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Effects of Attention on Infants' Preference for Briefly Exposed Visual Stimuli in the Paired-Comparison Recognition-Memory Paradigm

John E. Richards
University of South Carolina

This study examined the effect of attention on 3- to 6-month-olds' responses to briefly exposed visual stimuli. In Study 1, stimuli presented at 2.5 or 5.0 s resulted in a familiarity preference in a subsequent paired-comparison procedure. A novelty preference was found with 10.0- or 20.0-s exposure durations. In Study 2, a Sesame Street movie elicited heart-rate-defined attention phases and stimuli replaced Sesame Street during sustained attention, attention termination, or 5.0 s following attention termination. For 20 and 26-week-olds, stimuli presented for 5.0 s during sustained attention resulted in a novelty preference similar to that found when exposure time was 20.0 s. The duration of stimulus exposure during sustained attention in the familiarization phase was positively correlated with the preference for the novel stimulus in the paired-comparison procedure. Thus, processing of briefly presented visual stimuli differs depending on the type of attention in which the infant is currently engaged.

Infant recognition memory has been studied extensively using the paired-comparison procedure (Colombo, Mitchell, & Horowitz, 1988; Fagan, 1974; Rose, 1983). In this procedure, infants are exposed to a single stimulus ("familiar" stimulus) during a familiarization phase. Then, during a test phase that stimulus is paired with a stimulus not previously presented ("novel" stimulus). The paired-comparison procedure takes advantage of the infant's tendency to look more at the novel than at the familiar stimulus. *Novelty preference* is considered to be a measure of recognition of the familiar stimulus. The present study examined brief stimulus exposure durations in the familiarization phase that result in a *familiarity preference* during the test phase and the effect that attention in the familiarization phase has on the novelty–familiarity preference for briefly exposed visual stimuli.

One variable that affects recognition memory in the paired-comparison procedure is the duration of the exposure to the stimulus in the familiarization phase. Some studies have manipulated this variable explicitly (e.g., Fagan, 1974; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982; Wagner & Sakovits, 1986), whereas others used stimulus durations of varying intervals to achieve equivalent novelty preference proportions across different groups or different stimuli (Colombo et al., 1988; Freeseman, Colombo, & Coldren, 1993; Rose, 1983). At a given age, increased exposure duration during the familiarization phase results in increased fixation duration on the previously unexposed stimulus (novelty preference) during the paired-comparison test phase (Fagan, 1974). Across the 3- to 12-month-old age range, older infants need less exposure time to reach a comparable novelty preference level (Colombo et al., 1988; Rose, 1983; Rose et al., 1982).

A finding that occasionally has been reported is that following very brief exposures (5–10 s) to visual stimuli, the stimulus exposed on the familiarization phase is fixated longer than the novel stimulus during the paired-comparison test phase (Hunter, Ames, & Koopman, 1983; Hunter, Ross, & Ames, 1982; Rose et al., 1982; Wagner & Sakovits, 1986). This familiarity preference was reported by Rose et al. (1982) in a study with infants ranging in ages from 3 to 6 months. The infants were presented with 3-D stimuli for exposure durations from 5 to 30 s. Rose et al. (1982) reported that exposure durations of 5 or 10 s in the familiarization phase resulted in familiarity preference during the test phase. Exposure durations of 15 s (6-month-olds) or 30 s (3-month-olds) resulted in novelty preference. Similarly, Wagner and Sakovits (1986) reported a familiarity preference in the paired-comparison test phase in 9-month-olds for simple visual shapes at 10 s of stimulus exposure (46%), equal novel or familiar fixation times at 20 s, and a novelty preference at 60 s (56%). Rose et al. (1982), among others, argued that brief exposures result in incomplete processing of the stimulus information and the subsequent preference for the familiar stimulus is an attempt to complete processing. Following extended exposure durations and presumably more complete processing of stimulus information, the novel stimulus is fixated longer during the test phase.

The hypothesis that partial processing of stimulus information contributes to familiarity preferences after brief stimulus exposures was more directly tested in studies by Hunter et al. (1982, 1983). Infants that were totally habituated to a complex display of objects were compared with infants whose fixation in the familiarization phase was interrupted before habituation could take place. The interruption of the habituation sequence thus resulted in only partial familiarization with the stimulus. The

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Correspondence concerning this article should be sent to John E. Richards, Department of Psychology, University of South Carolina, Columbia, South Carolina 29208. Electronic mail may be sent via Internet to richards-john@sc.edu.

totally habituated infants spent most of the time on a subsequent test phase examining the novel stimulus, whereas the infants interrupted in the habituation spent more time examining the familiar stimulus in the test phase. This finding interacted with complexity of the stimulus; more complex stimuli resulted in familiarity preferences (Hunter et al., 1983). Brief exposure times for simple stimuli should allow full processing of the stimulus information and familiarity preference might never be expressed. More complex stimuli may be more likely to result in familiarity preferences at brief exposure times simply because partial processing of the stimulus information has occurred (Hunter et al., 1983).

The hypothesis that familiarity preferences are based on partial processing of the familiar stimulus might be tested by varying the intensity of cognitive processing that is occurring during the familiarization phase of the paired-comparison recognition memory procedure. Brief exposure to stimuli during intense cognitive activity should result in more complete information processing than exposure occurring during casual cognitive activity. Both Richards (1988; Richards & Casey, 1992) and Ruff (1986) have hypothesized that distinct phases of attention to visual patterns and objects differ in processing intensity level. *Sustained attention* is hypothesized in those models to be highly intensive, effortful, and efficient information acquisition, whereas *casual attention* (Ruff, 1986) or *attention termination* (Casey & Richards, 1991; Richards & Casey, 1991) is less intensive or resistant to information acquisition. Stimuli presented during sustained attention should have more complete processing than stimuli presented during casual attention. Thus, one might expect different amounts of familiarity preferences by presenting stimuli briefly during different attention phases.

Two studies examined the responses of 14-, 20-, and 26-week-old infants to briefly presented visual stimuli. In Study 1, visual patterns were presented with durations of 2.5, 5.0, 7.5, 10.0, or 20.0 s. Following the presentation, a paired-comparison procedure was used to present the familiar stimulus with a stimulus not previously seen. Study 1 determined if a novelty preference would result from the longest duration exposures and a familiarity preference would result from the shorter duration exposures. Study 1 was also designed to determine if these stimuli and durations resulted in the shift from familiarity to novelty preferences found in past research with infants of this age (e.g., Rose et al., 1982).

