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The Effects of Delay on Neonatal Retention of Habituated Head-Turning

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Recovery of neonatal head orientation following auditory habituation was used to examine the effects of intertrial delay. One of two words served as stimuli with criterion orienting and habituation established before the delay. Fifty-six full-term neonates were assigned randomly to one of four delay groups: 10 (control), 55, 100, or 145 s. The percentage of head-turns toward the sound source (with one turn per trial) for blocks of three trials served as the principal dependent variable. Recovery of localized head-turning increased as length of delay increased, with the 100- and 145-s groups showing greater recovery than the 10- and 55-s groups. Infants presented with control trials systematically turned away from the sound source following habituation. Selective sensory adaptation, spontaneous recovery, and short-term memory interpretations of these data are considered.

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Newborn attention habituates to redundant stimuli and is restored to novel stimuli (Brody, Zelazo, & Chaika, 1984; Slater, Morison, & Rose, 1983, 1984; Weiss & Zelazo, 1986; Zelazo, Brody, & Chaika, 1984). Habituation and discrimination of novel and familiar stimuli occur for heart-rate deceleration, visual fixation, and high-amplitude sucking to visual stimuli (Adkinson & Berg, 1976; Friedman, 1972; Milewski & Siqueland, 1975; Slater et al., 1983, 1984; Werner & Siqueland, 1978), and they occur for localized head turning and heart-rate deceleration to auditory stimuli (Brody et al., 1984; Clarkson & Berg, 1983; Zelazo et al., 1984). Habituation and recovery were shown also for respiration changes to olfactory stimuli (Engen, Lipsitt, & Kaye, 1963), and heart-rate deceleration to tactual stimuli (Pomerleau-Malcuit & Clifton, 1973). Nevertheless, little is known about newborn habituation beyond the demonstration that infants can discriminate novel from familiar stimuli.

Our limited knowledge of newborn attention is due largely to methodological shortcomings (Brody et al., 1984; Fantz, 1964; Slater et al., 1983, 1984; Wetherford & Cohen, 1973; Zelazo et al., 1984) and to the neonate's labile states (Clifton & Nelson, 1976). Moreover, demonstrations of newborn attention and habituation have included few experimental manipulations, are hampered by high subject attrition (Friedman, Bruno, & Vietze, 1974), and have used difficult-to-measure dependent variables (Clarkson & Berg, 1983) resulting in only sparse data on newborn perceptual-cognitive abilities. The absence of behavioral demonstrations implying higher-order processing including memory has led to the conclusion, perhaps prematurely, that newborn processing capabilities are qualitatively different from those of 3- to 4-month-old infants (Olson & Strauss, 1984).

Habituation and renewed responding to novel stimuli by older infants is generally considered an indication of information processing, including the capacity to remember events (Cohen, 1973, 1976; Lewis, 1971; Olson, 1976). However, existing demonstrations of newborn habituation can be accounted for by a selective receptor adaptation interpretation (Dannemiller & Banks, 1983, 1986) which implies that newborn behavioral habituation results from selective fatigue of the receptors and neurons excited by a repeated stimulus. Renewed responding to a novel stimulus occurs with excitation of different receptors. From this parsimonious view, neither habituation to a repeated event nor renewed responding to a novel stimulus requires memorial processes. Unfortunately, both of these interpretations have been formulated with a relative absence of direct evidence from newborn attention research. However, recent methodological and procedural advances for studying neonatal visual (Slater & Morison, 1985) and auditory (Muir & Clifton, 1984) attention afford an opportunity to empirically distinguish sensory adaptation from memorial views.

One new methodological development that may facilitate the study of newborn auditory retention and processing derives from recent demonstrations that newborns localize laterally presented sounds (Clarkson, Clifton, & Morrongiello, 1985; Clarkson, Morrongiello, & Clifton, 1982; Clifton, Morrongiello, Kulig, & Dowd, 1981; Field, DiFranco, Dodwell, & Muir, 1979; Morrongiello, Clifton, & Kulig, 1982; Muir & Clifton, 1984; Muir & Field, 1979). Zelazo and his associates (Brody et al., 1984; Swain & Zelazo, 1987; Weiss & Zelazo, 1986; Zelazo et al., 1984) adapted this procedure to show that 72-hour-old infants displayed habituation of localized head-turning to familiar sounds (words or rattles) and recovery to novel sounds (new words or different rattles). The use of no-change control groups in these studies revealed that low levels of head-turning toward the familiarized sound continued beyond the imposed habituation criterion compared to either within-group baseline levels or to between-group novel word conditions. Weiss and Zelazo (1986) used a partial-lag design (Bertenthal, Campos, & Haith, 1980) and Swain and Zelazo (1987) used 30 fixed trials to validate the criterion of habituation reported in previous studies (Brody et al., 1984; Zelazo et al., 1984). These data imply that the decrement in head-turning toward repeated auditory stimuli is not an artifact of an infant-controlled procedure and is consistent with Thompson and Spencer's (1966) criteria for habituation. Head-turning to sound is an unambiguous, easily elicited behavior that may be sensitive to a variety of temporal and stimulus parameters. Hence, this methodology holds potential for examining characteristics of newborn attention which may be analogous to research with older infants.

