant ($F(1, 61) < 1$).

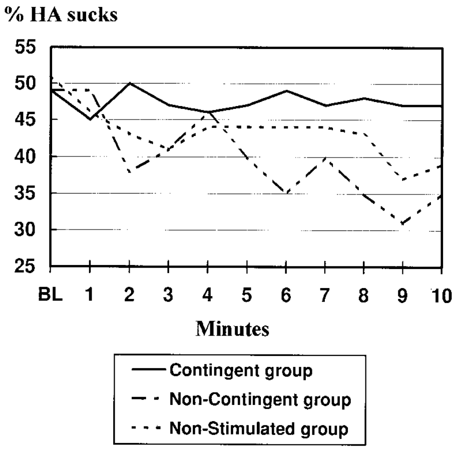

FIG. 2. Experiment 1: Mean proportions of HA sucks relative to global sucks plotted minute by minute including baseline (average of the last 2 min) for each condition: Contingent (solid line), Noncontingent (dashed line), and Nonstimulated (dotted line).

As is evident from these results, no definitive corroboration of either the elicitation hypothesis or the operant-conditioning hypothesis was found. To further investigate these results, we extended the analyses to include the evolution of global sucks as well as the proportion of HA sucks to global sucks. No group effect was observed on the linear evolution of global sucks: they remained approximately at baseline level in all groups. As for the linear trend of the proportions of HA sucks, the Noncontingent group behaved significantly differently from both the Nonstimulated group ($F(1, 61) = 5.5$, $p < .03$) as well as from the Contingent group ($F(1, 68) = 6.05$, $p < .02$). While proportions of HA sucks remained at baseline level in the Nonstimulated and Contingent groups, they decreased significantly over time in the Noncontingent group ($F(1, 19) = 11.01$, $p < .01$).

In summary, the evolution of sucking rates in the Contingent group did not differ from that of the Nonstimulated group, on HA sucks, global sucks, or HA proportions. However, the Noncontingent group's sucking behavior differed from that of both the Nonstimulated and the Contingent groups: HA proportions decreased over time only in the Noncontingent group.

Mean proportions of HA sucks relative to global sucks minute-per-minute are displayed in Fig. 2 for each group.

Sucking Pattern Analyses

Analyses of sucking rate patterns yielded two principal results. First, curiously, no difference in sucking rates between the Contingent and Nonstimulated groups was observed. Second, the decrease of HA sucks proportional to global sucks in the Noncontingent group compared to the Nonstimulated group shows that sucking responses are affected by the mere presentation of sounds. Further analyses of the sucking patterns were thus deemed necessary to refine and better understand these results.

A pause was defined as an interval between two sucks greater than 1.2 s. A burst was defined by two or more consecutive sucks (separated by less than 1.2 s), irrespective of their amplitude. For each subject, the mean number of sucking bursts, the mean number of sucks per burst, and the median of pause duration were calculated during the final two minutes of the baseline, and the following minutes truncated into three 3-min blocks. The median of pause duration was the measure chosen to compare the evolution of pauses over time, in order to minimize the influence of the extrema values on their distribution, as in DeCasper and Sigafoos (1983).

Two factors were considered: Group (Contingent, Noncontingent and Non-stimulated), and Time blocks as a repeated measure (baseline, and the three following blocks). The evolution of pause duration, for instance, was evaluated by a comparison between the baseline and the three blocks taken together, or by a comparison between the baseline and each of the three blocks.

Preliminary analyses. We verified that there was no Group effect on baseline, either on the median of pauses, the mean number of bursts, or the mean number of sucks per burst (for all analyses, $F(2, 110) < 1$).

Comparison between Contingent and Nonstimulated groups. The Contingent group and the Nonstimulated group did not differ significantly (for all interactions, $F(1, 91) < 1$), suggesting that the two groups shared similar sucking patterns.

Comparison between Noncontingent and Nonstimulated groups. A difference between these groups was observed only when comparing the evolution of the median of pauses between the baseline and the three following blocks ($F(1, 61) = 5.8$, $p < .02$). The duration of pauses increased after baseline to the three following 3-min blocks for the Noncontingent group ($F(1, 19) = 4.3$, $p < .04$), but not for the Nonstimulated group ($F(1, 42) = 1.6$). Furthermore, the pause-lengthening effect was more pronounced at the end of the session than at the beginning. The interaction between Groups and the baseline versus the first block was not significant ($F(1, 61) = 2.1$). The interaction was significant however between Groups and the baseline versus the second and the third block ($F(1, 61) = 4.3$, $p < .04$; $F(1, 61) = 5.5$, $p < .03$ respectively). The Noncontingent group therefore differed from the Nonstimulated one on the median of pauses between baseline and the last two 3-min blocks of the session. No other interaction was significant.