In Study 2, a Sesame Street movie was used to elicit changes in heart rate known to be associated with different attention phases (Richards & Casey, 1992). Sustained attention is accompanied by a deceleration of heart rate and a sustained lowered heart rate. Following sustained attention, the return of heart rate to its prestimulus level indicates the onset of attention termination, which is less intensive and is resistant to new stimulus information (Casey & Richards, 1988, 1991; Richards & Casey, 1991). A stimulus of 2.5 or 5.0 s in duration was presented at the heart-rate-defined attention phases of sustained attention, attention termination, and 5 s following attention termination. Following this exposure, a paired-comparison procedure was used to examine responses to the familiar stimulus and to a stimulus not previously seen. The purpose of Study 2 was to evaluate the effect that ongoing attention level during the familiarization phase has on the processing of the briefly presented visual stimuli. It was expected that more complete processing of the stimulus would occur when it was presented during the sustained lowered heart rate (sustained attention) than at the beginning of fixation (stimulus orienting) or when heart rate had returned to its prestimulus level (attention termination).

Study 1

Method

Participants. The participants were 15 full-term infants (gestational age > 38 weeks, birthweight > 2,500 g) sampled cross-sectionally at 14 (n = 5, M = 100.8 days, SD = 3.34), 20 (n = 5, M = 139.0 days, SD = 1.87), or 26 (n = 5, M = 184.6 days, SD = 2.70) weeks postnatal age. The infants had no acute or chronic pre- or perinatal medical complications and were in good health at the time of recording.

Apparatus. The infant was held in a parent's lap approximately 51 cm from the inner edge of two black and white 49 cm (19 in.) TV monitors. The center of each screen was 56 cm from the infant's eyes, and the far edge was 70 cm. The plane of the TVs was parallel to the infant's eyes. The TVs subtended 88° visual angle, with one TV subtending 44° visual angle. There was a visual angle of 48° from center to center of each monitor. An LED on the bottom center of each TV and an LED in the middle between the TVs blinked at a rate of 3.33 Hz. A neutral color material covered the surrounding area. A video camera was above the TVs, and in an adjacent room an observer judged infant fixations on a TV monitor. The session was recorded on videotape with a time code to synchronize physiological and experimental information for analysis.

The stimuli consisted of computer generated patterns (e.g., a series of computer generated concentric squares of varying size, a flashing checkerboard pattern, and a small box shape moving in a diamond). The stimulus display area was a 30-cm square area on one of the TV monitors, subtending 32° visual angle.

Procedure. On each trial, an LED was turned on. A stimulus was displayed when the infant looked in the direction of the LED or TV. The side of the LED on the familiarization phase was the side of the visual stimulus. The LED was presented in the middle on the test phase. There was a 10.0-s intertrial interval between the familiarization and test phases and between the test phase and the next familiarization phase. Testing was done only if the infants maintained an alert, awake state during the entire procedure (i.e., eyes open, no fussing or crying, and responding to the protocol).

Each infant received six experimental conditions in random order. The conditions differed in the duration of the visual stimulus during the familiarization phase. The stimulus was presented for accumulated fixation durations of 2.5, 5.0, 7.5, 10.0, or 20.0 s. An additional condition consisted of the paired-comparison test phase without a familiarization phase. Each exposure condition consisted of the continuous display of the familiar stimulus. The stimulus remained on until the infant accumulated the appropriate exposure duration.

The test phase for recognition memory followed the familiarization phase. The test phase consisted of the simultaneous display of the familiar stimulus and a novel stimulus for 20.0 s of accumulated fixation on either stimulus. The test phase was divided into two 10.0-s accumulated fixation trials, with the side of the stimuli reversed for the second 10.0-s accumulated fixation.

Fixation direction. A single observer in an adjacent room judged the fixation direction of the infant on a TV monitor. Two observers judged fixation direction off-line. One observer was blind to the type of trial (duration of exposure), the side of the stimulus display, and the age of the participant. The observers judged each look as looking at the right TV, looking at the left TV, or looking away. A time code recorded on the videotapes allowed the judgment of time with millisecond accuracy.

Table 1
Proportion Fixation Time on the Novel Stimulus During the Paired-Comparison Phase in Study 1

	Stimulus exposure duration				
Age	2.5 s	5.0 s	7.5 s	10.0 s	20.0 s
14 weeks	.53	.53	.44	.61*	.46
20 weeks	.54	.37*	.54	.56**	.57*
26 weeks	.32*	.24**	.60*	.57*	.71**
Total	.47	.39**	.48	.58*	.58**

Note. The error term for the total participants came from the condition main effect, whereas the entries for the individual ages were tested simply as differences from .50.
$^* p < .10$. $^{**} p < .05$.

The data for the analyses came from the ratings of only one of the off-line observers. Interrater reliabilities of fixation duration judgment were computed between the ratings of the two observers. The average difference in time between the judged occurrence of looks by the two observers was 0.723 s. The observers agreed on the time of looks within 1.0 s on greater than 95% of all judgments. The correlations between total looking-time judgments on the test phase ranged from .90 to .97 for the different conditions (*Mdn* = .94).

Results

The proportion of time fixating on the novel stimulus relative to the total time spent on the familiar or novel stimulus (novelty preference) was analyzed for the paired-comparison test phase. This proportion from the five exposure conditions was analyzed with an Age (3) × Condition (5) × Phase (2; 10.0-s exposures) interaction. The condition main effect was statistically reliable, $F(4, 48) = 2.74$, $p < .05$, and the Age × Condition effect approached statistical significance, $F(8, 48) = 1.86$, $p = .0883$. Table 1 shows the means for the proportion fixation time. Infants fixated longer on the familiar than on the novel stimulus in the 5.0-s exposure condition and longer on the novel stimulus in the 20.0-s exposure condition. Table 1 separates the means by the three ages. The 26-week-olds fixated longer on the familiar stimulus in the 2.5- and 5.0-s conditions, but changed to looking longer at the novel stimulus at the 7.5-s (or longer) condition. The 20-week-olds showed a familiarity preference at 5.0 s that changed to novelty preference by the 10.0-s exposure duration.

Discussion

Infants fixated longer on the familiar stimulus than on a novel stimulus when stimulus exposure during the familiarization phase was 5.0 s (familiarity preference). This fixation preference was reversed when stimulus exposure was 10.0 s or 20.0 s. There were some age differences, suggesting that the oldest infants showed this familiarity preference at the shortest exposure durations (2.5 and 5.0 s) and reversed their fixation to novelty preference by 7.5 s. The younger infants needed longer exposure for both familiarity preferences and the switch to novelty preferences. These results are similar to those of Rose et al. (1982). In their experiment, exposure durations of 5.0 s or 10.0 s resulted in familiarity preference during the test phase and exposure durations of 15.0 s (6-month-olds) or 30.0 s (3-month-olds) resulted in novelty preference. The present results and the Rose et al. (1982) results are consistent with the interpretation that more efficient visual stimulus processing comes with increasing age. Thus, across this age range, a shorter exposure is sufficient for the partial processing that results in familiar stimulus preference in the test phase. Shorter exposure also is sufficient for the change to novel stimulus preference.