Differential responsiveness to familiar stimuli following varied posthabituation delays has been used to assess memory formation in older infants and nonhuman primates. Three- to 6-month-old infants discriminate novel from familiar achromatic visual patterns and faces after delays varying from 2 hours to 2 weeks (Fagan, 1970, 1971, 1973, 1982). Following habituation of visual fixation to various geometric form-color combinations, infants as young as 2 months of age show modest discrimination 24 hours later, whereas 5-month-old infants display more pronounced effects (Martin, 1975). Using an operant paradigm, Rovee-Collier, Patterson, and Hayne (1985) found that 3-month-olds can distinguish familiar and novel mobile configurations up to 2 weeks after initial training if they are presented with a "reminder" 24 hours prior to a delayed retention test. Ungerer, Brody, and Zelazo (1978) reported that 2- to 4-week-old infants retained auditory information for 14 to 42 hours following training. Two-week-old infants presented with daily exposures to one of two words showed retention of the experimentally induced familiar word relative to novel words and an untrained control group. Colombo and D'Amato (1986) examined short-term visual and auditory memory in monkeys by varying the lengths of the intervals and the types of information that produced interference.

The time course for posthabituation retention following different delays and the concomitant assessment of spontaneous recovery have not been studied systematically in the human newborn. A mean intertrial interval of 10 s was used in the procedures reported by Brody et al. (1984), Zelazo et al. (1984), and Weiss and Zelazo (1986), implying that this duration was sufficient to maintain habituated levels of localized head-turning for neonates in the no-change control groups.

Examination of the newborn's capacity to retain previously familiar information over relatively short durations using the localized head-turning paradigm was the focus of this study. Thompson and Spencer (1966) suggested that spontaneous recovery of an habituated response following delayed presentation of the familiar stimulus was a defining characteristic of habituation. Thus, the intertrial delay after criterion habituation to a standard stimulus was varied using four durations with familiar rather than novel stimuli presented following habituation. Renewed attention to a previously habituated stimulus was expected to increase directly as the intertrial delay increased. The approximate limit of short-term newborn retention implied by relative recovery of localized head-turning was a question to be answered empirically.

METHOD

Subjects

Neonates were chosen from the well-baby nurseries of St. Margaret's Hospital for Women in Dorchester, Massachusetts and the Mortimer B. Davis Jewish General Hospital in Montreal, Quebec. A priori criteria for recruitment required that neonates be: (a) approximately 72 hours of age; (b) fed within approximately 1 hour of testing; and (c) asleep when located—pilot data indicated that infants who were previously awake were more likely to change state during the experimental session. Initially, 72 babies were recruited from the nursery, but 16 did not provide data due to fussiness (9), drowsiness (6), or failure to orient to the initial stimulus (1). The relatively low attrition rate (22.2%) was attributed to the careful recruitment of subjects, choice of test times, compelling auditory stimuli, and effective procedure. The final sample included 28 males and 28 females distributed equally across the four conditions (mean age of 63 hours; range = 23–81 hours). The sample was predominantly Caucasian with mid-socioeconomic status (SES). All newborns were healthy and full-term (39–41 weeks gestation), free from major delivery and birth complications, and weighed between 2,500 and 4,800 gms.

Apparatus and Stimuli

Auditory stimuli consisted of two words played on a Pioneer two-channel tape deck (model RT1050) and amplified through Fischer stereo speakers played at 75 dB. The words *tinder* and *beagle* were chosen as test stimuli because of their low frequency of occurrence (Kucera & Francis, 1967), comparable length, and phonetic content which were demonstrated previously to be discriminable by older infants (Eimas, 1975). Initially, one tape loop for each word was recorded by a female experimenter who repeated each word in a consistent volume and intonation at a rate of one word every 2 s. Each word was approximately 1 s in duration and was repeated three times on a tape loop. The loop was rerecorded on a larger reel-to-reel tape to produce 30 min of continuous recording. Each word was recorded on two of the four stereo tape tracks, and a silent switch box connecting the tape recorder and the stereo receiver enabled either pair of tape tracks to be played. Infants' head-turning and state changes were coded by pressing a silent button box connected to a Beckman R-511 Dynograph recorder and were time-locked with durations of stimulus presentations.

Procedure

A sleeping infant was taken from the nursery to a dimly lit, sound-attenuated adjacent room. To encourage an alert, inactive state for testing, a subset of behaviors including face-to-face looking, sucking, rooting, palmer, babinski, moro, and tonic-neck reflexes were elicited using a procedure that lasted 5 to 10 min. The infant's night shirt was then removed, if necessary the diaper was changed, and the infant was given approximately 1 ounce of 5% glucose water.