In summary, Contingent and Nonstimulated groups did not differ on mean sucking rates, nor did they differ on their patterns of sucking over time. In contrast, the Noncontingent group differed from the Nonstimulated group on the evolution of the mean proportion of HA sucking rates, as well as on the evolution of pause duration. The Noncontingent group also differed from the Contingent group on the proportion of HA suck, and to some extent, on the duration of pauses: there was a tendency for the pauses during the stimulation period to be longer in the Noncontingent group than in the Contingent group ($F(1, 68) = 3.44$, $p = .068$).

Discussion

Results of Experiment 1 do not support the operant learning hypothesis, because first, no increase was found in the Contingent group, and second, this group did not differ significantly from the Nonstimulated one, in contrast to what was observed in older infants (Trehub & Chang, 1977). The results do not support the elicitation hypothesis either, because sucking rates did not increase reliably in the Contingent and Noncontingent groups compared to the Nonstimulated group. And although effects of elicitation could have been demonstrated by modifications in the temporal organization of sucking depending on the moment of sound presentation (Sameroff, 1967), the Contingent group showed no difference from the Nonstimulated group in this aspect. Moreover, in the Noncontingent group, the only effect observed was a global lengthening of pauses as compared to the Nonstimulated group. This pause-lengthening effect did not appear to be systematically related to sound presentation, and there was no evidence of any burst-lengthening effect. Finally, post hoc complementary analyses (that are not detailed in this paper) based on the probabilities to modify the sucking activity depending on the delivery of sounds did not provide evidence that sound had a systematic effect on sucking responses. The results therefore do not support the prediction that sounds elicit sucking responses.

It is noteworthy however that a significant difference was observed between the Noncontingent and the Nonstimulated groups. This suggests that auditory stimulation does indeed have an effect on newborns' sucking behavior. Moreover, the difference between the Noncontingent and Contingent groups indicates that infants are sensitive to the mode of presentation of the stimuli. If newborns' sucking behavior were affected by the presence of auditory stimulation alone, irrespective of its presentation mode, Contingent and Noncontingent groups should not have behaved differently.

Nonetheless, two puzzling results surface at the end of these analyses: the absence of any sucking-rate increase in the Contingent group, and the absence of any significant difference between the Contingent and the Nonstimulated groups. As for the first curious outcome, the absence of an increase in sucking rate by the Contingent group, three potential explanations can be examined. First, a ceiling effect may be responsible: newborns would tend to start sucking at their maximum rate immediately after the nipple is introduced in their mouth (Levin & Kaye, 1964). Keeping in mind the high level of sucking rates required during baseline in order to participate in the present experiment, the ceiling effect could indeed have played a role. Second, newborns may have difficulties in increasing their sucking responses above their baseline rate in an instrumental learning situation. Indeed, it has been shown several times in newborns—and not only with the nonnutritive sucking response—that the operant could result in a decrease in the probability to produce nonreinforced responses (or less reinforced ones), rather than in an increased probability to produce reinforced responses (Moon, Cooper, & Fifer, 1993; Brown, 1972; Kobre & Lipsitt, 1972). Finally, newborns may simply require more time than older infants to learn the contingency. Thus the absence of reliable increase in HA sucks within the first minutes after baseline could be due to an insufficient exposure to the contingency situation (e.g. Reeve, Reeve, Brown, Brown, & Poulson, 1992).

As for the second curious outcome, the significant difference between Noncontingent and Nonstimulated groups, it is noteworthy that this result contrasts with that reported by Trehub and Chang (1977), who found no difference between 2-month-olds tested in a random noncontingent condition versus a nonstimulated one. Unlike that study, we observed a global effect of sucking disturbance reflected by a decrease of HA sucking rates as well as by a lengthening of the pauses. One possible hypothesis for explaining this disturbance is to refer to an Orienting Response to sound. As proposed by Sokolov (1963, p. 64), an Orienting Response is defined as a ‘‘response which mobilizes all resources for the perception of the stimulus.’’ The effect of the OR during the session could be attributable to the unpredictibility of sound presentation (Rohrbaugh, 1984). We shall further examine this hypothesis later.

Discrimination and Reinforcement

Let us return to the question of learning an association between HA sucking responses and sound stimulation in newborns. As yet, we have no evidence that HA sucking responses are reinforced by sound presentation, which would have been reflected by an increase in HA sucks. As suggested earlier, the situation tested in Experiment 1 may not have favored an observation of contingency learning, because of a ceiling effect or insufficient exposure to the situation.

To support the hypothesis of contingency learning and reinforcement, a situation in which a sucking-rate increase in a contingent condition could be observed was of course necessary. In several studies, neonates were reported to increase their sucking rates in response to a stimulus change in a contingent situation (e.g. Bertoncini et al., 1987; Bijeljac-Babic et al., 1993). We therefore tested stimulus discrimination in a contingent situation. The expected increase in sucking rates would be attributed to reinforcement only if it could be shown (1) that this increase bears exclusively on reinforced responses, that is, on HA sucks and not on global sucks; and (2) that it could be obtained in a contingent situation only, and not in a noncontingent one.