Study 2

The most common explanation given for the familiar stimulus preference after brief exposure is that the stimulus was only partially processed during familiarization (Hunter et al., 1982, 1983; Rose et al., 1982; Wagner & Sakovits, 1986). Thus, experimental manipulations that enhance or attenuate complete processing should affect familiarity preferences. The partial processing hypothesis might be tested by varying the intensity of cognitive activity occurring during the familiarization phase of the paired-comparison recognition memory procedure. Brief exposure to stimuli during intense cognitive activity should result in more complete processing than exposure of the same duration but occurring during casual cognitive activity. The second study examined the effect that ongoing attention level during the familiarization phase has on the processing of briefly presented visual stimuli.

In the second study, a stimulus was presented for a brief period of time during different phases of attention defined by heart rate change (Richards & Casey, 1992). Figure 1 contains a schematic illustration of the manipulations. A Sesame Street movie was used to elicit changes in heart rate known to be associated with different attention phases. After a delay, defined by the heart rate change on each trial, a visual pattern was presented for durations of 2.5 or 5.0 s. The delays were defined to make the presentation during sustained attention (heart rate deceleration), attention termination (return of heart rate to prestimulus level), or 5.0 s following attention termination. A fourth condition, *stimulus orienting*, was the presentation of the familiar stimulus for 2.5 or 5.0 s without the Sesame Street presentation (i.e., as in Study 1). The hypothesis of this study was that more complete processing of a stimulus should occur when it was presented during sustained attention than at the beginning of fixation (stimulus orienting) or during attention termination.

The hypothesis that the four exposure conditions would result in different amounts of processing was tested by comparing fixation duration in a paired-comparison test phase for these four conditions with two control conditions of no exposure (paired-comparison test phase only) and 20.0-s accumulated fixation. The fixation on the first stimulus in the test phase of the no-exposure control would be to a novel stimulus. A familiarity preference in the exposure conditions would be shown by first fixation durations on the test phase that were greater than first fixation duration for the no-exposure control. A familiarity preference could be interpreted as resulting from less complete processing of the familiar stimulus and should occur for the conditions in which exposure occurs during stimulus orienting or attention termination. The 20.0-s accumulation control was expected to result in novelty preferences on the test phase (e.g.,

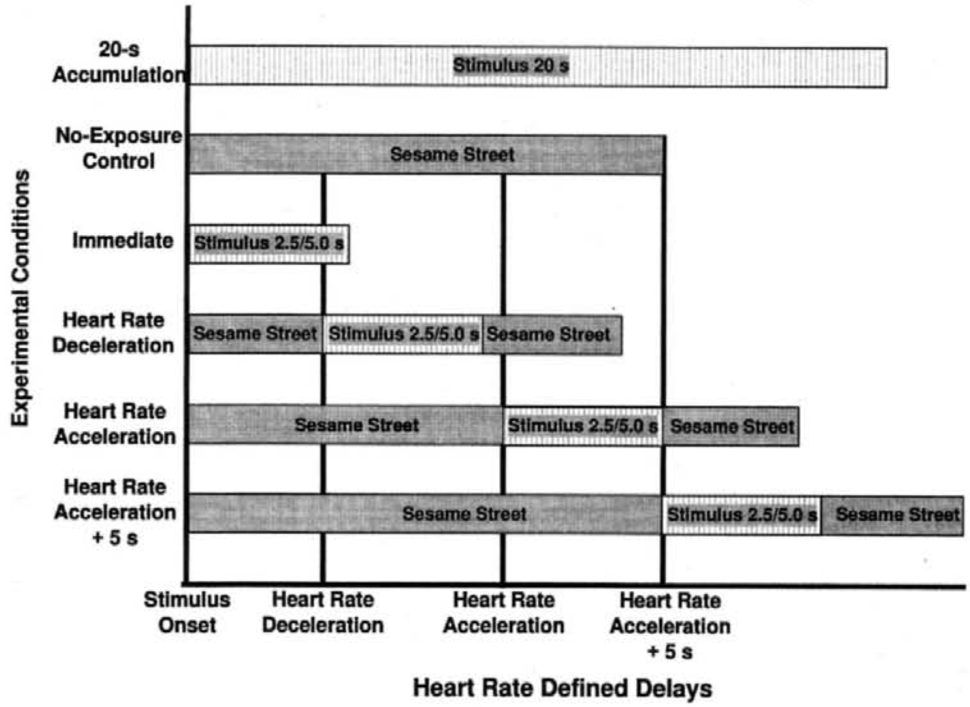

Figure 1. Schematic illustration of six experimental conditions in Study 2. The horizontal bars indicate the type of stimulus that was presented in the different attention phases, and the vertical lines indicate the heart rate defined delays. The familiar stimulus on the three conditions defined by heart rate changes (heart rate deceleration, heart rate acceleration, heart rate acceleration + 5 s) was presented starting with the beginning of the attention phase and may have overlapped subsequent phases. The figure is not drawn to scale in the time domain.

Table 1 from Study 1). A novelty preference in the brief exposure conditions would be shown by shorter fixation duration on the familiar stimulus compared with the no-exposure control, and fixation duration on the novel stimulus similar to that in the 20-s accumulation condition. Novelty preference would show more complete processing of the familiar stimulus during the familiarization phase and should occur for the conditions in which familiarization exposure occurred during sustained attention.

Method

Participants. The participants were 60 full-term infants (gestational age > 38 weeks, birthweight > 2,500 g) sampled cross-sectionally at 14 (n = 20, M = 99.7 days, SD = 4.36), 20 (n = 20, M = 144.5 days, SD = 2.67), or 26 (n = 20, M = 182.5 days, SD = 2.85) weeks postnatal age. The infants had no acute or chronic pre- or perinatal medical complications and were in good health at the time of recording. One-half of the participants at each age were in the 2.5-s exposure condition, and the other half were in the 5.0-s exposure condition.

Apparatus. The apparatus (i.e., TV monitors, LEDs, camera, and videotape recording) were the same as in Study 1. The stimuli were the same as in Study 1. Selected sections of a Sesame Street movie (*Follow That Bird*) were used to elicit heart rate changes.

Procedure. The infants received six experimental conditions each in random order. The conditions differed in the manner in which the stimulus was presented in the familiarization phase (see Figure 1). Each trial began with a 2.5-s minimum prestimulus period, and then the infant's fixation was directed to one of the TVs with a single LED under the TV monitor. Four of the conditions consisted of the familiar stimulus presentation for 2.5 or 5.0 s. These exposure durations were chosen on the basis of the familiarity preference shown in Study 1 for these durations. The six conditions were: (a) immediate trials, which consisted of the familiar stimulus presentation on a single TV for 2.5 or 5.0 s without the Sesame Street movie (stimulus orienting); (b) heart rate deceleration trials, which consisted of the initial presentation of the Sesame Street movie on a single TV until a slowing of heart rate (sustained attention), followed by the familiar stimulus for 2.5 or 5.0 s on the same TV, followed by the Sesame Street movie for 5 s; (c) heart rate acceleration trials, which consisted of the presentation of the Sesame Street movie until a heart rate deceleration, followed by a return of heart rate to its prestimulus level (attention termination), followed by the familiar stimulus for 2.5 or 5.0 s, and then the Sesame Street movie for 5.0 s; (d) heart rate acceleration + 5.0-s trials, which consisted of the presentation of the Sesame Street movie until a heart rate deceleration, followed by a return of heart rate to its prestimulus level, followed by an additional 5.0 s of the Sesame Street movie, followed by the familiar stimulus for 2.5 or 5.0 s, and then the Sesame Street movie for 5.0 s; (e) 20.0-s accumulation control condition, which consisted of the accumulation of 20.0 s of looking time at an immediately presented stimulus; and (f) no-exposure control, which consisted of the presentation of the Sesame Street movie until the heart rate acceleration criteria were met.