Once awakened, the baby was held by one experimenter at a 45° angle between vertical and supine with the infant's head and shoulders supported in the right hand and its lower back and buttocks in the left hand (cf. Muir & Field, 1979). The holder leaned against a warming table for support with stereo speakers placed on each side of the table approximately 30 cm from the infant's ears. A second experimenter stood immediately to the side of the holder and coded the infant's head-turning to either the left or right side by depressing buttons connected to the event recorder. State was monitored by coding the duration of eyes closed and fretting. Both the holder and coder were unaware of the subject's group assigment and the location and identity of the stimuli; they wore headphones through which they heard both stimulus words played in both ears. A third experimenter determined the group to which the subject was assigned, presented the stimuli, and tabulated the infant's responses "on line" to determine if a head-turn had been made and when criteria for orientation and habituation were achieved.

Stimuli were presented using an infant-controlled procedure in a left-right-right-left order with initial side of presentation counterbalanced within each group, as was the order of tinder and beagle as the experimentally induced familiar or novel stimuli. Each trial lasted either 30 s or until the infant demonstrated a sustained 3-s head-turn. The intertrial intervals averaged 8.1 s with a range of 2 to 35 s. Three responses were coded: The infant could turn toward or away from the sound source or produce no turn at all. Head turns were coded when the infant rotated the sagittal midline of his head 45° to either side. Any head-turn within the middle 90° of the 180° arc of possible turns was coded as "no turn." The 45° criterion is conservative relative to the criteria of 6° and 15° used by Muir and Field (1979) and Clifton et al. (1981), respectively, and was chosen to reduce the probability of spurious turns. Following each trial, the infant's head was recentered by the holder before beginning the next trial.

Interobserver reliability was calculated using two observers who coded head-turns independently with nonexperimental infants. Each reliability trial was exactly like experimental trials with one modification. Experimental trials were terminated if the infant demonstrated a head-turn for a 3-s duration, whereas reliability trials were presented for 15 s whether the infant demonstrated a head turn or not. This modification prevented one coder from influencing the other. For example, if one coder recorded a head-turn which resulted in terminating a trial, the second coder (who may not have coded the turn) would have been given feedback. Reliability coefficients for head-turning were determined as a percentage of agreement in which both coders recorded a 3-s head-turn in the same direction. Interobserver agreement was demonstrated in 90.54% of the reliability trials in which nine infants were assessed for a total of 349 trials.

The experimental paradigm consisted of three phases: (1) Orientation-Habituation Phase: initial presentation of the standard sound; (2) Spontaneous Recovery Phase: presentation of the standard sound for a minimum of six trials following one of four different intertrial delays; and (3) Novelty Phase: presentation of a novel sound. The initial Orientation-Habituation Phase had two criteria. Initial orientation required three turns toward the sound within four consecutive trials. Habituation required three successive trials in which no head-turn or turning away from the sound occurred following criterion orientation.

The systematic variation of delay was introduced during the interval between the third habituation and the first retention trial. At this point, each infant was held by the experimenter for one of the four randomly chosen periods, that is, 10- (control), 55-, 100-, or 145-s delays. During the delay, the holder either rocked, soothed, or aroused the infant with a pacifier to maintain a quiet alert state.

The Spontaneous Recovery Phase began after the assigned delay. At this point, infants were presented with the previously familiar standard sound for at least six trials. If the baby reoriented within six trials (three of four turns toward the sound), the sound continued until habituation was demonstrated for a second time, that is, no turns or turning away on three successive trials. If an infant began to reorient to the standard word on the fifth or sixth postdelay trial, up to three additional trials were presented to a maximum of nine trials. This procedure allowed the infant sufficient opportunity to achieve the criterion were it to occur.

The Novelty Phase began either after habituation to criterion to the post-delay standard or after the minimum six to nine trials of the standard when re-orientation did not occur. The novel word was presented for at least nine trials provided that the infant both oriented and habituated using the same criteria described for the initial Orientation-Habituation Phase. The experiment ended after habituation to the novel word.

Measures

The principal dependent variable was the percentage of trials in which localized head-turning occurred during each trial block with one response per trial. Four sets of analyses were performed: three separate analyses to assess each phase of the experiment, and one set of analyses to directly compare the three phases. In the initial Orientation-Habituation Phase, the four delay groups were compared across the first six standard trials divided into two trial blocks, and a second analysis across four trial blocks which included all the standard trials. Also, a "difference score" was calculated to contrast the frequency of turns toward or away from the stimulus to determine if directed head-turning exceeded chance levels (a score of 0). Earlier studies, for example, Muir and Field (1979), emphasized head-turning toward the sound source as the principal measure, but it is useful to recognize that head-turns can be made either toward or away from the source or no turn at all can occur (Clarkson et al., 1985). Assessment of the full range of possible turns offered concurrent validity of the procedure.