Experiment 2 is a partial replication of a study by Williams and Golenski (1978), who investigated discrimination responses in 2-month-old infants in a contingent situation and in two noncontingent ones: sounds were either randomly or periodically presented. Results showed that recovery in HA sucking rates could be obtained in a contingent situation only, suggesting that in older infants, sucking recovery can be attributed to reinforcement by stimulus novelty.

EXPERIMENT 2

We tested discrimination between /ba/ and /ʃu/ under two conditions: in the first condition (Contingent condition), we used a standard HAS procedure, in which stimuli were presented contingent upon infants' HA sucks (identical to the Contingent condition of Experiment 1). For half of the infants (Experimental group), stimulation was shifted after a satiation criterion had been reached, while the other group continued to receive the same stimulus (Control group). Subjects in the Control group are part of the Contingent group of Experiment 1. The satiation criterion was chosen for two reasons: first, it would ensure that subjects would be all equally familiarized with the first stimulus before the change. Second, it should prevent a possible ceiling effect: because stimulation would be shifted at a low point of sucking activity, subjects could ''re-increase'' their sucking rates without excessive efforts.

In the second condition (Noncontingent condition), the stimulus presentation was random, as in the Noncontingent condition of Experiment 1. In order to compare the results of the Noncontingent condition to those of the Contingent one, the moment of stimulus change was an important factor to consider. Recall that subjects tested in a noncontingent situation, who all listened to the same preregistered tape, heard exactly the same pattern of stimulation, regardless of their sucking activity. Consequently, to ensure that all subjects would receive the same amount of stimulation before the change, we applied a time-locked shift for a first group of subjects. However, as previously noted, the use of a satiation criterion may have statistical advantages in preventing a possible ceiling effect. For a second group therefore, the stimulus was shifted after a satiation criterion was reached. In the two resulting conditions (Noncontingent with Time-locked Shift, and Noncontingent with Satiation Criterion), stimulation was changed for only half of the subjects (Experimental groups) and remained unchanged for the other half (Control groups).

In the three groups (two Noncontingent, one Contingent), discrimination responses were evaluated based on a comparison between sucking rates before and after the stimulus change in both the Experimental and Control conditions. In order to support the reinforcement hypothesis, the following results were expected:

(1) In the Contingent group, a significant increase of HA sucking rates in the Experimental condition versus the Control condition.

(2) This increase in the Contingent group found only in HA sucks, demonstrated by no increase of global sucking rates in the Experimental condition versus the Control condition.

(3) The increase of HA sucks found only in the Contingent group. As a consequence, HA and global sucks should not increase significantly in the Experimental conditions of the two Noncontingent groups (with a Time-Locked Shift or with a Satiation Criterion).

Method

Subjects

Newborns were recruited at the Baudelocque Maternity Hospital in Paris and selected with the same criteria as those in Experiment 1. Two hundred nineteen subjects were tested. One hundred seventeen newborns were excluded for the following reasons: falling asleep (17), ceasing to suck during the experiment (29), crying or becoming fussy (13), rejecting the nipple (43), technical reasons (11), and, for infants who were to undergo a change of stimulation after having reached a satiation criterion, no satiation within 15 min (4).

The remaining 102 newborns (46 girls and 56 boys) completed the experimental session. Their mean age was 3.2 days, their mean gestational age was 39.2 weeks (from 37.5 to 41.5), and their mean birth weight was 3379 g (from 2720 to 4490). They were assigned to one of the two conditions: Contingent (40), Noncontingent with Time-Locked Shift (40), and Noncontingent with Satiation Criterion (22). In each condition, half of the subjects were randomly assigned to the Experimental condition and the other half to the Control condition.

Apparatus

The apparatus was the same as that in Experiment 1.

Stimuli

The stimuli were the same as those in Experiment 1.

Procedure

The criteria for baseline, HA sucks detection, and stimulus presentation were the same as those described in the corresponding conditions of Experiment 1.

Contingent group and Noncontingent group with a Satiation criterion. For all subjects, a Satiation criterion was calculated, equivalent to a 33% drop of HA sucking rates for two consecutive minutes, relative to the preceding minute. For half of the subjects in each group, i.e. the Experimental condition, the stimulus was changed after reaching this satiation criterion, while the Control subjects continued to receive the same stimulus. The preshift phase lasted a minimum of 5 min after baseline, and a maximum of 15 min. For both conditions, the post-shift period lasted 4 min.

Noncontingent group with Time-Locked Shift. Stimulation for half of the subjects was changed 6 min after baseline. At this point, Experimental subjects received the other stimulus, while Control subjects continued to receive the same stimulus. For both conditions, the post-shift period was 4 min long.

The order of stimulus presentation was counterbalanced in each condition for all groups.