The heart rate deceleration criterion was defined as five beats with interbeat intervals (IBIs) each longer than the median of the five prestimulus beats. The return of heart rate to its prestimulus level (heart rate acceleration) was defined as five beats with IBIs shorter than the median of the five prestimulus beats. The heart rate acceleration must have followed a heart rate deceleration. Trials were restarted if a heart rate deceleration did not occur within 10.0 s of stimulus onset so that the requisite criteria were met for each heart-rate-defined condition.

The test phase for recognition memory followed the familiar phase. The test phase differed from that in Study 1. A single LED was presented under one of the two TV monitors. When the infant was looking at the LED, or in the direction of the TV, the stimulus to which the infant was exposed was presented on that TV along with a novel stimulus on the adjacent TV. Thus, the infants' first fixation was always on the previously exposed stimulus (or a novel stimulus in the control condition). The novel stimulus on the adjacent TV monitor was presented to distract the infant from fixation on the familiar stimulus (cf. Casey & Richards, 1988). The two stimuli were presented for 20.0 s of accumulated fixation on either stimulus.

Measurement and quantification of heart rate. The electrocardiogram (ECG) was recorded with Ag-AgCl electrodes placed on the infant's chest. The ECG was digitized on-line at 1000 Hz (1 ms). The R-wave of the ECG was identified, and IBIs were computed. The IBIs were computed within 1 ms of the R-wave occurrence for the on-line evaluation of heart rate deceleration and the return of heart rate to its prestimulus condition. For the analyses, heart rate was computed by assigning values of heart rate to equal 500-ms intervals (0.5-s by 0.5-s heart rate) weighted by the proportion of the the beat occupying the interval (intervals variable in analysis of variance [ANOVA]). The Greenhouse–Geisser (Greenhouse & Geisser, 1959) ϵ-correction procedure was used for ANOVAs involving the heart rate intervals, because repeated physiological measures are known to violate the sphericity assumption of repeated measures ANOVA.

Fixation direction. Fixations were judged by two raters, as in Study 1. The average difference in time between the judged occurrence of looks by the two observers was 1.12 s. The observers agreed on the time of looks within 1 s on greater than 93% of all judgments. The correlations between total looking-time judgments on the test phase ranged from .87 to .95 for the different conditions (Mdn = .92).

Results

Heart rate responses. Heart rate change for the first 5.0 s of stimulus onset was analyzed to ensure that there were no differences in the heart rate response for the exposure duration conditions (2.0 or 5.0-s durations) or experimental conditions (i.e., six conditions illustrated in Figure 1). The heart rate change for the first 5 seconds of stimulus onset was analyzed with an Age (3) × Exposure Duration (2) × Phase (2; familiarization or test phase) × Experimental Condition (6) × Intervals (10; 0.5-s by 0.5-s) ANOVA. There were no statistically reliable main effects or interactions for the factors of age, exposure duration, or experimental condition. There were reliable main effects of phase, $F(1, 57) = 9.30$, $p = .0035$, and intervals, $F(9, 513) = 72.20$, $p < .0001$, $\epsilon = 0.2725$, but no reliable interactions. There was a decrease in heart rate of about −8 beats per minute (bpm) during the stimulus familiarization phase and −6 bpm for the test phase. The response pattern (intervals effect) was similar for the familiarization and test phases.

The heart rate changes defined according to the heart rate deceleration and acceleration criteria were examined to ensure that the experimental conditions involving the heart rate change had the desired effect and that similar changes occurred on the exposure and control trials. Heart rate 2.5 s before and after the stimulus exposure on the heart rate deceleration trials was compared with the heart rate deceleration in a comparable period of the control trial. Age, exposure duration (2), experimental condition (2), and intervals were variables in an ANOVA. There was a significant intervals effect, $F(9, 504) = 20.79$, $p < .0001$, $\epsilon = 0.2277$ but no other main effects or interactions were significant. Similarly, the return of heart rate to its prestimulus level was compared on the heart rate acceleration, heart rate acceleration + 5 s, and control trials. There was only a significant intervals effect, $F(9, 495) = 29.94$, $p < .0001$, $\epsilon = .2266$. Figure 2 shows the heart rate changes for the heart rate deceleration and heart rate acceleration trials. As expected from the definition of the criteria, there was a significant decrease in heart rate on the heart rate deceleration and control trial and a return to prestimulus heart rate level on the heart rate acceleration trials and the comparable portion of the control trial. The heart rate on the experimental trials did not differ from the control trial.

Fixation duration. The duration of fixation on the familiar and novel stimuli was analyzed in the paired-comparison test phase. First, the duration of the first fixation to the familiar stimulus (previously exposed for 2.5 or 5.0 s during familiarization phase) was compared with the first fixation duration for a stimulus in the no-exposure control trial. Second, the duration of fixation to the novel stimulus of the brief exposure conditions was compared with duration fixation to the novel stimulus on the traditional 20-s accumulation trial.[1] A familiarity preference would be shown by first fixation durations on the test phase for the exposure conditions being greater than first fixation duration for the no-exposure control in which both stimuli were novel. A novelty preference would be shown by shorter first fixations on the familiar stimulus compared with the no-exposure control and fixations on the novel stimulus similar in length to those found in the 20-s accumulation condition. A familiarity preference should result from less complete processing of the familiarization stimulus, and would be expected for the conditions in which exposure occurs during stimulus orienting or attention termination. More complete processing, expected during sustained attention, would be shown by novelty preferences.

The first fixation duration[2] during the test phase was analyzed

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[1] The ANOVA analyzing looks to the novel stimulus had missing data for infants for one or more of the factors. On any one trial, an infant may have looked at the first fixation stimulus for the entire 10 s of the test phase. This resulted in a missing cell for that infant for looks to the novel stimulus. Because of the missing cells, the ANOVA was computed with a general linear models approach using a nonorthogonal design. The effects (hypothesis and error) for the nested effects in the design were estimated by using "participants" as a class and nesting repeated measures (trial types) within this class variable. The PROC GLM of the Statistical Analysis System (SAS) was used for this computation. The pattern of significant effects was the same using this type of nonorthogonal design or by assigning a value of 0 s for looking at the novel stimulus in these missing cells.

