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Infant Memory for Object Motion across a Period of Three Months: Implications for a Four-Phase Attention Function

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Memory for object motion in 3-month-old infants was investigated across retention intervals of 1 or 3 months in three studies using a novelty preference method. Following familiarization to an object undergoing one of two types of motion, visual preferences for the novel motion were assessed after retention intervals of 1 min, 1 day, and 1 month (Experiment 1, $N = 120$) and 1 min, 1 day, 2 weeks, and 1 month (Experiment 2, $N = 74$). Results of both studies indicated a significant preference for the novel motion at the 1-min delay, a significant preference for the familiar motion at the 1-month delay, and no preferences at the intermediate retention intervals. In Experiment 3, memory was assessed after a 3-month interval and again, a significant familiarity preference was obtained. These results demonstrate that memory for object motion lasts across retention intervals of 1 and 3 months and that novelty and familiarity preferences interact with retention time. A four-phase function relating visual preferences and retention time was proposed. Phase 1, recent memory, is characterized by a novelty preference; phase 2, intermediate memory, is a period of transition characterized by no visu-

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al preference; phase 3, remote memory, is characterized by a familiarity preference; and phase 4, inaccessible memory, is also characterized by no preference. The finding of a transition period at intermediate retention times suggests that null preferences should not necessarily be taken as evidence of forgetting. Rather, more extended retention intervals should be included to interpret null findings obtained in the novelty preference method.

Although a great deal of research has focused on infant memory dur[illegible] the past 20 years, this research has been primarily limited to the study [illegible] visual recognition memory for static features of objects such as form, p[illegible] tern, orientation, and color. Using variations of the novelty preference paired-comparison procedure (Fantz, 1964), it has been found that yo[illegible] infants have excellent visual recognition of static features across retent[illegible] intervals of minutes, hours, or days (e.g., Bornstein, 1976; Cohen, Deloa[illegible] & Pearl, 1977; Cornell, 1979, 1980; Cornell & Bergstrom, 1983; Fag[illegible] 1971, 1977; Martin, 1975; Quinn, Siqueland, & Bomba, 1985; Rose, 19[illegible] and in one study recognition held up across a 2-week period (Fagan, 19[illegible] Thus, visual recognition of static information appears to be quite robust [illegible] short retention intervals, is manifested by a preference for novelty, an[illegible] influenced by a number of factors such as serial position of an it[illegible] whether familiarization exposures are massed versus distributed, whe[illegible] a brief reminder is introduced just prior to testing, task difficulty and c[illegible] plexity, length of familiarization, and age of the subject.

Few studies, however, have investigated the infant's memory for dyna[illegible] aspects of events despite the fact that it is through motion that most m[illegible] ingful properties of events are conveyed. Motion carries information a[illegible] the shape, substance, and composition of objects, their tempo and rhy[illegible] as well as object unity, permanence, causality, affect, and the self. Th[illegible] infants perceive and attend to motion specifying all of the above attri[illegible] es (e.g., Bahrick, 1983, 1987, 1992, Bahrick & Watson, 1985; Baillarg[illegible] 1987; Gibson, Owsley, Walker, & Megaw-Nyce, 1979; Kellman, Hof[illegible] & Soares, 1987; Kellman & Spelke, 1983; Mendleson & Ferland, 1[illegible] Ruff, 1982; Spelke, 1979; Walker, 1982; Walker, Owsley, Megaw-N[illegible] Gibson, & Bahrick, 1980), this rich and varied source of learning ha[illegible] ceived only scant attention in the literature on infant memory. The pr[illegible] research therefore focuses on memory for object motion.

One exception to the focus on infant memory for static visual fea[illegible] has been a series of studies by Rovee-Collier and her colleagues (e.g., [illegible] & Rovee-Collier, 1983; Hayne, Rovee-Collier, & Perris, 1987; Linde, [illegible] rongiello, & Rovee-Collier, 1985; Rovee-Collier & Fagen, 1981), using [illegible] jugate reinforcement to test cued recall for a conditioned response. Th[illegible] search has shown that once infants learn to kick their leg to cause a [illegible] mobile to move, they forget the contingency after 8–10 days. Howev[illegible] a reminder is given 1 day prior to test, memory is reactivated after a [illegible] of 2–4 weeks. Thus, when memory is assessed under these procedu[illegible] is quite long lasting, even in infants as young as 2 months. This method was also adapted to study infant categorization and memory for 3-dimensional objects by varying the presentation order, number, color, and/or patterning of elements in the mobile (e.g., Fagen, 1984; Hayne et al., 1987; Rovee-Collier & Sullivan, 1980). Typically, memory for these attributes held up for 1–3 days without a reminder and as long as 2 weeks with a reminder. This method provides converging evidence with the novelty preference method for the robustness of memory in infancy and demonstrates that infants abstract and retrieve color, pattern, and number information in moving, 3-dimensional objects.

The nearly exclusive reliance on the preference for novelty as an index of infant memory has received recent criticism. In the novelty preference method, the infant is first familiarized with a stimulus for a fixed period of time. It is assumed that if infants have had sufficient time to form a memory representation, they will prefer a novel stimulus over the familiar one when the two are presented together (Fantz, 1964). After a retention interval, chance preferences are eventually obtained and are assumed to reflect a lack of memory for the familiar stimulus. However, the assumptions that novelty preferences are the best indicators of memory and that null results reflect forgetting have been challenged.

Under some conditions, preferences for familiarity are obtained. Very young infants have demonstrated immediate memory with a preference for the familiar stimulus, while older infants showed novelty preferences (e.g., Colombo & Bundy, 1983: Greenberg, Uzgiris, & Hunt, 1970; Wetherford & Cohen, 1973; Weizmann, Cohen, & Pratt, 1971). These findings were initially viewed as support for Hunt's (1970) two-stage view that infants show a familiarity preference until about 2 months of age and then a preference for novelty emerges. However, the earlier studies (Greenburg et al., 1970; Weizmann et al., 1971) were longitudinal and the amount of familiarization time was confounded with subject age. Subsequent studies revealed that the shift from familiarity to novelty preferences was a function of the amount of familiarization time with the target stimulus (Hunter, Ames, & Koopman, 1983; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). For older infants, very short familiarization exposures led to familiarity preferences, while longer familiarization exposures led to familiarity preferences, while longer familiarization periods elicited novelty preferences. Even infants under 2 months who had sufficient familiarization time demonstrated novelty preferences (e.g., Bushnell, McCutcheon, Sinclair, & Tweedlie, 1984; Friedman 1972; Milewski & Siqueland, 1975; Quinn, Siqueland, & Bomba, 1985; Slater, Morison, & Rose, 1982). Shifts in preference from familiarity to novelty most likely reflect different phases of information processing that occur at any age. However, as Hunter et al. (1983) pointed out, several studies using very short familiarization exposures failed to obtain familiarity preferences with older infants (e.g., Cornell, 1979; Fagan, 1974; Lasky, 1980; Rose, 1980). They believe that the above findings can be reconciled if stimulus complexity is taken into account relative to the age of the subject. Their research with older infants demonstrated that stimuli that were complex for subjects of that age elicited familiarity preferences after brief exposures and novelty preferences after longer exposures, while very simple stimuli elicited no preferences after brief exposures. In line with these results, Hunter and Ames (1988) have proposed that across increasing familiarization time, infants demonstrate a progression from familiarity to novelty preferences with a period of no preference in between. Progression through this cycle is thought to be faster for older infants with simple stimuli and slower for younger infants and more complex stimuli. Wagner and Sakovits (1986) have also presented evidence of a relation between familiarization time, stimulus complexity, and preference in line with the views of Hunter and Ames (1988).