In the Spontaneous Recovery Phase, percent of trial blocks with a head-turn toward the standard stimulus was compared for the four groups following the delay. A Delay-Group main effect was predicted. A difference score was also used to compare head-turns toward or away from the standard stimulus following posthabituation delays. Analyses of turns away from the sound provide a vehicle to assess posthabituation attention to the familiar word. In particular, head turns away from the redundant information following habituation can indicate whether newborns respond systematically, implying central processing, or at change levels, implying selective receptor adaptation. In the Novelty Phase, head-turns to the novel stimulus were compared over trial blocks for the four delay groups. Recovery to a novel word in the four conditions would confirm that all children were awake and aroused equally and that fatigue was not a determinant of the results. The novelty test also offers an opportunity to compare differential influences of delay conditions.

The last analysis compared percentage of localized head-turns using the first six trials of each phase among groups. This mixed group analysis compared each neonate's postdelay head-turning with initial responding during standard and novelty trials. Similarly, response to the novel stimulus presented in the last phase of the experiment was compared to response during the initially novel standard trials. This analysis offered a relative estimate of habituation and recovery independent of the criteria. Moreover, the first six standard trials served as an economical comparison for responses to novelty and postdelay familiarity. Without this analysis, it would have been necessary to add four control groups, corresponding to the four experimental groups, which would receive the novel stimulus following the delay during the Spontaneous Recovery Phase. The base against which recovery was compared in posthabituation trials was the 10-s delay control group in this study. A low level of posthabituation, localized head-turning occurred to redundant stimulation in three previous studies (Brody et al., 1984; Weiss & Zelazo, 1986; Zelazo et al., 1984) and was confirmed using a fixed-trials procedure (Swain & Zelazo, 1987). These studies demonstrated that newborn infants localized laterally presented novel, but not familiar, stimuli following criterion habituation, and recovery closely resembled initial responding to the standard stimulus. The cost associated with adding four postdelay novelty groups to the present design was not justified given the high probability that response to those stimuli would closely resemble the levels expected during the initial standard and posttest novelty phases.

RESULTS

Sex Differences

Initial two-way analyses of variance were calculated to rule out possible sex differences. Comparisons of boys and girls revealed a nonsignificant tendency for girls to turn toward the standard sound at a slightly higher percentage than boys, $F(1,54)=3.10$, $p<.10$. However, boys and girls responded similarly to the standard sound following the delay, $F(1,24)=0.02$, and the novel sound at the end of the session, $F(1,54)=0.51$. Hence, all subsequent analyses were calculated with data pooled across Sex with Delay Group as the independent variable and trial blocks as a repeated measure.

Orientation–Habituation Phase

Initial orientation was assessed in a four-group analysis of variance with two trial blocks as a repeated measure using the first six trials of the standard sound. Percentage of head-turns toward the stimulus was the dependent measure. There were no main effects among groups, $F(3,52)=1.25$, or trial blocks, $F(1,52)=0.01$, and no Group × Block interaction, $F(3,52)=0.90$. Likewise, the number of trials required to demonstrate the criterion of orientation to the standard was compared between the four delay groups using a one-way analysis of variance. Infants required an average of 7.8, 8.3, 4.5, and 7.9 trials in the 10-, 55-, 100-, and 145-s delay conditions, respectively, to achieve criterion for orientation, $F(3,52)=1.96$. These data demonstrate similarity among the four groups.

The initial Orientation-Habituation Phase was also evaluated by dividing the total number of standard trials into four nearly equal trial blocks. This Vincent method (Vincent, 1912; Woodworth & Schlossberg, 1954; Zelazo et al., 1984) was appropriate for an infant-controlled procedure because all of the responses that occur across the varied numbers of trials could be used. If the number of trials did not divide equally into four blocks, one extra or one less trial was randomly assigned to the middle two trial blocks. A backward habituation curve, often reported for habituation data with older infants, was not used because data during the initial trials are not generally included. Because we are interested in initial orientation as well as habituation, a procedure that represented all of the data was preferable. Moreover, the backward habituation curve tends to distort the shape of the acquisition phase, as Cohen and Menten (1981) report.

As indicated in Figure 1, the initial high level of localized head-turning was followed by a decline across trial blocks by every group, $F(3,156) = 39.08$, $p < .0001$, confirming that the criterion for habituation yielded a statistically significant decrement. It is important to recognize that the significant decrease in head-turning toward the standard sound may be an artifact of using an infant-controlled habituation-to-criterion procedure. However, the data reported previously using this procedure (i.e., Zelazo et al., 1984) indicated that no-change control neonates maintained low levels of responding following criterion habituation.

Comparison of the number of trials to achieve the criterion of habituation also indicated that the four groups were similar, $F(3,52) = 0.33$, during standard trials. Mean trials to habituation were 17.1, 19.1, 19.4, and 18.9 for the 10-, 55-, 100-, and 145-s delay conditions, respectively.

Despite similarity among groups on other measures, delay groups differed in the percentage of head-turning during the Orientation-Habituation Phase when compared over the quartile blocks, $F(3,52) = 3.73$, $p < .02$. Pairwise comparisons indicated that only two groups differed statistically—those that subsequently received the longest delays. As can be seen in Figure 1, the two functions are parallel with a higher level of responding among infants who were to experience the 100-s delay, $t(26) = 3.75$, $p < .01$. All other pairwise group comparisons were nonsignificant.