[2] To make the durations for the two analyses comparable, the dependent variable for the familiar stimulus was the duration of the first fixation, whereas for the novel stimulus, it was the accumulation of fixation through the first 10 s of fixation accumulation on either stimulus. The fixation duration data from the first 10 s had skewness and kurtosis parameters consistent with a normal distribution, whereas the variables from the full 20-s exposure would have had to be transformed to fit the normality assumptions of ANOVA.

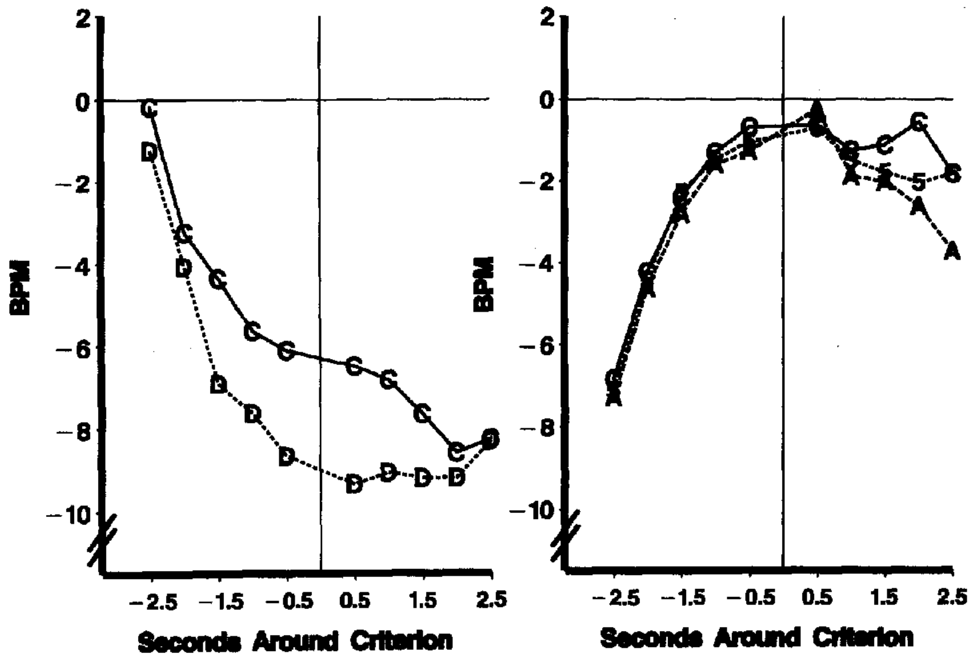

Figure 2. Heart rate 2.5 s before through 2.5 s after the heart rate deceleration (left) and heart rate acceleration (right) criteria were met. C = control; D = heart rate deceleration; A = heart rate acceleration; 5 = heart rate acceleration + 5 s; BPM = beats per minute.

with an Age (3) × Exposure Duration (2) × Experimental Condition (5; four exposure delay conditions and control) ANOVA. There was a statistically reliable main effect of testing age on the first fixation, $F(2, 54) = 5.65, p = .0059$. The fixations were longest for the youngest infants, at an intermediate level for the 20-week-olds, and shortest for the oldest infants. There was a statistically reliable interaction of age, exposure duration, and experimental condition on the first fixation duration, $F(8, 212) = 2.50$ $p = .0128$. There were no other statistically reliable effects. The accumulated fixation duration on the novel stimulus during the first 10.0 s of the paired-comparison test phase was analyzed with an Age (3) × Exposure Duration (2) × Experimental Condition (5; four brief exposure delay conditions and 20.0-s accumulation) ANOVA. The only statistically reliable effects were an interaction of age and exposure duration, $F(2, 54) = 3.88, p = .0266$, and an interaction of age and experimental condition, $F(8, 167) = 2.43, p = .0165$. The pattern of results for the three-way interaction on the first fixation duration and the two-way interactions on the fixation on the novel stimulus were examined with post hoc Scheffe tests. This test was chosen because it is the most conservative in protecting error rate. The mean square error for all tests came from the error for the Age × Exposure Duration × Experimental Condition interaction.

Table 2 lists the conditions with significant multiple comparisons for the significant interaction effects. First, several of the brief exposure conditions resulted in a familiarity preference. These conditions had a significantly longer first fixation on the familiar stimulus in the exposure conditions ($M = 5.35$ s, $SD = 3.32$) than the first fixation in the no-exposure control condition when the first stimulus was novel ($M = 4.04$ s, $SD = 2.74$). Four of the six possible heart rate acceleration conditions showed this pattern of results. Second, a novelty preference was shown for some of the conditions. These conditions had significantly shorter first fixations on the familiar stimulus ($M = 3.02$ s, $SD = 1.78$) compared with first fixations on the no-exposure control ($M = 4.04$ s, $SD = 2.74$). The fixation duration for the novel stimulus in these conditions ($M = 5.01$ s, $SD = 2.29$) was equal to or greater than fixations on the novel stimulus in the 20-s accumulation trials ($M = 4.79$ s, $SD = 2.62$). Novelty preference was evident only for the 20- and 26-week-olds, for the 5-s exposure condition on the heart rate deceleration trials and the heart rate acceleration + 5-s trials. Finally, some conditions showed durations of the first fixation on the familiar stimulus that were not significantly different from the no-exposure control. On these trials the familiar stimulus (i.e., previously exposed stimulus) fixation duration ($M = 4.19$ s, $SD = 2.63$) was the same as a novel stimulus in the no-exposure control ($M = 4.04$ s, $SD = 2.74$). This suggests that information from the familiar stimulus was not retained from the previous brief exposure. These conditions had a significantly shorter fixation duration on the novel stimulus for the brief exposure trials ($M = 3.46$ s, $SD = 2.49$) than for the 20.0-s accumulation trials ($M = 4.79$ s, $SD = 2.62$).

Familiarization phase–test phase correlations. The results in Table 2 are striking in the ordering of the experimental conditions during the familiarization phase with the resultant first fixation and novel stimulus fixation durations. A familiarity preference was found for conditions in which stimulus exposure occurred during the attention termination phase (heart rate acceleration trials). A novelty preference occurred for those conditions in which the stimulus exposure occurred during the sustained attention phase (e.g., 5.0-s exposure, heart rate deceleration trials). Thus, it appears that there was a relation between the duration of stimulus exposure during the differing attention types of the familiarization phase and the resultant fixations on the paired-comparison test phase. The relation between the duration of stimulus exposure during the differing attention phases could not be determined from the a priori defined experimental conditions. For example, the immediate and 20.0-s accumulation conditions were not defined according to the attention phases. Similarly, the heart rate acceleration + 5.0-s condition was defined to occur 5.0-s after heart rate returned to prestimulus level, but attention could be reengaged and other heart rate changes may have occurred. In each of these conditions, the durations of stimulus orienting, sustained attention, and attention termination could vary from 0 s up to the maximum time of the brief stimulus (2.5 or 5.0 s; or 20.0-s in the 20.0-s accumulation condition). Two analyses were done to examine the relation between familiar stimulus exposure during the attention phases and the resultant novelty preference in the test phase.