According to both views, as familiarization time is increased, after an initial familiarity preference, a period of chance responding occurs and then the novelty preference emerges. Hunter and Ames (1988) suggest that chance responding occurs because of a decreasing preference for familiarity and an increasing preference for novelty where the attention holding properties of the two stimuli are approximately equal. Null results are thus not necessarily indicative of a lack of memory or discrimination, but may reflect a phase of information processing where memory continues to develop (Wagner & Sakovits, 1986). Thus, contrary to popular belief, when assessing immediate memory with this method, null results should not be taken as an index of forgetting or lack of discrimination without first establishing from what point along the preference curve the results were drawn.

Sophian (1980, 1981) has also criticized the reliance of researchers on novelty preferences as indices of memory for similar reasons. She has argued that memory is confounded with preference, and therefore, null results cannot be taken as evidence of memory failure. This is true even when short retention intervals yield evidence of a novelty preference and longer ones do not, or when a preference is obtained at one age and not at another. However, in several studies (e.g., Fagan, 1973, 1977; Pancratz & Cohen, 1970) an attenuation of a novelty preference which emerges across retention time has been taken as evidence of forgetting. Sophian maintains that it is equally plausible that infants regain interest in familiar stimuli after a delay.

Thus, by extending the views of Hunter and Ames (1988), and Wagner and Sakovits (1986) (which assume memory will be tested immediately after familiarization) to the domain of retention time, one might predict a similar pattern of changing preference across retention time. That is, as retention time increases, an initial novelty preference may weaken and revert to a preference for familiarity, with a period of no preference in between. Although Wagner and Sakovits (1986) suggest such an extension of their view, no empirical evidence is yet available.

The present research evaluates the extension of these views to the domain of retention time by testing infant memory across several retention intervals spanning a 3-month period, and examining the direction of preferences at each interval. In three experiments, memory was assessed well beyond the point where chance responding was first obtained to provide the opportunity for observing any emergent familiarity preferences. A four-phase function relating infant attention to novel versus familiar stimuli across retention time is proposed. Given sufficient initial familiarization, phase 1, recent memory, is characterized by a novelty preference, phase 2 is a transition period from novelty to familiarity preferences characterized by no preference, phase 3, remote memory, is characterized by a familiarity preference, and phase 4, inaccessible memory, is again characterized by null preferences. In addition to testing this view, the studies contribute to our knowledge of infant memory in an area that has been virtually ignored, that of long-term memory for dynamic information.

EXPERIMENT 1

This study was conducted as a preliminary test for the hypothesized interaction between preference and retention time and assessed infant memory across a period of 1-month. Three-month-old infants returned to our lab after intervals of 1 min, 1 day, or 1 month for a test of their memory for events that they had viewed in one of our prior studies on intermodal perception (Bahrick, 1987, 1988). All subjects had previously seen two objects moving in an arc-shaped trajectory. For the memory test they viewed two displays, one depicting the familiar motion and the other a novel, horizontal motion. Controls who received no familiarization with the events were also tested to determine baseline preferences for the two motions at each age.

Method

Subjects. Seventy-two infants who had successfully completed one of two experiments (Bahrick 1987, 1988) were randomly assigned to one of three retention interval conditions, with 24 per group. Those in the 1-min and 1-day delay conditions were 3 months at the time of testing (M = 100.4 days, SD = 5.7, and M = 98.8 days, SD = 3.2, respectively), while those in the 1-month delay condition were 4 months at the time of testing (M = 133.8 days, SD = 8.2). In addition 48 naive subjects participated in one of two control groups, with 24 in each group. One group was matched for age with the 3-month-olds (M = 98.2 days, SD = 3.3) and the other was matched for age with the 4-month-olds (M = 134.4, SD = 3.2). The data of 16 additional subjects were rejected because of excessive fussiness (N = 8), experimenter error or equipment failure (N = 3), falling asleep (N = 1), excessive side bias (N = 3; see Procedure section for more detail), and for obvious visual abnormalities (N = 1). Subjects were recruited through the local birth records and all were healthy with no complications at delivery.

Stimulus events. Super-8 sound, color films of two kinds of rattle-like objects were used. One depicted a single, large blue and yellow marble inside a Plexiglas cylinder, and the other a group of 15 small blue and 28 small yellow marbles also inside a Plexiglas cylinder. The cylinders were abruptly moved in an arc-shaped trajectory so that with each sudden motion their natural visible and audible impacts were apparent. The objects moved in an erratic temporal pattern, displaying approximately 44 impacts per minute. These were the events used by Bahrick (1987, 1988) and served as the familiarization events in the present study. A second set of events was developed for the memory test phase. They depicted the same objects moving horizontally. The cylinders were held in a horizontal position and abruptly moved from left to right and back again in an erratic temporal pattern. With each sudden motion the marbles struck the surface of the cylinder, making a visible impact approximately 46 times per minute, but no sounds were audible.

Apparatus. All events were filmed with a Eumig 128 XL super-8 sound movie camera. Infants were seated in a standard infant seat facing a split projection screen approximately 64 cm away. The film images were about 34 × 34 cm and a set of Christmas tree lights and a mechanical toy dog were positioned between them and used to attract the infants' attention between trials. The films were displayed with two side-by-side Eumig S926GL super-8 color, sound move projectors. Soundtracks were played through a speaker centered between the two film images and about 1.5 m away.

Infant visual fixations were monitored by one or two observers from apertures located just below the projection screen. They depressed one button while the infant fixated the right-hand screen and another while the infant fixated the left-hand screen. The button boxes were connected to a Rustrak strip-chart recorder which provided a permanent record of the fixation data.

Procedure. The experiments on intermodal perception (Bahrick, 1987, or 1988) served as the familiarization phase for the experimental subjects. During the familiarization phase all subjects were exposed to films of the single, large marble and the group of small marbles, moving in the arc-shaped trajectory. Films of the two objects were presented side by side along with the natural soundtrack to one of them. Most subjects (N = 50) had participated in one of the four conditions of the Bahrick (1987) study. In this study subjects received a 6-min exposure to the two films side by side across two 90-s preference trials and a 3-min search phase. During the first preference trial the soundtrack to one event was continuously played and during the next, the soundtrack to the other was played. During the search phase, subjects viewed the two films along with intermittent bursts of the soundtrack from each (see Bahrick, 1987, for more detail). The remaining infants (N = 22) had participated in the Bahrick (1988) study where the same two events had been presented for a total of 4 min across 16 15-s preference trials. The soundtrack to each of the events was played on eight trials, in a random order (see Bahrick, 1988, for more detail).

Following their successful completion of the intermodal perception study, infants returned for a novelty preference memory test to assess their memory for the motion of the objects after a 1-min, 1-day, or 1-month delay. The apparatus and testing booth were identical to that experienced during familiarization. Twenty-four subjects were randomly assigned to each retention interval condition. The novelty preference test consisted of a silent, 90-s presentation of two films side by side. One film depicted one of the familiar objects moving in the familiar arc-shaped trajectory and the other depicted the same familiar object moving in the novel horizontal trajectory. Half of the subjects in each retention interval condition received their test with the single, large object and the other half were tested with the group of smaller objects. Lateral position of the familiar motion was also counterbalanced within each object x retention interval condition.

Two groups of control subjects, one matched for age with the 3-month-olds and the other matched for age with the 4-month-olds (those in the 1-month delay condition), were also tested in the novelty preference memory test alone to establish a baseline preference for the two types of motion at each age. Type of object and lateral position of the arc-shaped motion were counterbalanced within each group.

For the memory test it seemed important to ensure that subjects had seen both events and made a visual choice between them. Thus, a criterion, that subjects devote at least 3% of their total looking time to the less preferred side, was imposed. The data of three subjects were rejected for failure to meet this criterion, one from the 1-min delay condition and two from the 4-month-old control group.

Visual fixations were monitored by one or two trained observers who were unaware of the lateral positions of the novel and familiar events. The aperture used by the primary observer was encircled by a cardboard occluder that prevented her from seeing the images projected to the screens even if she turned her head.