Head-turning toward the standard word was found in an average of 61% of the trials across the first three quartiles of stimulus presentation. This finding

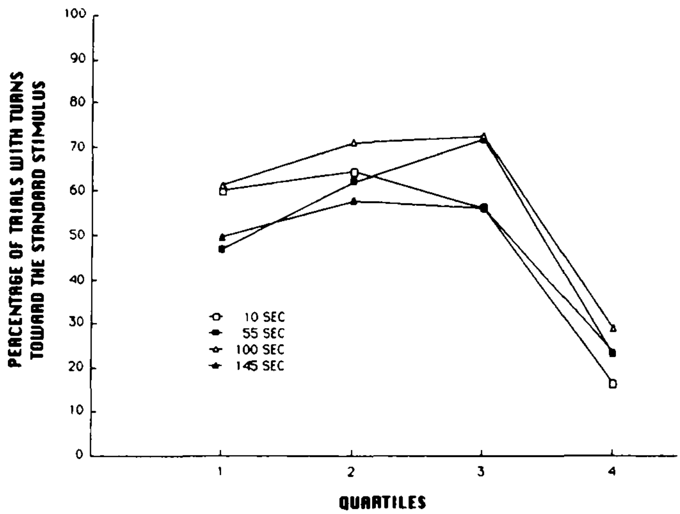

Figure 1. Mean percentage of head-turns toward the standard sound across quartile trial-blocks during the Orientation-Habituation Phase.

is within the limits of earlier reports of newborn orientation to sound which ranged from 45% to 87% (Morrongiello et al., 1982; Muir & Field, 1979). Localized head-turning during the last quartile of the standard was low (23%) and, although influenced by the use of an habituation criterion, was similar to previous studies (Brody et al., 1984; Zelazo et al., 1984).

To determine if head-turning toward the standard stimulus was a random event, a difference score was calculated by subtracting the number of trials with a turn away from trials with a turn toward in each quartile block of the Orientation-Habituation Phase collapsing over all four groups. If attention to the standard stimulus approached chance levels, there would be approximately equal numbers of trials with a turn toward or away, and the difference between head-turns should approach zero. However, when the difference scores were compared to chance levels with Student's t-test, turns toward were similar to turns away during block 1, $t(55) = 1.47$, but greater in both blocks 2, $t(55) = 3.99$, $p < .001$, and 3, $t(55) = 7.42$, $p < .001$. This pattern was reversed with more turns away than toward the standard sound in block 4, $t(55) = -3.88$, $p < .001$. Thus, orientation occurred during blocks 2 and 3, whereas turns away predominated during block 4.

Spontaneous Recovery Phase: Delay

The principal question asked in this study is whether recovery of head-turning can discriminate among infants who have experienced different durations of delay from the presentation of the last habituation stimulus to the reappearance of the standard. The four delay groups were examined over two trial blocks consisting of the first three (block 1) and second three (block 2) postdelay trials. An analysis of variance was calculated for the four delay conditions with Trial Blocks as the repeated measure. As anticipated, duration of delay influenced recovery of localized head-turning among the groups, $F(3,52) = 12.37$, $p < .0001$. As indicated in Figure 2, degree of recovery was a function of delay with the greatest increment occurring between the 55- and 100-s delay periods. Recovery did not vary significantly over trial blocks, $F(1,52) = 0.01$, and there was no Group × Block interaction, $F(3,52) = 1.20$. A polynomial trend analysis of the main effect for the four durations of delay was performed to examine the pattern of recovery. Localized head-turning recovered linearly as the duration of delay increased, $F(1,52) = 10.40$, $p < .01$. There were no quadratic, $F(1,52) = 0.27$, or cubic effects, $F(1,52) = 1.66$.

Recovery following delay was also assessed in pairwise comparisons using the Newmann-Keuls Test. Infants in the two longer delay groups displayed greater recovery than infants in the two shorter delay groups, $p < .05$. Neither differences between the 10- and 55-s groups nor between the 100- and 145-s groups reached significance. Thus, recovery following the 100- and 145-s delays exceeded not only the slight spontaneous recovery that occurred for the 10-s delay control group, but also the level that occurred following the 55-s delay.

The percentage of turns toward, no turns, and turns away occurring during the six trials following the intertrial delays is depicted in Figure 3. Student's

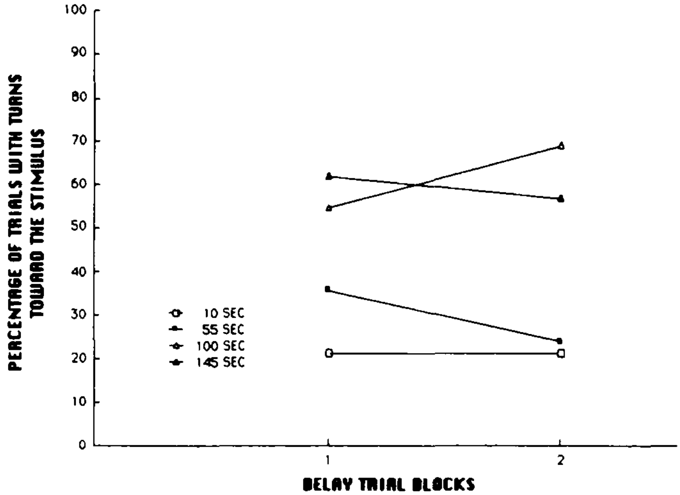

Figure 2. Mean percentage of head-turns toward the standard stimulus following the posthabituation delay. Trial block 1 represents the mean percentage of head-turning during postdelay trials 1, 2, and 3, and trial block 2 represents postdelay trials 4, 5, and 6.