Results

For each group, Student's *t* tests were performed on the difference scores (sucking rates in the 2 min after the shift minus sucking rates in the 2 min before). Condition (Experimental vs. Control) and Order of stimulus presentation (/ba/ as the first stimulus vs. /ʃu/) were between-subjects factors. The effect of the stimulus change was analyzed on HA sucking rates as well as on global sucking rates. For the Contingent group, difference scores of HA sucking rates in the Experimental condition were expected to be significantly higher than in the Control condition. For the two Noncontingent groups, we had no directional hypothesis.

When subjects' sex was included in the plan of analyses, only one significant main effect emerged, in the Noncontingent group with a Satiation Criterion: boys produced more HA sucks than girls on the last 5 min of the preshift phase ($F(1, 14) = 8.7$, $p = .01$). When the analysis was restricted to the last 2 min of the preshift phase, the effect of sex disappeared ($F(1, 14) = 1.5$).

For each condition in each group, difference scores in HA sucking rates are presented in Fig. 3.

Preliminary analyses for each group. For global and HA sucks, we verified that there was no effect of Condition or Order, as well as no significant interaction of Condition and Order, on baseline, and on the last 5 min of the preshift phase. No significant effect of Order was found in any of the analyses detailed below.

Contingent Group

Effect of stimulus change on HA sucks. There was a significant effect of Condition on the difference scores ($t(36) = 1.82$, $p = .038$, one-tailed). In the Experimental condition, a significant increase of 8 HA sucks was found ($t(18) = 3.4$, $p < .01$, one-tailed). The 2 HA suck increase displayed in the Control condition was not significant ($t(18) = 1.6$). Is this increase found exclusively on HA sucks, as predicted by the reinforcement hypothesis?

Effect of stimulus change on global sucks. There was no significant effect of Condition on the difference scores in global sucking rates ($t(36) < 1$), suggesting that stimulus change in the Contingent group resulted in a selective increase in HA sucks.

Noncontingent groups

In both Noncontingent groups, with either Time-Locked Shift or Satiation Criterion, there was no significant effect of Condition on the difference scores

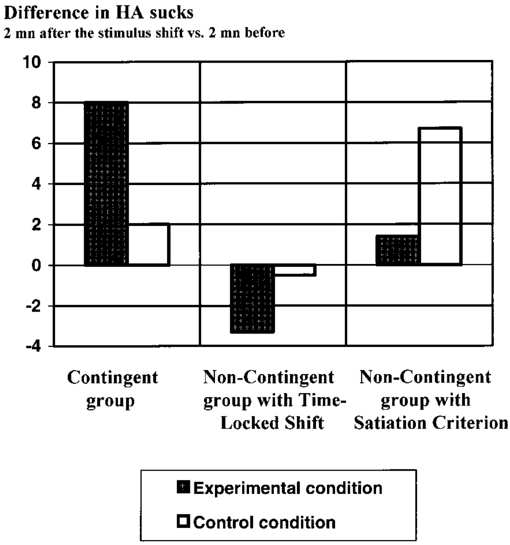

FIG. 3. Experiment 2: Mean difference of HA sucking rates between the first two postshift minutes and the last two preshift minutes for the Experimental and Control conditions of each group: Contingent (left), Noncontingent with Time-Locked Shift (middle), and Noncontingent with Satiation Criterion (right).

in HA sucks (respectively, $t(36) < 1$; $t(18) = 1.7$, $p = .1$). Hence the stimulus change in the Experimental conditions did not result in any significant changes in HA sucking rates as compared to the associated Control conditions.

Nonetheless, upon closer inspection of Fig. 3, there was a similar tendency for the difference scores in HA sucks in the Experimental conditions to be lower than those in the associated Control conditions: in the Noncontingent group with Time-Locked Shift, HA sucks decreased more in the Experimental condition than in the Control one (−3.5 and −0.5 HA sucks, respectively); in the Noncontingent group with Satiation Criterion, HA sucks increased less in the Experimental condition compared to the Control one (+1.4 and +6.7 HA sucks, respectively).

Discussion

The results support the hypothesis that speech sound novelty reinforces associated sucking responses, because only the Contingent group displayed a significant HA sucking-rate increase after the stimulus change. Moreover, in this group, HA sucks increased selectively after the stimulus shift, suggesting that infants did learn the contingency between HA sucks and stimulus presentation. These two results support the hypothesis that neonates tested under HAS do in fact learn the contingency between HA sucks and sound presentation. Consequently, the explanation classically proposed to explain older infants' sucking behavior in the HAS paradigm appears to apply to newborns as well.

Moreover, Williams and Golenski (1978), who conducted the same kind of experiments with older infants, concluded that contingency is an essential parameter for observing discrimination responses in infants, when indexed to a **recovery** in sucking rates after a stimulus change. The present results strongly support this conclusion in neonates.