Results

Across the five groups, subjects spent an average of 77.6 s (SD = 10.6) of the 90-s test trial (86% of the available time) fixating the films. Mean fixation times for the 1-minute, 1-day, and 1-month delay conditions and the 3 and 4-month controls were 70.9 (SD = 12.3), 76.2 (SD = 8.9), and 81.5 (SD = 11.6) and 76.9 (SD = 9.4) and 82.5, (SD = 10.7), respectively. To determine whether subjects in the experimental conditions spent more time watching the test displays as retention time increased, a one-way ANOVA was conducted on mean fixation times during test. Results revealed a significant main effect ($F(2,69) = 5.5$, $p = .006$), suggesting that the test displays elicited more attention after longer retention intervals than shorter intervals.

Looking data were expressed in terms of the proportion of total looking time (PTLT) infants spent fixating the novel/horizontal motion. Statistical tests were conducted to determine whether subjects who received different types of familiarization experiences (Bahrick, 1987, N = 50; Bahrick, 1988, N = 22) showed differential performance on the memory test phase. Results indicated no significant differences in the PTLT to the novel display for subjects in any retention interval condition (all p's > .1). Thus, the nature of the familiarization experience was not considered further.

Interobserver reliability was calculated on the basis of 22 subjects (30%) across the five conditions and was .98 (SD = .037). PTLTs to the horizontal motion were calculated for each of three 30-s blocks of the 90-s trial and a Pearson product–moment correlation between the PTLTs derived from observations of the primary and secondary observers was calculated. These correlations were then averaged across subjects to obtain a mean reliability score.

Results of the novelty preference tests are displayed in Fig. 1. Single-sample t tests were performed on the PTLTs for each group against the chance value of .50 to determine whether infants showed any preferences for the

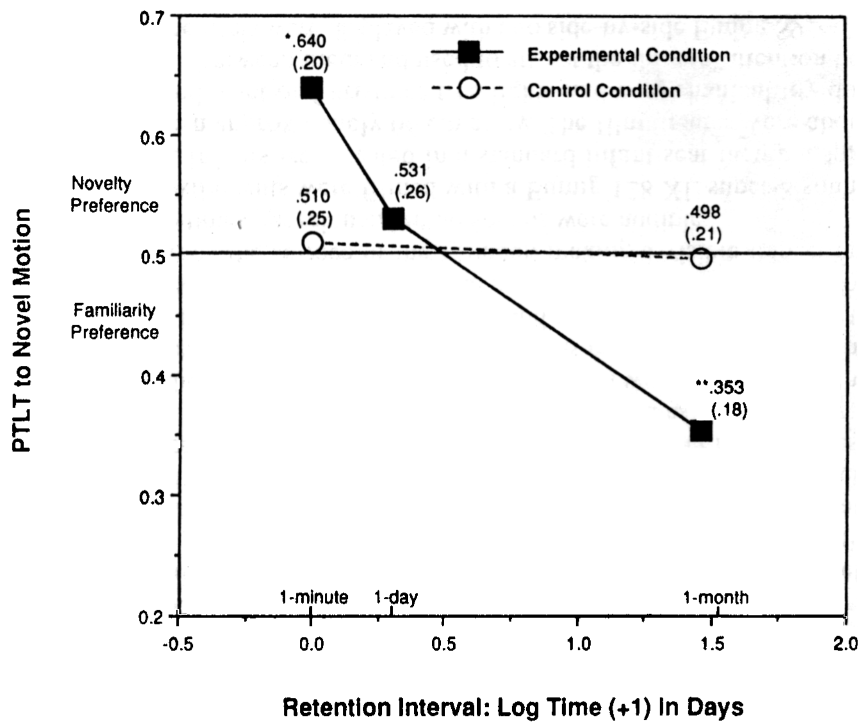

FIG. 1. Experiment 1: Mean proportions of total looking time and standard deviations to the novel motion as a function of retention time (*$p < .005$, **$p < .001$).

novel/horizontal motion. Results indicated that controls showed no significant preference for the horizontal motion at 3 months or at 4 months ($M = .51$, $t(23) = .19$, $p > .10$; $M = .50$, $t(23) = .06$, $p > .10$, respectively; note that all t tests reported here are two-tailed). However, subjects in the 1-min delay condition significantly preferred the novel/horizontal motion ($M = .64$, $t(23) = 3.46$, $p < .005$), those in the 1-day delay condition showed chance responding ($M = .53$, $t(23) = .59$, $p > .1$), and those in the 1-month delay condition demonstrated a significant preference for the familiar arc-shaped motion ($M = .35$, $t(23) = -3.93$, $p < .001$). A one-way analysis of variance was conducted on the looking proportions of the three experimental groups, followed by a trend analysis. Results indicated a significant main effect of condition ($F(1,69) = 10.88$, $p = .0001$) and a significant linear trend ($F(1,69) = 21.33$, $p < .0001$), with no quadratic component. Thus, mean looking preferences for the novel motion showed a significant linear decrease across retention time.

An analysis of variance was conducted to determine if there was a significant interaction between retention time and visual preferences as predicted by the proposed four-phase attention function. This was done by including the looking proportions of subjects under the 1-min and 1-month delay conditions along with their respective controls in a two-way analysis of variance with subject age at test (3 versus 4 months) and condition (experimental versus controls) as main factors. Results indicated a main effect of age at test ($F(1,92) = 11.82$, $p = .001$) and an interaction between condition and test age ($F(1,92) = 9.98$, $p < .002$). This reflects the fact that looking proportions were higher than those of controls (novelty preference) at the 1-min delay and lower than those of controls (familiarity preference) at the 1-month delay. Planned comparisons were conducted across means of the four conditions using Duncan's multiple range test at the .05 level. It was found that the mean PTLT of the 3-month-olds in the 1-min delay condition was different from that of the 3-month controls, the PTLT of the 4-month-olds in the 1-month delay condition was different from that of the 4-month controls, and the PTLTs of the 3- and 4-month-olds in the experimental conditions differed significantly. Thus, infants in the 1-min delay condition showed a significant novelty preference and greater fixation to the horizontal motion than their age-matched controls, while those in the 1-month delay condition showed a significant familiarity preference and less fixation to the horizontal motion than their age-matched controls.

Additional analyses tested whether the experimental subjects showed any change in looking to the novel motion across the three 30-s blocks of the 90-s test trial. A two-way mixed ANOVA with delay condition (1 min, 1 day, 1 month) as the between-subjects factor and trial block (3) as the within-subjects factor was performed on the PTLTs. Results indicated a main effect of trial block, $F(2,138) = 7.87$, $p = .006$, where mean PTLTs increased across blocks. Further analyses assessed which delay conditions

showed trends across trials. Results indicated a significant linear increase in looking to the novel motion across trial blocks for the 1-min delay condition ($F(2,46) = 3.99$, $p = .025$), a marginally significant increase for the 1-day condition ($F(2,46) = 3.14$, $p = .053$), but no change for the 1-month condition ($F(2,46) = 1.39$, $p > .1$).

To determine whether subjects showed a preference for one object over the other or for one lateral position over the other, further analyses were conducted. A three-way analysis of variance was performed on the PTLTs with condition (5), type of object (2), and lateral position of the horizontal motion (2) as main factors. Only a significant main effect of condition was found ($F(4,100) = 5.268$, $p = .001$). There was no main effect of stimulus ($F(1,100) = .093$, $p > .10$) or lateral position ($F(1,100) = .199$, $p > .10$), nor did any of the interactions reach significance ($p > .05$ on all tests.).