The relation between familiar stimulus exposure during each attention phase of the familiarization period and resultant paired-comparison performance was examined with correlation coefficients. The variable from the familiarization phase was the amount of exposure time of the familiar stimulus occurring in each attention phase (stimulus orienting: from stimulus onset to heart rate deceleration; sustained attention: heart rate deceleration and sustained lowered heart rate, until return of heart rate to prestimulus level; attention termination: return of heart rate

Table 2
Significant Multiple Comparisons During the Test Phase of the Paired-Comparison Procedure

Age (in weeks)	Exposure duration (in seconds)	Delay condition
Conditions generating first fixation on familiar stimulus greater than no-exposure control (familiarity preference)		
14	2.5	HR acceleration
14	5.0	HR acceleration
14	2.5	HR acceleration + 5/s
20	5.0	Immediate
20	2.5	HR acceleration
26	2.5	Immediate
26	5.0	HR acceleration
Conditions generating fixation on novel stimulus equal to or greater than 20-S accumulation control (novelty preference)		
20	5.0	HR deceleration
20	5.0	HR acceleration + 5/s
26	5.0	HR deceleration
26	5.0	HR acceleration + 5/s
Conditions generating first fixation on familiar stimulus same as no-exposure control, and fixation on novel stimulus less than 20-s accumulation control (novel-like response to familiar stimulus)		
14	2.5	Immediate
14	5.0	Immediate
20	5.0	HR acceleration
26	2.5	HR deceleration
26	2.5	HR acceleration

Note. HR = heart rate.

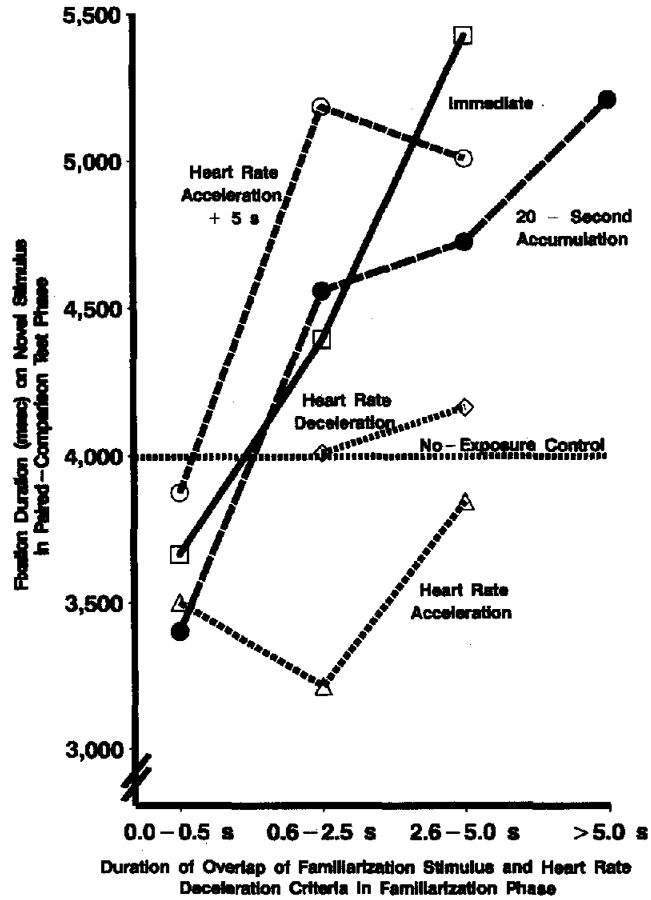

Figure 3. The amount of familiar stimulus exposure during sustained attention in the familiarization phase and fixation duration on the novel stimulus in the first 10 s of the paired-comparison test phase.

to prestimulus level). The variables from the test phase were the first fixation duration, the novel stimulus fixation duration for the first 10.0 s, and the proportion fixation on the novel stimulus for the entire 20.0 s. A significant positive correlation was found between the amount of familiar stimulus exposure that occurred during sustained attention on the familiarization phase and the resulting novelty preference on the test phase (novel stimulus fixation duration, $r = .20$, $p < .01$; proportion fixation on the novel stimulus, $r = .14$, $p < .05$). The longer the exposure during sustained attention in the familiarization phase, the longer the fixation duration on the novel stimulus was in the test phase. The duration of familiar stimulus exposure in the attention phases did not vary randomly in most of the conditions because of the duration (2.5 and 5.0 s) and attention phase (immediate, heart rate deceleration, heart rate acceleration, heart rate acceleration + 5.0 s) manipulations. The attention phase durations varied nonexperimentally only on the 20-s accumulation condition. For that condition, there was a positive correlation between stimulus exposure during sustained attention in the familiarization phase and subsequent longer fixation on the novel stimulus in the test phase ($r = .39$, $p < .01$).

Figure 3 illustrates the relation between the amount of familiar stimulus exposure during sustained attention in the familiarization phase and the resultant fixation on the novel stimulus in the paired-comparison test phase. This figure was done to ensure that the correlations showed a linear relation, were not due to outliers, and did not differ across experimental conditions, because empirically measured attention phase durations were not completely isomorphic with the experimental conditions (e.g., heart rate acceleration + 5.0 s could have had continued acceleration or another deceleration; 20.0-s accumulation varied nonexperimentally). The five experimental conditions with stimulus exposure (immediate, heart rate deceleration, heart rate acceleration, heart rate acceleration + 5.0 s, 20.0-s accumulation) were divided at different durations of the amount of familiar stimulus exposure during sustained attention (Figure 3). The selected durations were 0 to 0.5 s, 0.6 to 2.5 s, 2.6 to 5.0 s (could occur on 5.0 or 20-s accumulation trials), and greater than 5.0 s (could occur only in the 20.0-s accumulation trials). Figure 3 shows a marked positive linear relation between familiar stimulus exposure during sustained attention and subsequent fixation duration on the novel stimulus for all but the heart rate acceleration trials. This relation was examined for individual participants with scattergrams for the experimental conditions represented in Figure 3. The linear relation between exposure during sustained attention in the familiarization phase and fixation duration on the novel stimulus in the test phase held across a wide range of durations for individuals for both variables and was not due to outliers on either measure.

General Discussion

There were similar results across the two studies that replicated past findings of familiarity preferences for briefly exposed visual stimuli. For the 26-week-olds, when the stimulus was presented at stimulus onset, the briefest stimulus exposures (2.5 and 5.0 s in Experiment 1; immediate, 5.0 s in Experiment 2) resulted in longer fixation in the test phase on the previously exposed stimulus than on the novel stimulus. The 20-week-olds showed this familiarity preference at the 5.0-s exposure in both studies. The 14-week-olds did not show a familiarity preference for stimuli presented in the immediate type in either study. This finding replicates the finding of familiarity preferences for briefly exposed visual stimuli and a decline across this age range in the exposure duration necessary for eliciting familiarity preference or novelty preference (Rose et al., 1982).