However, contrary to what is reported by Williams and Golenski, Experiment 2 shows that in both Noncontingent groups, the stimulus change seems to have similar inhibiting effects upon the spontaneous evolution of sucking rates. Figure 3 reveals that in both Noncontingent groups, the differences in HA sucks before and after the change are lower in the Experimental conditions than in the corresponding Control conditions. These observations are closely related to the results obtained in Experiment 1, which indicated that the introduction of an auditory stimulus after baseline in a noncontingent situation resulted in a decrease in the amplitude of sucks as well as in a lengthening of pauses, compared to a nonstimulated control groups. These effects were interpreted as an Orienting Response to sound presentation. The same kind of Orienting Response seems to be elicited by a stimulus change as well.

In summary, this experiment demonstrates first that, similar to Williams and Golenski's (1978) results for older infants, contingency is a necessary condition for observing discrimination in neonates, as reflected by sucking rate **recovery.** This recovery, observed exclusively on HA sucks, suggests that newborns do learn the contingency between HA sucks and sound presentation. Second, this experiment, together with Experiment 1, suggests that newborns tested in a noncontingent situation do react to a stimulus introduction or to a stimulus change, although this reaction is observed by an inhibition rather than by an increase in sucking rates.

EXPERIMENT 3

In the Contingent condition of the previous experiment, we observed a consistent increase in HA sucking rates in response to a stimulus change. This result contrasts with what was observed in the Contingent condition of Experiment 1, in which no increase of HA sucks was observed during the first postbaseline minutes. At least three explanations can account for this discrepancy.

First, the lack of initial sucking rates increase in Experiment 1 could have been due to a ceiling effect of baseline constraints, which would have masked the effects of learning. Indeed, a high level of activity was required during baseline for newborns to participate in the experiment. In contrast, the use of a satiation criterion in Experiment 2 may have reduced such an effect: by changing stimulation at a low point of activity, one allows subjects to recover their sucking rates without excessive efforts.

Second, to learn the contingency between HA sucks and sounds and to exhibit the expected outcome, that is, to increase sucking rates, newborns may require more exposure to the situation than older infants. During the first 5 min postbaseline of contingent stimulation in Experiment 1, newborns produced a mean of 25 HA sucks per minute, which corresponded to approximately 18 stimulus presentations. This may not be sufficient for newborns to learn the contingency. In the following minutes, some other factors may have covered the expected increase in sucking rates, such as fatigue and satiation to the unchanging stimulus.

Finally, the lack of initial increase could be attributed to the—deliberately—poor reinforcement value of the stimulation versus the more reinforcing stimuli such as the mother's voice or intrauterine heartbeat of previous experiments. Nevertheless, the stimuli that were used in this study seem to be reinforcing enough to promote an increase in HA sucking rates, at least at the moment of stimulus change, as observed in Experiment 2.

Experiment 3 was designed to facilitate an initial increase in sucking rates in a contingent situation. First, to avoid a ceiling effect, no criterion was introduced during baseline. Second, to encourage contingency learning, more evidence of the response–stimulus association was provided to the subjects: this was achieved by using a higher reinforcement rate than in Experiment 1. Finally, to improve the reinforcing value of stimulation, a condition was applied in which the stimulus was frequently changed (Alternated condition). This condition was compared to a Monotonic one, in which the stimulus remained the same throughout the session. This design was inspired by a study by Cowan, Suomi, and Morse (1982) with 2-month-old infants. In this study, an experimental group received 30-s blocks of one stimulus alternating with 30-s blocks of a second stimulus. The control group received the same stimulus throughout the session. Their results showed a consistent linear increase in sucking rates in the experimental group, but no increase in the control group, which remained at baseline level, suggesting that alternating stimuli had more reinforcing power than did monotonic stimuli.

In the present experiment, the effect of contingent presentation of sounds on HA sucks was evaluated using an analysis of linear trend over the first minutes of stimulation. If newborns can increase their HA sucks in response to short speech sounds, it should be observed in both groups, or at least in the group receiving more reinforcing stimuli (Alternated group). In order to verify that multiple stimulus changes are more reinforcing than single stimulus tokens, a comparison between the HA sucks in the two groups was examined also.

Method

Subjects

Newborns were recruited at the Baudelocque Maternity Hospital and they were selected by the same criteria as the preceding experiments. Fifty subjects were tested. Twenty newborns were excluded for the following reasons: falling asleep (9), ceasing to suck during the experiment (6), crying or becoming fussy (3), and rejecting the nipple (2). The remaining 30 newborns (13 girls and 17 boys) completed the experimental session. Their mean age was 2.8 days. Their mean gestational age was 39.5 weeks (from 37.5 to 41.3), and their mean birth weight was 3475 g (from 2880 to 4400). Newborns were randomly assigned to one of the two conditions: 15 subjects in the Alternated group and 15 in the Monotonic group.