Discussion

Results of this study demonstrated a novelty preference after a 1-min retention interval, no preference after a 1-day interval, and a familiarity preference after a 1-month interval. The familiarity preference provides evidence of memory for object motion across a 1-month period. Such extended retention in infants of this age has not been previously documented without using a reminder or retrieval cue prior to test. Further, the novelty preference after 1 min and familiarity preference after 1 month lends empirical support to the view that a relationship between length of the retention interval and preferences for familiarity exist. Finally, in the context of the pattern of preferences across retention time, the null results of the 1-day delay condition suggest that there may be a period during which infant preferences are in transition from novelty to familiarity, while memory is still intact. This transition period is characterized by no significant preferences. These findings provide support for the hypothesized four-phase function depicted in Fig. 2, relating visual preferences to retention time. Phase 1, recent memory, is characterized by a preference for novel stimuli given sufficient initial familiarization time. Phase 2, intermediate memory, is characterized as a transition period where no significant preferences are evident. Phase 3, remote memory, is characterized by a preference for more familiar stimulation. Finally, phase 4, inaccessible memory, is presumably characterized by no significant preferences. These data also fit nicely with the functions proposed by Hunter and Ames (1988) and Wagner and Sakovits (1986) describing an interaction between novelty and familiarity preferences across increasing familiarization time.

Further, the significant effect of trial block reflected a shifting interest for novelty versus familiarity within a testing session as well. At the shortest retention interval infants' interest in the novel motion increased significantly over trial blocks. Infants may be processing, or reducing uncertainty associated with the old motion rapidly and then shifting to explore the new

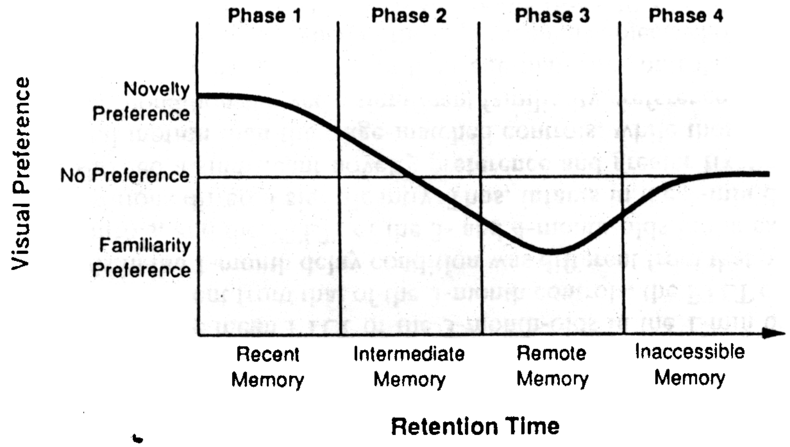

FIG. 2. Four-phase model of infant attention: Visual preferences as a function of retention time.

motion. This is consistent with memory savings effects found previously using this method (Cornell, 1979). In contrast, in the 1-month delay condition, interest in the old motion was apparent from the start and was maintained over the entire session. Perhaps reduction of uncertainty or processing the old motion takes more time after longer retention intervals. Nevertheless, even after a 1-month delay, the familiar event recruits more attention than a novel event.

However, since no prior research had documented a familiarity preference after such an extended retention interval it seemed important to replicate these findings before firm conclusion were drawn. For this reason, Experiment 2 was undertaken.

EXPERIMENT 2

Would infants again demonstrate a changing preference from novelty to familiarity across a 1-month period? By replicating key aspects of the design while changing many of its details, we hoped to increase the generalizability of the conclusions and our confidence in the results. Further, since the first author had moved from Berkeley to Miami, the new data were collected in a different laboratory with a new staff and a new subject population. Thus, any idiosyncracies due to the testing situation, the laboratory set-up, experimenters, or the subject sample would be eliminated.

Several improvements and changes over the prior design were made. First, since infants had not participated in a prior study, uniform familiarization to the events was possible. This allowed us to counterbalance the novel and familiar motions across subjects, eliminating the need for con-

ized with only one type of object undergoing one motion. Fourth, a fourth retention interval was added at 2 weeks delay. This provided an additional data point and enables us to verify the decreasing preference for novelty across retention time and determine whether there are any reversals in the direction of the predicted function. Finally, new events were developed using videotaped displays, with new objects and motions similar to those of the prior study, but somewhat simpler.

Method

Subjects. Seventy-four 3-month-old infants with a mean age of 99.2 days ($SD = 6.6$) at their first visit participated. Data for 55 additional subjects were rejected from the study due to excessive crying ($N = 8$), experimenter error or equipment failure ($N = 7$), parental interference ($N = 1$), failure to return for the second visit ($N = 8$), failure to show sufficient attention during familiarization ($N = 10$), and excessive side bias ($N = 21$). (See Procedure for a description of the attention and side bias criteria.) All subjects were recruited through use of local birth records and were healthy with no complications at delivery.

The number of subjects whose data were rejected from this study was higher than that of the prior study for several reasons. First, the rejection rate includes subjects who failed to complete the familiarization period and who failed to show up for the second visit, whereas those of the prior study did not. Second, a procedure for preventing excessive side bias used in the prior study, was not imposed in the early phases of testing. By carefully centering the infant's head with small pillows, and using the lights to attract attention to center after subjects failed to fixate one of the displays, side bias was reduced after the first weeks of data collection.

Stimulus events. Videotaped displays were made of four events depicting two types of objects (a single object and a compound object, see Fig. 3) undergoing two distinctive motions (horizontal and circular). The objects and motions, although similar to those of Experiment 1, were designed to be simpler and more distinctive. The objects were suspended from a short string attached to a stick. The single object consisted of a single, large, yellow-striped, metal washer (8 cm in diameter), and the compound object consisted of a cluster of 18 small, orange, metal nuts (approximately 4.5 × 13 cm). The objects were filmed against a black background and moved in two ways: they were pulled in a circular path across a yellow plastic tray with blue stripes, and were swung from left to right and back again, in a horizontal path, striking a white circular target to the left side of the display. An erratic temporal pattern characterized the bursts and pauses in the motions of both objects. The events were videotaped along with their natural sounds. When they underwent the circular motion the objects produced a continuous scraping sound and when they swung horizontally they produced

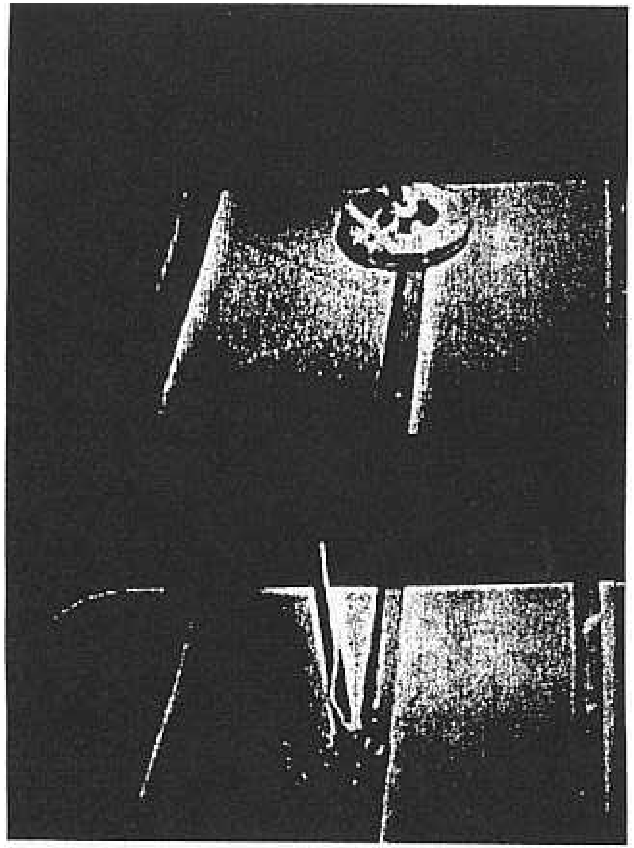

FIG. 3. Photograph of the stimulus objects.

Apparatus. Infants were seated in an infant seat and faced two side-by-side 19-inch (Panasonic BT-S1900N) video monitors, approximately 75 cm away. The monitors were surrounded by black posterboard and between them was a strip of colored Christmas tree lights and a mechanical toy dog just above. The lights and dog were used to attract the infants' attention between trials.