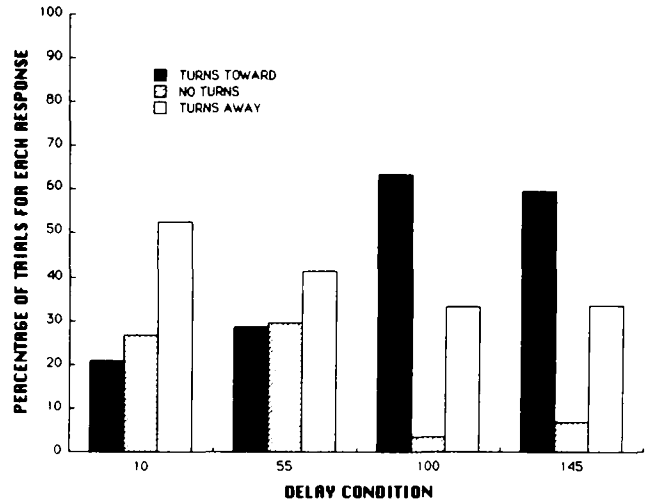

Figure 3. Mean percentage of head-turns toward, no turn, or turns away from the standard stimulus during the six posthabituation delay trials.

t-tests were calculated by subtracting the number of turns toward from the number of turns away for each infant in each delay condition to determine if the infant's postdelay behavior approached chance levels. However, infants in the 10-s control condition turned away from the familiar word, $t(13)=3.20$ $p<.005$. Turns toward the sound source predominated in the 100-s, $t(13)=2.10$, $p<.05$, and 145-s, $t(13)=-2.70$, $p<.01$, delay groups, whereas no difference was found for infants in the 55-s delay group, $t(13)=1.03$.

Novelty Phase

A novel word was presented following the delay phase to confirm that infants in all groups remained similarly aroused and responsive to the auditory stimuli and to compare their relative arousal and responsiveness to novelty. The first six trials were divided into two Trial Blocks as in the Orientation-Habituation Phase. A four-group analysis of variance, with two Trial Blocks as a repeated measure, revealed comparable percentages of head-turning toward the novel stimulus among the four delay groups, $F(3,52) = 1.60$, and Trial Blocks, $F(1,52) = 0.77$, with no Group × Block interaction, $F(3,52) = 1.80$. Recovery was similar for all groups.

A second analysis was performed to assess responding throughout the novelty phase. The total number of trials was divided into near-equal quartile blocks similar to the Orientation-Habituation Phase. The percentage of head-turns toward the sound in each Trial Block, as shown in Figure 4, served as the dependent measure. A four-group analysis of variance with four Trial Blocks as a repeated measure revealed that the delay groups responded similarly to the novel word, $F(3,52) = 1.42$, and that localized head-turning declined over Trial Blocks, $F(3,52) = 50.75$, $p < .0001$. A Group × Trial Block interaction, $F(9,156) = 2.69$, $p < .006$, qualifies the main effect. Infants in the 100-s delay condition demonstrated greater responsiveness during Trial Blocks 1 and 2 and declined during block 3, whereas infants in the 10-s delay condition increased over Trial Blocks, showing greatest responsiveness in the third Trial Block.

Difference scores (turns away subtracted from turns toward) collapsed over Groups revealed that turns toward the sound were greater during blocks 1, $t(55) = 1.88$, $p < .05$, 2, $t(55) = 3.73$, $p < .001$, and 3, $t(55) = 7.16$, $p < .001$,

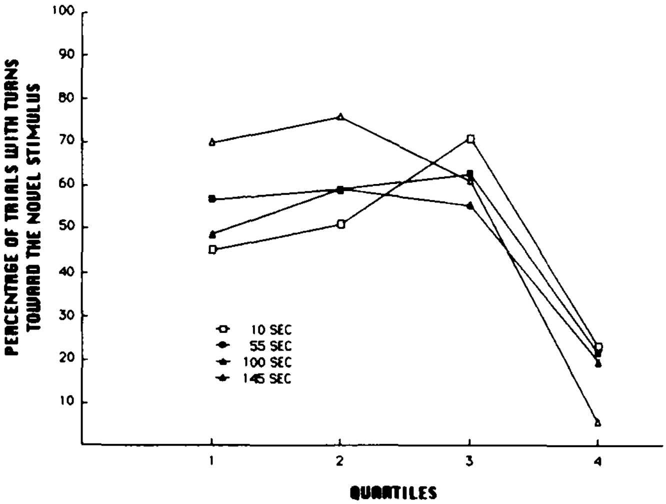

Figure 4. Mean percentage of head-turns toward the novel sound across quartile Trial Blocks during the Novelty Phase.

whereas turns away predominated during block 4, $t(55) = 5.19$, $p < .001$. The difference scores in the first three trial blocks indicate that localized head-turning to the novel sound exceeded chance levels.