As hypothesized, there was a differential effect of stimulus exposure during different attention phases on the infants' fixation preference in the test phase. For the 20- and 26-week-old infants, stimulus exposure of 5.0-s duration in sustained attention led to a preference for the novel stimulus in the test phase. This recognition memory for the briefly exposed stimulus was as complete as recognition memory in the traditional 20-s accumulated fixation condition. This finding was true if the stimulus exposure was controlled by presenting it contingent on heart rate changes (heart rate deceleration) or if it was presented when the infant was receptive to new visual stimuli and showed an appropriate heart rate change (heart rate acceleration + 5.0 s). Infants at those same ages show longer fixation on the familiar stimulus when such exposure occurred in less intensive attention phases, either stimulus orienting at the beginning of fixation (immediate) or attention termination occurring in the course of fixation after sustained attention had occurred (heart rate acceleration). An important qualification in this respect is that some conditions resulted in familiarity preference or novelty preference depending on whether an appropriate heart rate change had taken place in that trial. For example, the immediate and heart rate acceleration + 5.0-s conditions were not strictly defined by heart rate changes. Familiarity preference and novelty preference in those two conditions depended on the amount of time that sustained attention (defined by heart rate change) occurred (Figure 3). This also was true for the 20.0-s accumulation control trial that overall resulted in novelty preference (Table 1 from Study 1) but showed a shift from familiarity preference to novelty preference depending on the heart rate changes occurring in the trial (Figure 3).

These results support the interpretation of familiarity preferences following brief stimulus exposure being due to partial processing of stimulus information. The sustained attention phase is thought to involve active, effortful processing and is the most efficient phase for extracting stimulus information. When the exposure of the familiarization phase was limited to sustained attention, presumably more of the stimulus information was encoded. On the subsequent test phase, the infant preferred to look at the novel stimulus. The stimulus orienting and attention termination exposure trials involved less efficient information extraction, resulting in less complete processing of stimulus information and familiarity preference during the subsequent test phase (top of Table 2). This manipulation resulted in similar familiarity preferences as were found in Hunter et al. (1982, 1983), in which stimulus processing was necessarily partial because a habitation sequence was interrupted before full habituation occurred. The interrupted habituation manipulation used by Hunter et al. (1982, 1983) and the attention phase exposure manipulation used in this study resulted in varying degrees of processing of information for the familiar stimulus and subsequent differences in stimulus preference on the test phase. These manipulations are better confirmatory evidence for the partial processing hypothesis than those studies simply manipulating stimulus exposure times (e.g., Rose et al., 1982; Wagner & Sakovits, 1986).

An important finding from the current study is the linear relation between exposure during sustained attention and subsequent novelty preferences. For all exposure conditions other than the heart rate acceleration condition, approximately 2.5 to 5.0 s of exposure during sustained attention led to fixation duration on the novel stimulus that was longer than the no-exposure control and the same or longer than the 20.0-s accumulated fixation condition (middle of Table 2 and Figure 3). The brief exposure conditions that produced the longest fixation duration on the novel stimulus were the heart rate deceleration condition and the heart rate acceleration + 5.0-s conditions. The heart rate deceleration condition represents an empirical definition of sustained attention (Richards, 1987), and heart rate is experimentally constrained on those trials. In the heart rate acceleration + 5.0-s condition, on some trials the infant may have been inattentive (attention termination), may have become receptive to new stimulus exposure, or attention may have been reengaged on the Sesame Street stimulus. For this condition, post hoc assessment of how much exposure occurred during sustained attention showed that stimulus exposure during sustained attention and subsequent novelty preference were positively correlated (Figure 3). These two trial types artificially constrained sustained attention or attention termination durations so that the correlation of exposure time and subsequent novelty preference was not totally justified. On the other hand, sustained attention duration in the 20-s accumulation condition varied nonexperimentally and showed a positive correlation between sustained attention exposure and subsequent novelty preference.

The preference for the familiar stimulus during the test phase following brief exposure in the familiarization phase is not an ubiquitous finding across studies. For example, in some studies, exposure to a stimulus for 5.0 s (Fagan, 1974; Rose, Feldman, McCarton, & Wolfson, 1988) or 10.0 s (Freeseman et al., 1993) resulted in a novelty preference or no preference, but did not result in familiarity preferences. Most studies of infant recognition memory never reported familiarity preferences even with short exposure durations (Fagan, 1974; Rose et al., 1988; Colombo et al., 1988; Freeseman et al., 1993). In these studies, variations of stimulus exposure duration resulted in equal preference (brief exposures) or novelty preference (longer exposures), but no significant familiarity preferences. Lasky (1980) reported two experiments with such a finding. In the first, 15.0, 30.0, or 50.0 s of exposure to black and white photographs of faces to 6-month-old infants resulted in no preference, novelty preference, or familiarity preference, respectively. In a second experiment with abstract patterns and exposure durations of 2.5, 5.0, 10.0 or 20.0 s, Lasky found no familiarity preferences for the shortest durations and novelty preferences at 10.0 or 20.0 s of exposure time.

An instructive comparison can be made among three studies of 6-month-old infants in which exposure duration and stimulus complexity were manipulated. Lasky (1980) did not elicit familiarity preferences with either 2.5-s or 5.0-s exposures of abstract patterns or with 15.0-s exposure to face stimuli. Rose et al. (1988), however, reported that abstract patterns, similar to those used by Lasky (1980), elicited a novelty preference with only 5.0 s of exposure and faces elicited novelty preference with 20.0 s of exposure. Thus, the brief exposure times (2.5 and 5.0 s) used by Lasky for the abstract patterns were too close to the time sufficient for novelty preferences (5 s in Rose et al., 1988), and the brief exposure time (15.0 s) for the face stimuli was too close to the time sufficient for novelty preferences (20.0 s in Rose et al., 1988). Alternatively, the 3-D stimulus in a Rose et al. (1982) study that elicited familiarity preferences after 5.0 or 10.0 s of exposure took 15.0 s (Rose et al., 1982) or 20.0 s (Rose et al., 1988) before novelty preference was elicited. The exposure durations that result in familiarity preference must be substantially shorter than those durations resulting in novelty preference. This would suggest that simple stimuli needing only brief exposure to elicit novelty preference allow full (or sufficient) processing of the stimulus information and could never result in familiarity preferences. Instead, some minimal level of stimulus complexity is necessary for such familiarity preferences to occur at shorter durations. More complex stimuli may be more likely to result in familiarity preferences at short or intermediate exposure times simply because partial processing of the stimulus information has occurred (Hunter et al., 1982, 1983). A general model of a random–familiar–random–novel preference pattern related to stimulus exposure thus is untenable (cf. Colombo, 1993; Wagner & Sakovits, 1986).