The events were videotaped with a Panasonic (WV 3170) color video camera. They were edited and presented with a Panasonic VHS (NV A500) edit controller connected to two Panasonic video decks (NV-8500 and AG-6300) and an audio mixing console (Numark Studio Mixer, Model DM-400W). The decks were connected so that the experimenter could present the visual display from either deck to the right- or the left-hand video monitors. The soundtracks emanated from a speaker between and just below the two monitors. One or two trained observers monitored the infants' visual fixations as in Experiment 1 from apertures between or toward the sides of the monitors.

Procedure. Infants were randomly assigned to one of four retention interval conditions, 1 min (N = 24), 1 day (N = 16), 2 weeks (N = 16), and 1 month (N = 18). On their first visit subjects in all conditions received an identical familiarization phase consisting of four 40-s trials (intertrial intervals approximately 4 s long) of two identical events, played side by side and out of phase with one another. Within each retention interval condition the type of object (single versus compound) and the type of motion (circular versus horizontal) presented for familiarization were counterbalanced as nearly as possible. During each familiarization trial, the natural soundtrack was synchronized with the motions of one event and was unsystematically our of phase with the motions of the other, as in Experiment 1. The lateral position of the sound synchronized event alternated across trials such that half of the subjects within each subgroup received a RLRL order while the other half received a LRLR order. A minimum criterion of 120 s fixation to the event of the possible 160 s was imposed. This familiarization criterion was established to ensure that subjects received sufficient familiarization with the displays and would have a uniform basis for subsequent memory testing.

Following familiarization under one of the four object/motion conditions subjects received a novelty preference memory test. Subjects in the 1-min delay condition were removed from the infant seat and entertained prior to testing. Subjects in the 1-day delay condition were all tested 1 day after familiarization, those in the 2-week delay condition returned to the lab after 13.8 days (SD = 1.33), and those in the 1-month delay condition returned after 32.2 days (SD = 4.77). The preference test consisted of two silent 60-s trials of the familiar object and motion along side that of the familiar object undergoing the novel motion. The lateral positions of the novel and familiar displays were switched from one trial to the next for each subject and the initial lateral position of the novel display was counterbalanced across subjects within each object x motion group.

To ensure that infants had noticed that two different displays were presented, a "side bias" criterion was imposed to eliminate the data of subjects who looked almost exclusively to one side on each trial. It was required that subjects fixate the least preferred side at least 5% of their total looking time on each trial. Across groups, this averaged 2.5 and 2.4 s, for trials 1 and 2, respectively. The data from 21 subjects were rejected on this basis (N = 12, 4, 1, and 4 for the 1-minute, 1-day, 2-week, and 1-month delay conditions, respectively).

Trained observers monitored the infants' visual fixations and were unaware of the lateral positions of the novel and familiar displays during the test and of the sound matched display during familiarization.

Results

Familiarization data. Fixation times during the familiarization period were expressed in terms of the proportion of available looking time subjects spent fixating the displays on each 40-s trial and were averaged across trials. On average, infants fixated either one or the other of the two identical familiarization displays 86% of the time available, totaling 138.15 s across the four trials. To determine whether the mean familiarization times differed across retention interval conditions, a one-way between subjects analysis of variance was conducted on the proportions of available looking time. Results indicated no main effect ($F(3,70) = .28, p > .1$), with subjects showing mean proportions of .86, .85, .87, and .87 in the 1-min, 1-day, 2-week, and 1-month delay conditions, respectively.

The familiarization data were also examined to determine whether subjects showed intermodal matching by looking predominantly to the sound-synchronized event. Consistent with findings of Bahrick (1987), the PTLT directed to the sound synchronous event ($M = .503$, $SD = .113$, $N = 74$) was not significantly different from chance.

Interobserver reliability was calculated on the basis of 21 subjects by correlating the proportion of available looking time spent fixating the displays across the four trials as reported by the primary versus the secondary observer. The average correlation was .99 ($SD = .037$).

Memory test data. Across the four retention interval conditions, subjects spent a mean of 97.5 s ($SD = 14.6$) of the total 120 s (81% of the available time) viewing the video displays, 50.4 s ($SD = 7.5$), on trial 1, and 47.1 s ($SD = 8.7$) on trial 2. For the 1-min, 1-day, 2-week, and 1-month retention interval conditions, these means were 89.2 ($SD = 17.1$), 99.7 ($SD = 16.8$), 100.5 ($SD = 8.8$), and 104.1 ($SD = 7.0$), respectively. A between subjects analysis of variance conducted on these means revealed a main effect of retention interval ($F(70,3) = 4.83, p = .004$). Thus, as in Experiment 1, with increasing retention time, subjects spent more time viewing the test displays.

Results of the novelty preference test were expressed in terms of the PTLT infants spent fixating the object undergoing the novel motion. This was calculated separately for each trial and averaged across the two trials to obtain a mean proportion for each subject. Interobserver reliability was calculated on the basis of 18 subjects by correlating the PTLTs derived by observations of the primary and secondary observers, across six 20-s block of the two trials and was .972 ($SD = .037$).

Results of the study are depicted in Fig. 4. To address the primary researcl question, under which retention interval conditions did infants show memor and what was the direction of their preferences, single-sample planned t-test were conducted on the PTLTs to the novel motion against the chance value o .50 for each condition. Results indicated a significant preference for the nove motion in the 1-min delay condition ($t(23) = 2.35, p = .028$), no visual pref erences for subjects in the 1-day or the 2-week delay conditions ($t(15) = .5,$, $= .31$; $t(15) = .16, p = .87$, respectively), and a significant preference for th familiar motion for the 1-month delay condition ($t(17) = -2.79, p = .013$). Thu consistent with Experiment 1, memory was demonstrated by a novelty prefe ence after the 1-min delay and a familiarity preference after the 1-month dela

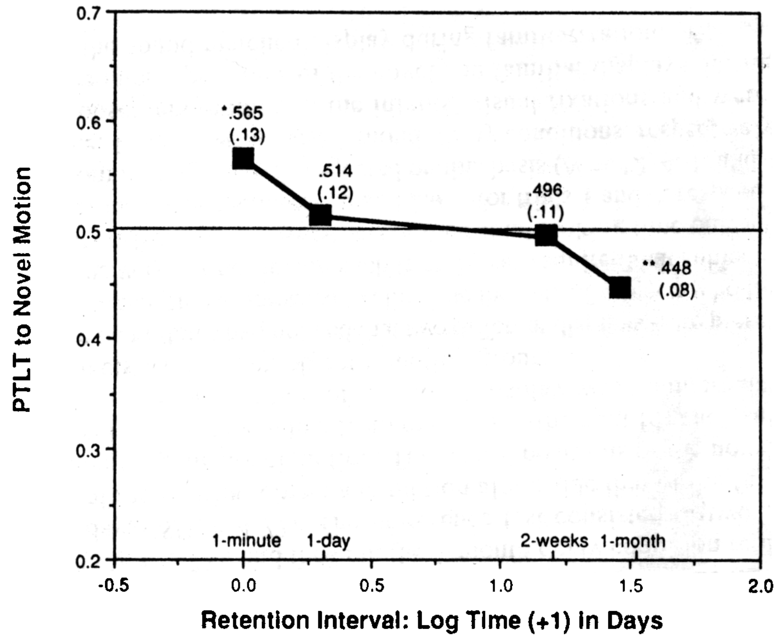

FIG. 4. Experiment 2: Mean proportions of total looking time and standard deviations to the novel motion as a function of retention time (*$p < .05$, **$p < .02$).