A one-way analysis of variance was calculated for the four groups using the number of trials-to-orientation as the dependent measure. Criterion level of recovery was set at three of four consecutive trials in which the infant turned toward the sound source. The results were similar for the four groups with means of 8.2, 7.0, 5.2, and 7.3 trials for the 10-, 55-, 100- and 145-s delay groups, respectively, $F(3,52) = 1.09$. The number of trials-to-habituation was similar also, $F(3,52) = 1.71$, requiring 19.6, 16.9, 13.5, and 16.0 trials for the 10-, 55-, 100-, and 145-s groups, respectively. Thus, infants in all four conditions demonstrated comparable head-turning to the novel word indicating that observed differences among the four groups following the delay periods are not easily attributable to differential arousal or fatigue.

Comparison of Initial Orienting, Familiarity, and Novelty Responses

The following analysis was calculated to assess habituation and recovery trends between and within groups, independent of the orientation and habituation criteria. This was possible by comparing percentage of localized head-turning during the first six trials of each phase measures that were relatively uninfluenced by the imposed criteria. A four-group analysis of variance was calculated with the first six trials of the standard, postdelay, and novelty phases serving as repeated-measure Trial Blocks. As indicated in Figure 5, Groups, $F(3,52) = 9.00$, $p < .0001$, and Trial Blocks, $F(2,104) = 7.47$, $p < .0009$, differed, and there was a significant Group × Block interaction, $F(6,104) = 26.90$, $p < .02$.

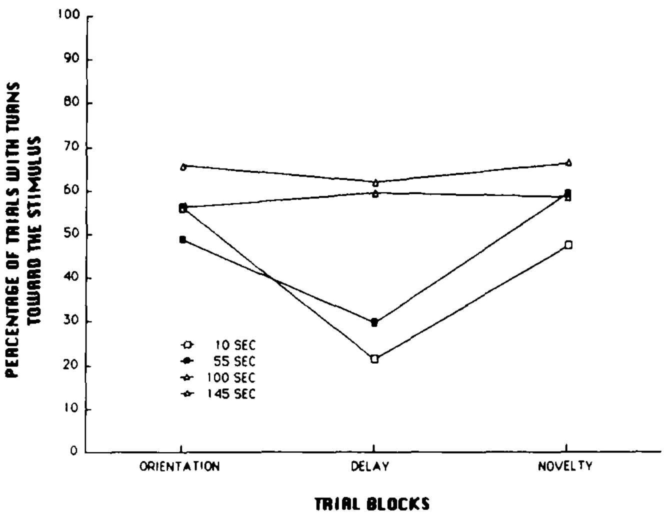

Figure 5. Mean percentage of head-turns toward the stimulus during the first six trials of the Orientation-Habituation (block 1), Postdelay (block 2), and Novelty (block 3) Phases.

Percentage of localized head-turning following the 10- and 55-s delays remained significantly below the initial standard trials, indicating habituation, and increased to posttest novelty trials, implying recovery of attention. Moreover, newborns showed similar percentages of localized head-turning to the initially novel standard stimulus, the familiar stimulus following the 100- and 145-s delays, and the novel stimulus during the Novelty Phase.

DISCUSSION

The results from this experiment replicate the finding that newborns localize and habituate head-turning to familiar auditory stimuli and renew responding to novel stimuli (Brody et al., 1984; Clarkson et al., 1982; Clifton et al., 1981; Field et al., 1979; Muir & Field, 1979; Zelazo et al., 1984). These data extend the initial demonstration of newborn habituation and novelty effects to include the influence of intertrial delay on previously habituated stimuli. Neonates in this study did not show renewed attention similar to that given to a novel stimulus when the retention test occurred within 55 s of the last habituation trial. However, head-turning toward the previously familiar stimulus recovered spontaneously when the retention test occurred following delays of 100 and 145 s. Moreover, neonates in the 10-s delay control group showed more turning away than turning toward the sound source during the trials following criterion habituation, indicating that posthabituation behavior was nonrandom.