Apparatus

As in the previous experiments, a pacifier was connected to a Gould P23 pressure transducer. This time, however, the transducer was directly connected to an IBM-compatible personal computer. The computer, equiped with an OROS board, detected the sucking responses and ensured the presentation of the digitized stimuli. Sounds were delivered through a stereo amplifier and two loudspeakers, identical to those used in Experiment 1.

Stimuli

The stimuli were the same as those in Experiments 1 and 2. The French syllables /ba/ and /ʃu/ were digitally stored on the computer that converted the digital files to analog form each time HA sucks were detected, with a minimal SOA of 800 ms.

Procedure

The procedure was the same as described above for the Contingent condition, without the minimal sucking requirement during the 2-min baseline. The amplitude thresholds for detecting the to-be reinforced HA sucks were identical for all infants and corresponded to approximately the top 80% of the sucks. During the stimulation phase, the stimulus was changed every minute for subjects in the Alternated condition, while it remained unchanged for the Monotonic group. The order of stimulus presentation was counterbalanced: half of the newborns received /ba/ as the first stimulus, and the other half received /ʃu/. The entire stimulation phase lasted 10 min (9 stimulation shifts for the Alternated group).

Results

The mean HA sucking rates minute by minute for each group are plotted in Fig. 4. As can be seen in this figure, none of the groups displayed any increase in HA sucks. Rather, after several minutes of stable sucking rates in both groups, HA sucks decreased in the Monotonic group, but not in the Alternated group. In order to determine the moment when the two groups began to differ significantly, analyses of HA suck linear trends were conducted for each group over the first 6, 8, and 10 min of the session. The plan of analyses included three factors: Group (Alternated vs. Monotonic), Order of stimulus presentation (/ba/ as the first stimulus vs. /ʃu/), and Time. No effect

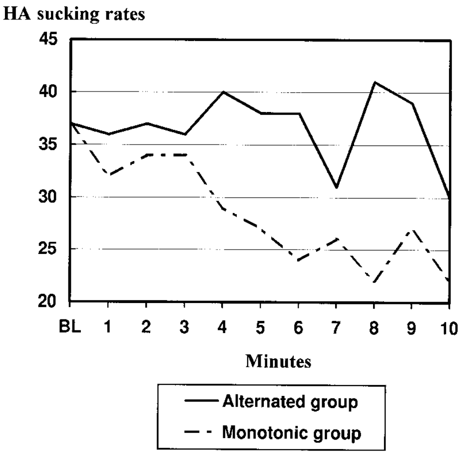

FIG. 4. Experiment 3: Mean high-amplitude sucking rates plotted during baseline (average of sucking rates in the last 2 min) and 10 min of alternated contingent presentation (Alternated group, solid line) or 10 min of unchanging contingent stimulation (Monotonic group, dashed line).

of Order was found, nor was there any interaction of Order with another factor.

Monotonic group. There was a significant linear trend of HA sucks on the first 6 min after baseline ($F(1, 13) = 8.6$; $p = .01$), on 8 min ($F(1, 13) = 5.3$; $p < .04$), and on 10 min ($F(1, 13) = 4.7$; $p < .05$), indicating that HA sucking rates decreased linearly over time.

Alternated group. The linear trend analysis for HA sucks over 6, 8 or 10 min was never significant (for all, $F(1, 13) < 1$), indicating that HA sucking rates remained at the same level throughout the session.

Comparison between Monotonic and Alternated groups. We verified first that there was no significant effect of Group on HA sucking rates during baseline. The Group effect on the linear trend on HA sucks was significant at 6 min ($F(1, 26) = 6.6$, $p < .02$), nearly significant at 8 min ($F(1, 26) = 4.1$, $p = .052$), and not significant at 10 min ($F(1, 26) = 1.9$).

In summary, HA sucking rates decreased over time for the Monotonic group, whereas no change in sucking activity was observed for the Alternated group. In addition, the effect of Group was more consistent at 6 min than at 8 and 10 min.

Discussion

Despite the measures taken to minimize a potential ceiling effect and to favor the observation of a reinforcement effect, no increase in HA sucking rates could be observed in any of the two contingent groups tested in Experiment 3. It seems that the higher sucking rates neonates produce in such a situation occur immediately after the nipple is introduced in the mouth, that is, during baseline (Levin & Kaye, 1964). Unless they receive a change in stimulation at an unusually low point of sucking activity, as when reaching a satiation criterion, newborns appear to be unable to increase their sucking activity in response to short speech sounds.

Provided that newborns at best maintain their sucking activity at baseline level, the results of Experiment 3 are similar to those reported by Cowan et al. (1982) in 2-month-old infants. In the Cowan et al.'s study, infants in the alternating stimulus group showed a consistent increase in HA sucking rates whereas infants in the nonalternating stimulus group maintained a constant level of sucking activity. In the present experiment, sucking rates in the Alternated group were always higher than those in the Monotonic group, thus exhibiting an effect of stimulus variability on sucking activity.