iar. Table 1 depicts the data broken down in this way. Looking preferences to the horizontal and circular motions when each was novel versus familiar are shown for each retention interval along with a difference score. As can be seen, for the 1-min delay condition, the PTLT to the horizontal motion when it was novel was significantly greater than the PTLT to the horizontal motion when it was familiar ($t(22) = 2.76, p = .005$, shown by the difference score in Table 1) and similarly, the PTLT to the circular motion when it was novel was significantly greater than the PTLT to the circular motion when it was familiar (same values since the two proportions are complements and derived from the same subjects). Infants looked more to each motion when that motion was novel than when it was familiar after a 1-min delay. In contrast, for the 1-month delay condition, the PTLT to the horizontal motion when it was familiar was significantly greater than the PTLT to the horizontal motion when it was novel ($t(16) = 2.65, p = .019$), and its complement, the PTLT to the circular motion when it was familiar, was significantly greater than the PTLT to the circular motion when it was novel. Thus, infants looked more to each motion when it was familiar than when it was novel after a 1-month delay. This pattern, where memory is expressed as a novelty preference after a short delay and as a familiarity preference after a very long delay was found in two separate studies and sug-

TABLE 1
Experiment 2: Mean Proportions of Total Looking Time and Standard Deviations to Each Motion When the Motion Was Novel versus Familiar

Retention interval	Novel horiz	Familiar horiz	Difference	Novel circ	Familiar circ	Difference
1 Min						
M	.50	.37	.13**	.63	.50	.13**
SD	.09	.13		.13	.09	
N	12	12		12	12	
1 Day						
M	.49	.46	.03	.54	.51	.03
SD	.12	.13		.13	.12	
N	8	8		8	8	
2 Weeks						
M	.475	.48	−.005	.52	.525	−.005
SD	.09	.13		.13	.09	
N	8	8		8	8	
1 Month						
M	.45	.56	−.11*	.44	.55	−.11*
SD	.10	.07		.07	.10	
N	9	9		9	9	

* $p < .02$
** $p < .005$

Note that the novelty and familiarity preferences depicted in Table 1 can also be evaluated in relation to the a priori or baseline preferences for each motion. Thus, for the horizontal motion, the a priori preference would be derived by averaging the PTLTs to the horizontal motion when it was novel and when it was familiar (columns 1 and 2) and similarly for the circular motion (columns 4 and 5 averaged).

To determine whether looking proportions differed across retention interval conditions a one-way analysis of variance was conducted. Results indicated a significant main effect ($F(3,70) = 3.65$, $p = .017$), with the 1-min group showing the highest mean (.56) and the 1-month group the lowest mean (.45, see Fig. 4). A Duncan multiple range test indicated that these two means differed significantly at the .05 level. A trend analysis revealed a significant decreasing linear trend ($F(1,70) = 10.74$, $p = .0016$) across retention time, as in Experiment 1.

To test for trial effects, a two-way mixed ANOVA with delay condition (1 min, 1 day, 2 weeks, 1 month) as the between-subjects factor and trial (1,2) as the within-subjects factor was conducted on the PTLTs. Results indicated only a marginally significant main effect of trial ($F(1,70) = 3.31$, $p = .073$), where mean PTLTs increased from the first to the second trial. This increase, however, was significant for only the 1-min retention interval condition, $M = .49$, trial 1; $M = .64$, trial 2, $t(23) = 2.73$, $p = .012$).

The pattern was similar to that of Experiment 1 where mean PTLTs increased across trial blocks for all but the 1-month delay condition.

Further analyses assessed whether subjects showed any effects of object or motion on PTLTs. A three-way analysis of variance was performed with retention interval condition, type of object (single versus compound), and novel motion (circular versus horizontal) as between-subjects factors. Results indicated a main effect of condition as previously documented, no main effect of type of object ($F(1,58) = .055$, $p > .1$), and a significant main effect of type of motion ($F(1,58) = 5.72$, $p = .02$). Apparently infants showed a greater PTLT to the novel motion when it was circular ($M = .54$) than when it was horizontal ($M = .48$). Only one interaction reached significance, that between type of object and type of motion ($F(1,58) = 5.28$, $p = .025$). Subjects showed a greater novelty preference for the compound object when it underwent the circular motion ($M = .58$) but not when it underwent the horizontal motion ($M = .45$). None of these effects, however, interacted with retention interval and thus do not qualify the main results. As depicted by the significant difference scores in Table 1, infants looked more to each motion when it was novel than when the motion was familiar under the 1-min delay condition, and under the 1-month delay condition they looked more to each motion when it was familiar than when it was novel.

Further, to test for side preferences, PTLTs spent fixating the right-hand display (regardless of whether it was novel or familiar) were averaged across trials. A one-way analysis of variance indicated that these proportions did not differ significantly across conditions ($F(3,70) = .72$, $p > .1$) or from the chance value of .50 according to single-sample t-tests ($p > .1$, all tests). However, the average proportion across the four conditions, ($M = .542$) did show a significant right looking preference ($t(73) = 2.0$, $p < .05$).

Discussion

The pattern of results obtained in Experiment 2 replicated that of Experiment 1. Infants demonstrated a significant novelty preference after a 1-min delay, a significant familiarity preference after a 1-month delay, and no visual preferences during the two intermediate intervals. Results of the additional retention interval at 2-weeks add further support for the four-phase attention function. These data also conformed with the monotonically decreasing novelty preference function obtained in Experiment 1. Further, because the findings of Experiment 1 were replicated in Experiment 2 using different events and procedures and a different staff and subject population, confidence in the results is enhanced.

The null results of the 2-week retention interval condition raise a question regarding the duration of the transition phase. From the group data reported here, it appears to last at least 2 weeks. It should be noted, however, that these data consist of group means from cross-sectional research. Although the preference functions of individual subjects are likely to progress through the four phases, the duration of each phase may vary considerably across subjects, even for a given task. Thus, the shape of the group curve may not accurately reflect that of individual subjects. In particular, the length of the transition period may be exaggerated if different infants make a transition from novelty to familiarity preferences at different points in time. Figure 5 presents the data of individual subjects and suggests that the data are centered around the mean for each group, rather than appearing bimodally distributed. This issue is further evaluated under General Discussion.

During the familiarization periods of Experiments 1 and 2, the natural sounds made by the events were played while during the test, the events were presented silently. This may have enhanced preferences by adding a novel dimension to both the "novel" and "familiar" test displays. Also, the sounds may have guided infant attention to dynamic information, accentuating their attention to and subsequent memory for the object motions. Whether such extended retention would have been found for silent events is not known. Nevertheless, since most moving objects in the environment also produce sounds congruent with their motions, the familiarization phase should be seen as similar to infants' encounters with natural events.

EXPERIMENT 3

This study was undertaken to assess the limits of infant memory for object motion. Given that Experiments 1 and 2 provided evidence of memory after a period of 1 month, a much longer retention interval, that of 3

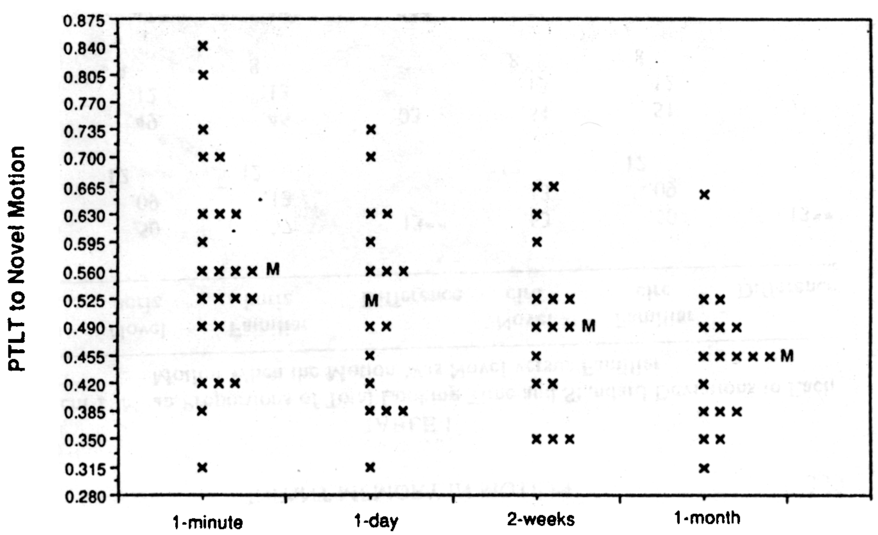

FIG. 5. Experiment 2: Mean proportions of total looking time to the novel motion for individual subjects as a function of retention time.

months, was selected. Thus, this study was similar to that of Experiment 2, except that infants were 6 months old at the time of retesting.