The results of the present study lend support to the interpretation that stimulus complexity by itself, or differing exposure time by itself, does not engender the familiarity and novelty preference shift. Rather, these factors contribute to the shift from familiarity to novelty preferences by affecting the completeness of information acquisition. The stimuli in the present study took 10.0 or 20.0 s of exposure time to result in novelty preferences (Table 1), and thus can be considered more complex than stimuli that result in novelty preferences after only 5.0 to 10.0 s of exposure time (e.g., static abstract patterns used by Lasky, 1980, and Rose et al., 1988). The stimuli from this study also did not vary among themselves in complexity, and exposure times for the brief exposure conditions were not dramatically varied (2.5 or 5.0 s). The most striking finding of the current study was that given the same brief exposure time and the same stimulus complexity level there was a shift from familiarity preference to novelty preference for the different attention phase exposures. Stimulus complexity and exposure duration may affect how completely stimulus processing may occur during exposure and affects the subsequent response to the familiar or novel stimuli in the test phase. The intensity of cognitive processing also affects the completeness of stimulus processing independent of stimulus complexity and exposure duration.

The present study confirms previous findings of an increase from 14 to 26 weeks of age in visual stimulus information processing efficiency. For the immediate presentation conditions (Study 1; Immediate in Study 2), the 26-week-old infants showed familiarity preferences at the 2.5-s exposure, the 20-week-olds showed familiarity preferences after the 5.0-s exposure, and the the 14-week-olds did not show familiarity preferences with any exposure duration. A familiarity preference in the test phase was predicated on the attention termination exposure for the youngest infants. Conversely, the 20- and 26-week-olds showed novelty preferences at shorter durations than did the 14-week-old infants. The older two age groups profited more from the sustained attention exposure than did the youngest age group (middle of Table 2), even to the reversal of the familiarity preference found with the older age groups in the immediate presentation conditions (cf. Table 1 or the top of Table 2 with the middle of Table 2). The finding that less exposure time is necessary for novelty preference for the 20- and 26-week-old infants than for the 14-week-old infants replicates several studies showing that older infants need less exposure time to reach a comparable novelty preference level (Colombo et al., 1988; Rose, 1983; Rose et al., 1982). The complementary finding that less exposure time is necessary to show familiarity preferences for older infants implies that the process changing with age is common to the familiarity preference and the novelty preference effects. A likely candidate is the efficiency with which information is acquired from the visual patterns. The older infants require less time than the younger infants for partial processing leading to the familiarity preference and less time for complete processing leading to novelty preference (cf. Rose et al., 1982, 5-s exposure with 3.5- and 6-month-old infants, or Hunter et al., 1983, with 8- and 12-month-old infants).

The sustained attention and novelty preference relation in this study is interpreted as resulting in more complete stimulus information processing than the immediate or heart rate acceleration manipulations. The traditional accumulated fixation procedure is an immediate presentation condition. It may take several seconds to engage sustained attention, and so novelty preference does not emerge until sufficient time has elapsed in attention engagement (e.g., Figure 3). There are at least two unresolved issues given this interpretation. The familiarity preference in the attention termination conditions suggests that at least partial processing occurred. This was most evident in the 14-week-old infants, who did not show a familiarity preference for stimuli in the immediate condition at any stimulus exposure duration. This finding is inconsistent with the notion that attention termination is resistant to new stimulus information (e.g., Casey & Richards, 1991; Richards & Casey, 1991) because this manipulation enhanced stimulus processing over immediate presentation conditions with similar exposure times. A second unresolved issue is the assumption that familiarity preference represents partial information processing, whereas novelty preference represents full stimulus processing. Direct manipulations of the amount of stimulus information that can be acquired or measurement of actual information acquisition would be necessary to directly confirm this hypothesis.

References

Casey, B. J., & Richards, J. E. (1988). Sustained visual attention measured with an adapted version of the visual preference paradigm. *Child Development, 59,* 1514–1521.

Casey, B. J., & Richards, J. E. (1991). A refractory period for the heart rate response in infant visual attention. *Developmental Psychobiology, 24,* 327–340.

Colombo, J. (1993). *Infant cognition: Predicting later intellectual functioning.* Newbury Park, CA: Sage.

Colombo, J., Mitchell, D. W., & Horowitz, F. D. (1988). Infant visual attention in the paired-comparison paradigm: Test–retest and attention–performance relations. *Child Development, 59,* 1198–1210.

Fagan, J. F. (1974). Infant recognition memory: The effects of length of familiarization and type of discrimination task. *Child Development, 45,* 351–356.

Freeseman, L. J., Colombo, J., & Coldren, J. T. (1993). Individual differences in infant visual attention: Four-month-olds' discrimination and generalization of global and local stimulus properties. *Child Development, 64,* 1191–1203.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika, 24,* 95–112.

Hunter, M. A., Ames, E. W., & Koopman, R. (1983). Effects of stimulus complexity and familiarization time on infant preferences for novel and familiar stimuli. *Developmental Psychology, 19,* 338–352.

Hunter, M. A., Ross, H. S., & Ames, E. W. (1982). Preferences for familiar or novel toys: Effect of familiarization time in 1-year-olds. *Developmental Psychology, 18,* 519–529.

Lasky, R. E. (1980). Length of familiarization and preference for novel and familiar stimuli. *Infant Behavior and Development, 3,* 15–28.

Richards, J. E. (1987). Infant visual sustained attention and respiratory sinus arrhythmia. *Child Development, 58,* 488–496.

Richards, J. E. (1988). Heart rate changes and heart rate rhythms, and infant visual sustained attention. In P. K. Ackles, J. R. Jennings, & M. G. H. Coles (Eds.), *Advances in psychophysiology* (Vol. 3, pp. 189–221). Greenwich, CT: JAI Press.

Richards, J. E., & Casey, B. J. (1991). Heart rate variability during attention phases in young infants. *Psychophysiology, 28,* 43–53.

Richards, J. E., & Casey, B. J. (1992). Development of sustained visual attention in the human infant. In B. A. Campbell, H. Hayne, & R. Richardson (Eds.), *Attention and information processing in infants and adults* (pp. 30–60). Hillsdale, NJ: Erlbaum.

Rose, S. A. (1983). Differential rates of visual information processing in full-term and preterm infants. *Child Development, 54,* 1189–1198.

Rose, S. A., Feldman, J. F., McCarton, C. M., & Wolfson, J. (1988). Information processing in seven-month-old infants as a function of risk status. *Child Development, 59,* 589–603.

Rose, S. A., Gottfried, A. W., Melloy-Carminar, P., & Bridger, W. H. (1982). Familiarity and novelty preferences in infant recognition memory: Implications for information processing. *Developmental Psychology, 18,* 704–713.

Ruff, H. A. (1986). Components of attention during infants' manipulative exploration. *Child Development, 56,* 621–630.

Wagner, S. H., & Sakovitz, L. J. (1986). A process analysis is infant visual and cross-modal recognition memory: Implications for an amodal code. *Advances in Infancy Research, 4,* 195–217.

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