Taken together, the performances of the two groups tested in Experiment 3 support hypotheses of contingency learning and reinforcement by stimulus novelty. The decrease in sucking rates exhibited by the Monotonic group can be attributed to satiation to the unchanging stimulus, whereas the sustained, though elevated, level of activity in the Alternated group suggests that multiple stimulus changes reinforce newborns' sucking responses; consequently, satiation requires more time (see Cowan et al., 1982, for a similar interpretation of their results). The decline of the group interaction after 8 min of sound presentation may reflect either a progressive loss of interest (or novelty) for the alternating stimuli in the Alternated group, or else a global effect of fatigue.

Furthermore, the results of Experiment 3 showed that the procedure designed by Cowan et al. was suitable for investigating discrimination in newborns, as well as in older infants. The comparison between sucking rate linear trends in two conditions, alternating and monotonic, can be taken as evidence of stimulus discrimination. This method has since been successfully applied by Sansavini, Bertoncini, and Giovanelli (1997) in testing discrimination of stress patterns in newborns. It is noteworthy that the proportion of subject rejection in this procedure is much lower than in the classical HAS experiments, presumably because of the use of time-locked alternated shifts.

GENERAL DISCUSSION

In order to verify that operant learning is involved in the HAS paradigm with neonates, we expected to observe an increase in HA sucking responses only when sound was contingently presented. The present results suggest that, unless in a situation where newborns are changed of stimulation at an abnormally low point of activity—as in Experiment 2, they are unable to increase their HA sucking rate above baseline level, at least when short speech sounds are used as reinforcers. Hence, newborns' nonnutritive sucking activity seems to be less alterable, more reflex, than that of older infants, presumably because sucking at birth is more strictly tied to survival than later in development.

At first glance, the results of these experiments differ from those obtained in similar studies in older infants (Trehub & Chang, 1977; Williams & Golenski, 1978; Cowan et al., 1982). However, if we take for granted newborns' inability to increase their sucking rates above baseline, the studies follow remarkably similar patterns. Newborns' and infants' sucking activity consistently followed the same directions. For instance, both newborns and infants demonstrated a sucking-rate recovery after a stimulus change only in a contingent situation (Williams & Golenski, 1978). In addition, as in older infants (Cowan et al., 1982), HA sucking rates in newborns were found to be higher in a situation in which stimuli were regularly alternated, than in a monotonic one. These results suggest that newborns, as older infants, learn the contingency between their High-Amplitude sucking responses and the presentation of short speech sounds, whose novelty acts as a reinforcer.

It is important, however, not to confuse the notion of ''contingency learning'' with the notion of voluntary behavior. To paraphrase Poulson (1984, p. 104), we think we have demonstrated that there is a ''functional (causal) relationship between'' newborns' sucking and sounds, such that sounds meet the definition of reinforcers for infants' sucking.

As for reinforcers, it could be argued that the absence of sucking-rate increase reported in this study was due to the poor reinforcing value of the stimuli that newborns received (that is, single syllables). Indeed, other studies have succeeded in establishing operant conditioning of the nonnutritive sucking response in more complex situations by using especially strong reinforcers (the mother's voice in DeCasper & Fifer, 1980; Spence & DeCasper, 1987; Moon & Fifer, 1990; intrauterine heartbeat in DeCasper & Sigafoos, 1981). However, as discussed in the introduction, the use of such biologically relevant stimuli may weaken the conclusion that general learning capacities were involved in those situations. In fact, when presumably less reinforcing stimulation was used, such as maternal language speech samples (Moon, Cooper, & Fifer, 1993), evidence for operant learning was far less clear.

An unexpected result that emerged from this study was the sucking rate modifications observed in the noncontingent situation, after baseline or after a stimulus change. More research is needed to determine whether these modifications—HA sucks decrease and pause duration lengthening—can be attributed to Orienting Responses to sound presentation, as was previously proposed. In that case, it would be of interest to use them as discrimination responses. Actually, Orienting Responses have the interesting property of habituating rapidly with very few presentations of stimuli. In addition, the course of Orienting Response habituation and dishabituation have been shown to depend directly on stimulus characteristics such as frequency of presentation and complexity (e.g. Sokolov, 1963; Swain, Zelazo, & Clifton, 1993).

In contrast, in operant-learning situations, the modifications of the responses may also have to be related to the processing of the contingency itself, and not only to the processing of the stimuli. However, paradigms based on the use of Orienting Responses may be well adapted for testing discrimination abilities, but not for the exploration of cognitive processes such as those involved in categorization, which requires the perceptual information to be integrated at a higher level of representation. Consequently, HAS remains the more appropriate procedure for investigating representation capacities in newborns (e.g., Bijeljac-Babic et al., 1993; Bertoncini, Floccia, Nazzi, & Mehler, 1995).