Subjects

Sixteen 3-month-old infants whose mean age was 96.2 days (SD = 5.2) at their first visit participated. Familiarization data for 10 additional subjects were collected but rejected because they failed to return for the memory test. No other data were rejected and all subjects met the attention and side bias criteria described for the memory test of Experiment 2 (possibly because they were much older at the time of testing).

Procedure

The apparatus, stimulus events, and procedures for the familiarization phase were identical to those of Experiment 2. Following familiarization under one of the four object/motion conditions, infants received a 3-month retention interval (M = 92.6 days, SD = 9.4) prior to returning for the memory test. The test was identical to that of Experiment 2 except that two additional 60-s preference trials were added, making a total of four silent trials displaying the familiar object undergoing the familiar versus novel motions side by side. As before, the lateral positions of the display were switched from one trial to the next. The purpose of additional trials was to minimize the likelihood of a type 2 error, and allow for the possibility that memory might emerge over time.

Results

Familiarization data. On average subjects fixated one of the two identical familiarization displays 84% of the available looking time, totaling 133.87 s across the four trials. This figure is very similar to that of Experiment 2 (86%). Also, as in Experiment 2, subjects showed no evidence of intermodal matching on the basis of sound–motion synchrony (M = .50, SD = .09, $t(15)$ = .17, $p > .05$).

Interobserver reliability was calculated as before, and the average correlation was .95 (SD = .13) on the basis of 8 subjects of the total 16.

Memory test data. Subjects spent a mean of 156.1 s (SD = 43.9) of a total of 240 s (65% of the available time) viewing the test displays (with means of 49.6, 44.4, 42.5, and 32.8 s for trials 1,2,3, and 4, respectively).

Results of the novelty preference memory test were calculated as before by averaging the PTLTs across trials to obtain a grand mean proportion for each subject. Interobserver reliability calculated on the basis of 5 of the 16 subjects averaged .95 (SD = .073).

To address the main research question, whether subjects demonstrated evidence of memory for object motion, the data were analyzed in two ways as before. First, a single sample t test was conducted on the mean PTLT to the novel motion demonstrated a significant preference for the familiar motion ($M = .447$, $SD = .09$, $t(15) = 2.33$, $p = .034$), indicating memory over a 3-month period. The magnitude and direction of these findings virtually replicated those of the 1-month retention interval condition of Experiment 2. Second, the data were broken down, in Table 2, to compare looking preferences for each motion when it was familiar versus when it was novel. As can be seen from the table, the PTLT to the horizontal motion when it was familiar was significantly greater than the PTLT to the horizontal motion when it was novel ($t(14) = 2.57$, $p = .023$), and similarly, the PTLT to the circular motion when it was familiar was greater than the PTLT to the circular motion when it was novel (same values). Infants demonstrated memory across the 3-month period by fixating each motion more when it was familiar than when that motion was novel.

Secondary analyses were conducted to determine whether subjects showed any change in looking to the novel motion across trials. A one-way, repeated measures analysis of variance on the PTLTs for each trial (1–4) revealed no significant main effect of trial ($F(3,45) = .52$, $p > .1$).

Additional analyses assessed whether infants showed any effects of object or motion on PTLTs. A two-way analysis of variance was performed with type of object (single versus compound) and novel motion (circular versus horizontal) as between-subjects factors. Results indicated no main effect of object, or object X motion interaction (p's $> .1$); however, there was a marginally significant main effect of type of motion ($F(1,12) = 4.13$, $p = .065$). In contrast with the effects observed in Experiment 2, subjects marginally preferred to watch the horizontal motion ($M = .49$, $SD = .075$, $N = 8$) when it was novel over the circular motion ($M = 40$, $SD = .089$, $N = 8$). This, however, did not qualify the main findings as reflected by the significant difference scores in Table 2. In addition, to test for side preferences, the PTLT to the right-hand screen (regardless of whether it was novel or familiar) was tested against the chance value of .50 and indicated no departure from chance ($t(15) = .92$, $p > .1$).

TABLE 2
Experiment 3: Mean Proportions of Total Looking Time and Standard Deviations to Each Motion When the Motion Was Novel versus Familiar Following a 3-Month Retention Interval

	Novel horiz	Familiar horiz	Difference	Novel horiz	Familiar horiz	Difference
M	.49	.60	−.11*	.40	.51	−.11*
SD	.08	.09		.09	.08	
N	8	8		8	8	

* $p < .025$

Comparisons across Experiments 2 and 3. Further analyses assessed how results of Experiment 3 fit with those of Experiment 2. A one-way analysis of variance was conducted with retention interval as the main factor (5 levels) on the mean PTLTs across all trials and revealed a significant effect ($F(4,85) = 4.01$, $p = .005$). A Duncan multiple range test indicated that the 1-min group differed significantly from both the 1-month and the 3-month groups at the .05 level. Further, a trend analysis revealed a significant decreasing linear trend ($F(1,85) = 11.30$, $p = .0012$), demonstrating that the 3-month retention interval falls along the decreasing function defined by the retention data of Experiment 2.

Discussion

Surprisingly, results of the 3-month delay did not provide evidence of forgetting, but of extremely long-lasting memory for object motion. Three-month-old infants remembered across an interval of 3-months, a period equal to the length of their lifetime. Such extended memory has not been previously documented using the novelty preference method but converges with recent findings of long-lasting natural, ecological memories by older infants (Myers, Clifton, & Clarkson, 1987; Perris, Myers, & Clifton, 1990) where memories for similar events that occurred in the first year of life were retained for as long as 2 years.

Further, the finding of a familiarity preference after a 3-month delay replicates and confirms the results of Experiments 1 and 2, that remote memories are expressed as a visual preference for familiarity.

GENERAL DISCUSSION

Experiments 1, 2, and 3 provide converging evidence for infant memory for object motion across a period of months and support the hypothesis that attention to novel and familiar stimuli interact with retention time. A strikingly parallel pattern of results was found across Experiments 1 and 2. Visual preferences for novelty decreased linearly across retention time. Recent memory (1-min delay) was demonstrated by a significant novelty preference, intermediate memory (1-day and 2-week delays) was expressed as a null preference, and remote memory (1-month delay) was expressed as a significant familiarity preference. Experiment 3 provided an independent confirmation that remote memory is expressed as a familiarity preference, even after a delay of 3 months. Preferences for novelty and familiarity interact with retention time in a manner that complements the way that they interact with familiarization time when immediate memory is assessed (e.g., Hunter & Ames, 1988; Rose et al., 1982; Wagner & Sakovits, 1986).

Of central importance was the finding that 3-month-olds are able to remember the motion of an object they saw for only a few minutes across a period of at least 3 months. Such extended retention has not been previously found in infants so young. To date, the longest retention interval over which infants have shown visual recognition in the novelty preference method was 2 weeks, in a study with 5-month-olds, using photographs of faces (Fagan, 1973). It may be that the present focus on dynamic information is responsible for such extended recognition, given its importance for conveying information about meaningful properties of events. Other studies showing extended retention in infants, using different methods, have also focused on event memory or cued recall of information abstracted from moving stimuli. Rovee-Collier and Fagen (1981) found that infants remember the contingency between their leg motion and the motion of a mobile for up to 8 days without a retrieval cue and as long as 1 month with a retrieval cue. Recent research on long-term memory for events has shown that children remember aspects of an event (an auditory localization study) that they participated in as infants across a period of 1–2 years (Myers et al., 1987; Perris et al., 1990). Studies of deferred imitation have shown that infants can recreate simple actions on novel objects after delays of 24 h at 9 months and after delays of 1 week at 14 months of age (Meltzoff, 1988a, 1988b). The present findings thus fit well with recent findings of extended event memory in older infants and children.