At least three interpretations can be offered for the finding that localized head-turning recovers spontaneously following delays of 100 and 145 s. First, it could be argued that renewed orientation is the result of the postrefractory reactivation of the previously fatigued neural set that was associated with the familiar stimulus (Dannemiller & Banks, 1983, 1986). This view implies that infants in the 10- and 55-s delay conditions were selectively fatigued to the familiar stimulus and that the refractory period necessary for spontaneous recovery of these cells falls between 55 and 100 s. However, this interpretation seems unlikely because the speech stimuli used in this study and by Brody et al. (1984) and the wide-band rattle sounds used in previous localized head-turning research (Clifton et al., 1981; Morrongiello et al., 1982; Muir & Field, 1979; Zelazo et al., 1984) appear too diffuse and varied to fit a selective receptor adaptation model. More importantly, infants in the 10-s delay control group systematically turned away from the familiarized standard following criterion habituation. Selective receptor "fatigue" implies a reduction of central nervous system (CNS) responsiveness and chance levels of head-turning following habituation with the incidence of "turns away" equivalent to the occurrences of "turns toward." The results indicate that these infants continued to identify both the location and familiarity of the repeated word after achieving criterion habituation. Because redundant stimuli elicit avoidant behaviors among older infants (Zelazo, Kagan, & Hartmann, 1975), it is possible that neonatal turning away may be an avoidant reaction. It is difficult to reconcile these data with a selective receptor adaptation view.

A second interpretation of these data is that habituation and renewed head-turning following delays of 100 and 145 s may be spontaneously generated random patterns of the organism mediated by changes in level of arousal. It could be argued that criterion habituation is no more than a chance occurrence of three successive turns away or no turns. However, the data from the 10-s delay control group, in which the standard stimulus continued for six trials beyond the criterion for habituation, contradict this artifact hypothesis. The low spontaneous recovery of localized head-turning or statistical regression demonstrated by the 10- and 55-s delay groups remained significantly below their own baseline and novelty posttest levels and the levels for infants in the longer delay groups. Infants in the control group turned toward the sound in only 21% of the six posthabituation trials compared to a range of 50% to 75% during initial standard and posttest novelty trials. Moreover, these data are consistent with four studies showing prolonged low-level responding following criterion habituation (Brody et al., 1984; Swain & Zelazo, 1987; Weiss & Zelazo, 1986; Zelazo et al., 1984). Together, these data imply that the habituation criterion is not merely a statistical artifact.

The argument that spontaneous recovery was due to differential arousal effects during the longer delay periods seems unlikely for three reasons: (a) arousal effects were as likely during the 55-s delay period as the longer delay periods; (b) infants in every group were similarly responsive to the novel posttest stimulus; and (c) neonates in the 10-s control group consistently turned away from the familiar sound following the delay. Implicitly, the control infants were sufficiently aroused to be able to consistently locate and turn away from the redundant sound. An adequate interpretation of these data must account for bidirectional responding. Explanations which account for these data as random spontaneous recovery and differential arousal are too simplistic.

A third interpretation is that these data reflect short-term memory as a function of brief delays (Brody et al., 1984; Colombo & D'Amato, 1986; Leaton & Tighe, 1976; Thompson & Spencer, 1966; Zelazo et al., 1984). For example, the systematic turning away from the repeated standard sound following criterion habituation implies that a salient feature of the stimulus may be stored for brief periods and may moderate behavior as a function of degree of familiarity. If a memory interpretation holds, these results imply that the outer limit of the 63-hour-old neonate's ability to retain redundant information in memory using the head-turning paradigm is between 55 and 100 s. These limits may be specific to the stimulus conditions and paradigm used, and the generalizability of this finding to other circumstances must await further research. Nonetheless, the essentially identical results for the 100- and 145-s delay conditions can be viewed as a within-experiment replication and provide generality of recovery to two durations of delay. A memory interpretation gains credibility from a recent demonstration of retention of a conjugate foot-kicking task over a 1-week period by 2-month-olds (Vander Linde, Morrongiello, & Rovee-Collier, 1985) and by a previous demonstration of long-term retention of spoken words by 2- to 4-week-olds (Ungerer et al., 1978). Indeed, DeCasper and Fifer (1980) and DeCasper and Spencer (1986) provide evidence for newborn retention of auditory learning in utero.

Thompson and Spencer (1966) suggested that one defining characteristic of habituation may be found from training "beyond the zero or asymptotic response level. Additional habituation training given after the response has disappeared or reached a stable habituated level will result in slower recovery" (p. 19). The significant Delay Group × Trial Block interaction during the Novelty Phase is consistent with this definition and offers some support to a retention interpretation. If the habituation criterion employed in this study and previous work is valid (Brody et al., 1984; Zelazo et al., 1984), then the 10-s delay control trials represent postasymptotic training. As can be seen in Figure 4, the 10-s control group increased responding to the novel sound but at a slower rate than the other groups.

It is our contention that previous failures to obtain habituation and recovery in newborn attention were due to methodological limitations, a position echoed by Slater et al. (1984). However, the adaptation of localized head-turning to an habituation-recovery paradigm may offer one method for expanding the database on newborn retention. The paradigm employed and the central findings of this experiment support the suggestion that localized head-turning is a readily observable response that may be manipulated relatively easily to study short-term retention among human neonates just as it is used to study short-term memory in nonhuman primates (Colombo & D'Amato, 1986). It is our impression that these results indicate that newborn infants retain information for specific stimuli and actively process and compare new information with these experiences.

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