REFERENCES

Bertoncini, J., Bijeljac-Babic, R., Blumstein, S., & Mehler, J. (1987). Discrimination in neonates of very short CV's. *Journal of the Acoustical Society of America,* **82,** 31–37.

Bertoncini, J., Floccia, C., Nazzi, T., & Mehler, J. (1995). Morae and syllables: Rhythmical basis of speech segmentation in neonates. *Language and Speech,* **38,** 311–329.

Bijeljac-Babic, R., Bertoncini, J., & Mehler, J. (1993). How do four-day-old infants categorize multisyllabic utterances? *Developmental Psychology,* **29,** 711–721.

Bloom, K. (1984). Distinguishing between social reinforcement and social elicitation. *Journal of Experimental Child Psychology,* **38,** 93–102.

Brown, J. (1972). Instrumental control on the sucking response in human newborns. *Journal of Experimental Child Psychology,* **14,** 66–80.

Cowan, N., Suomi, K., & Morse, P. A. (1982). Echoic storage in infant perception. *Child Development,* **53,** 984–990.

DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voice. *Science,* **208,** 1174–1176.

DeCasper, A. J., & Sigafoos, A. D. (1983). The intrauterine heartbeat: A potent reinforcer for newborns. *Infant Behavior and Development,* **6,** 19–25.

Eimas, P. D., Siqueland, E. R., Jusczyk, P. W., & Vigorito, J. (1971). Speech perception in infants. *Science,* **171,** 303–306.

Jusczyk, P. W. (1985). The high-amplitude sucking technique as a methodological tool in speech perception research. In G. Gottlieb & N. A. Krasnegor (Eds.), *Measurement of audition and vision in the first year of postnatal life: A methodological overview* (pp. 195–222). Norwood, NJ: Ablex.

Kobre, K. R., & Lipsitt, L. P. (1972). A negative contrast effect in newborns. *Journal of Experimental Child Psychology,* **14,** 81–91.

Levin, G. R., & Kaye, H. (1964). Nonnutritive sucking by human neonates. *Child Development,* **35,** 749–758.

Lipsitt, L. P., Kaye, H., & Bosack, T. N. (1966). Enhancement of neonatal sucking through reinforcement. *Journal of Experimental Child Psychology,* **4,** 163–168.

Moon, C., Cooper, R. P., & Fifer, W. P. (1993). Two-day-olds prefer their native language. *Infant Behavior and Development,* **16,** 495–500.

Moon, C., & Fifer, W. P. (1990). Syllables as signals for 2-day-old infants. *Infant Behavior and Development,* **13,** 377–390.

Poulson, C. L. (1984). Operant theory and methodology in infant vocal conditioning. *Journal of Experimental Child Psychology,* **38,** 103–113.

Reeve, L., Reeve, K. F., Brown, A. K., Brown, J. L., & Poulson, C. L. (1992). Effects of delayed reinforcement on infant vocalization rate. *Journal of the Experimental Analysis of Behavior,* **58,** 1–8.

Rohrbaugh, J. W. (1984). The orienting reflex: Performance and central nervous system manifestations. In R. Parasuranam and D. R. Davies (Eds.), *Varieties of attention* (pp. 323–373). Orlando: Academic Press.

Sameroff, A. J. (1967). Non-nutritive sucking in newborns under visual and auditory stimulation. *Child Development,* **38,** 443–452.

Sameroff, A. J., & Cavanagh, P. J. (1979). Learning in infancy: A developmental perspective. In Joy D. Osofsky (Ed.), *Handbook of infant development* (pp. 344–392). New York: Wiley.

Sansavini, A., Bertoncini, J., & Giovanelli, G. (1997). Newborns discriminate the rhythm of multisyllabic stressed words. *Developmental Psychology,* **33**.

Siqueland, E. R. (1968). Reinforcement patterns and extinction in human newborns. *Journal of Experimental Child Psychology,* **6,** 431–442.

Siqueland, E. R., & Lipsitt, L. P. (1966). Conditioned head-turning in human newborns. *Journal of Experimental Child Psychology,* **3,** 356–376.

Sokolov, E. N. (1963). *Perception and the conditioned reflex.* New York: MacMillan.

Spence, M. J., & DeCasper, A. J. (1987). Prenatal experience with low-frequency maternal-voice sounds influences neonatal perception of maternal voice samples. *Infant Behavior and Development,* **10,** 133–142.

Swain, I. U., Zelazo, P. R., & Clifton, R. K. (1993). Newborn infants' memory for speech sounds retained over 24 hours. *Developmental Psychology,* **29,** 312–323.

Trehub, S. E., & Chang, H. W. (1977). Speech as reinforcing stimulation for infants. *Developmental Psychology,* **13,** 170–171.

Williams, L., & Golenski, J. (1978). Infant speech sound discrimination: The effects of contingent versus noncontingent stimulus presentation. *Child Development,* **49,** 213–217.

RECEIVED: August 4, 1994; REVISED: May 28, 1996