Whether memories tapped in the present research reflect the functioning of processes consistent with implicit or with explicit memory phenomenon in adults (e.g., Roediger, Weldon, & Challis, 1989; Schacter, 1987, 1992) is not known. Some investigators have hypothesized that the novelty preference method taps implicit memory and this memory is mediated by a system that emerges early in development, whereas explicit memory is mediated by a system that emerges later, around the age of 8–9 months (e.g., Schacter & Moscovitch, 1984). Other research, however, suggests that infants may indeed be capable of inferential thought and conceptual processing, thought to be required for explicit memory (see Mandler, 1988, 1992a, 1992b, for reviews). Further, McKee and Squire (1993) have argued that the novelty preference method taps the functioning of declarative memory processes, on the basis of research with normal, and amnesic adults. Whether performance in the novelty preference method reflects declarative memory in infants as well remains a topic for future research, however.

Another reason that memory has not been previously documented across longer retention intervals using the novelty preference method may be that null results have been mistaken as evidence of forgetting. Prior studies which have found a decrement in novelty preferences at a particular retention interval have not tested memory after longer intervals to assess the possibility of emergent familiarity preferences. The present results, however, suggest that a transition period exists, where visual preferences are not evident but memory is nevertheless intact. This period may be quite extended when one examines group means, as previously noted. Further, because the timing of the different phases of the attention cycle may be influenced by factors such as subject age, task difficulty or complexity, and

amount of familiarization time, it may be difficult to determine whether a finding of no preference is the result of a transition period where memory is accessible, or of phase 4, where memory is presumably inaccessible. Thus, it is important for investigators using this method to incorporate tests at intervals well beyond the point where chance responding is first obtained to disambiguate any null findings. Consequently, memory for certain static features may be just as robust and long lasting as that for dynamic information, but evidence of memory may not have been revealed by the typical use of the novelty preference method. Further research is needed to clarify this issue.

The four phases of the attention function are not viewed as discrete, but as general descriptions of a continuous preference cycle (see Fig. 2). Phase 1, immediate or recent memory, is characterized by a novelty preference given sufficient initial familiarization time. Phase 2, intermediate memory, is a transition period during which preferences shift from novelty toward familiarity and null preferences are obtained. During this phase memory is intact yet not manifested by a visual preference. Phase 3, long-term or remote memory, is characterized by a familiarity preference. Subjects apparently regain interest in the more familiar event after an extended retention interval, given no intervening exposure to the event. Finally, it is hypothesized that phase 4, a period of inaccessible memory (at least under the given retrieval conditions) will also be characterized by no significant preferences at longer retention intervals. The duration of each of the phases may depend on a number of factors possibly including the nature of the material to be remembered, its difficulty relative to the subject's age, how well it was originally learned, and whether one examines group means versus preference functions of individual subjects in longitudinal data. The present data indicate that under the current conditions, the novelty preference phase is short lived, lasting a maximum of 1 day, while the transition phase may last much longer (at least 2 weeks, according to results of Experiment 2) when assessing preferences with group means. Finally, the familiarity preference phase may be the longest in duration, lasting at least several months. The limits of this phase and the existence of phase 4 will be investigated in future research.

What might be the nature of the proposed transition phase? Similar to the transition documented by Hunter and Ames (1988) after manipulating familiarization time, the transition found in the present data may also be a product of the novel and familiar stimuli competing for attention. As infants remember less about the familiar event, its interest value may gradually increase relative to that of the novel event. This is consistent with optimal level theories (e.g., Berlyne, 1960, 1970; Walker, 1964) which propose that preference and uncertainty are related by an inverted-U-shaped function. In this case one would expect to find a transition period where visual preferences of individual subjects generally fall close to 50%. That is, at the individual subject level, a gradual transition in preference from novelty to familiarity is made. The lengthy transition phase may also suggest the possibility that two memory processes are interacting. For example, short retention intervals may reflect the workings of explicit memory (or both explicit and implicit memory), whereas long intervals may reflect only implicit functioning. Thus, a gradual transition in preference may be made as different processes come into play. From these perspectives, one would expect the duration of the transition phase to be fairly lengthy.

Alternatively, it may be that the extended transition period is only an artifact of the group curve, and individual subjects make an abrupt transition from a novelty to a familiarity preference. That is, an all or none function may characterize the individual data, and preferences may essentially switch from novelty to familiarity when forgetting of the familiar event has reached a certain threshold. However, if different subjects make this transition at different points in time, the group data would also show null preferences for an extended period. In this case one would expect the distribution of preferences around the mean to be much more bimodal or extreme, whereas according to the former account they should be quite centralized. A Moses test of extreme reactions (Siegel, 1956) was conducted comparing the distribution from the 1-day group of Experiment 1 with that of the 1-min group, and comparing the distributions from the 1-day and 2-week groups of Experiment 2 with that of the 1-min group. Results indicated no evidence of disparity between the distributions, ($p = .143$; $p = .273$; $p = .456$, respectively). Further analyses indicated that the data from the transition periods do not show greater variability than data from the novelty and familiarity preference phases of each study according to a Cochran Q test ($F(2,115) = .2675$, $p = .527$; $F(3,70) = .34$, $p = .441$, for Experiment 1 and 2, respectively; see Fig. 5 for Exp. 2). These findings suggest that at the individual subject level, the transition period may be best characterized as a gradual shift in preference from novelty to familiarity with the majority of subjects showing preferences close to 50%. The analyses thus cast doubt on the all or none model as a description of individual preference curves.

Further research is needed to clarify the nature of the interaction between visual preferences and retention time at the individual subject level. The duration of each phase of the attention cycle and the shape of the function will best be revealed by longitudinal studies assessing retention across several intervals. The extent to which variables such as type of retention material (e.g., dynamic versus static information; visual versus auditory or tactile information) and task difficulty relative to subject age affect this function are also not known. Finally, assessing the generalizability of the four-phase attention function to memory for information other than object motion requires further research.

The results of the present studies and the four-phase attention function also have important implications for methodology in the study of infant

memory, cognition, and perception, particularly with respect to the novelty preference method. They suggest that novelty and familiarity preferences, when used across a number of retention intervals, provide a viable alternative to the popular mobile conjugate reinforcement method for assessing memory across very long time spans in infancy. It is also hoped that these data will stimulate theoretically motivated research regarding the bases for the observed relations between attention and memory, and open the door to further studies investigating the nature of very long-lasting memories in young infants. The proposed four-phase attention function complements that of Wagner and Sakovits (1986) and Hunter and Ames (1988) and together provide a more cohesive picture of how visual preferences interact with familiarization and retention time. Since many methods rely on infant looking patterns, our understanding of this response system is of general theoretical and methodological importance.

Finally, the results of these studies fit well with the recent emphasis on ecological and autobiographical memory for events in young children (e.g., Fivush, 1984; Hamond & Fivush, 1991; Hudson & Fivush, 1991; Price & Goodman, 1990) and with the findings that older infants can recreate events after long delays (Meltzoff 1988a, 1988b). Although at present we do not have any basis on which to postulate the functioning of explicit or declarative memory from data generated by the novelty preference method with infants, our findings of surprisingly long-lasting remote memory in infancy are consistent with recent findings of long-lasting explicit memory for events by young children. Thus, the precursors to children's memory for remote events, may be productively investigated with very young infants using the present methods. Whether or not there is continuity in memory processes between remote memory in infancy and later long-term memory for events is not yet known.

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