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The Effect of Retrieval Cues on Visual Preferences and Memory in Infancy: Evidence for a Four-Phase Attention Function

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Bahrick and Pickens (1995) proposed a four-phase model of infant attention, suggesting that recent memories are expressed as a visual preference for novelty, intermediate memories as a null preference, and remote memories as a preference for familiarity. The present study tested a hypothesis generated from this model that a retrieval cue would increase memory accessibility and shift visual preferences toward greater novelty to resemble more recent memories. Results confirmed our predictions. After retention intervals associated with remote memory, previously observed familiarity preferences shifted to null preferences, whereas after a retention interval associated with intermediate memory, the previously observed null preference shifted to a novelty preference. Further, a second experiment found that increasing the exposure to the retrieval cue could shift the familiarity preference to a novelty preference. These findings support the four-phase model of infant attention and suggest that novelty, null, and familiarity preferences lie along a continuum and shift as a function of memory accessibility.

Recent research exploring the nature and extent of long-term memory in children has revealed remarkably long-lasting recall of events (see Fivush,

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1993 for a review). Children have shown detailed memory across periods of weeks, months, and even years for events such as a trip to Disneyworld (Hamond & Fivush, 1991), a trip to an archaeological museum (Hudson & Fivush, 1991), going to a zoo, circus, or birthday party (Fivush, Gray, & Fromhoff, 1986; Todd & Perlmutter, 1980), and a major hurricane that struck their home (Bahrick, Parker, Fivush, & Levitt, in press). The gap in the literature between research on memory in infancy and childhood, however, is striking. This gulf exists in part because methodological limitations constrain the questions we can ask of infants and preverbal children. Only two studies to date have investigated memory across the periods of infancy and childhood (Myers, Clifton, & Clarkson, 1987; Perris, Myers, & Clifton, 1990). Children who had participated in an auditory localization study 1–2 years earlier, as infants, showed memory for action sequences after being reintroduced to the experimental procedure and apparatus. To systematically bridge this gap, however, will also require expanding the methods available for use with infants to allow us to ask questions more comparable to those we ask of children. For example, what is remembered and for how long; under what conditions is memory facilitated or impaired?

Assessment of memory in infants is by nature indirect. One method that has revealed evidence of robust memory in infants is the conjugate reinforcement procedure which tests cued recall for a conditioned response (Davis & Rovee-Collier, 1983; Hayne, Rovee-Collier, & Perris, 1987; Rovee-Collier & Fagen, 1981). In this method infants are taught to kick their leg to cause a mobile to move. Then memory for the contingency (the relation between the leg kicking behavior and the movement of the mobile) is used to infer how long and under what conditions the infant's memory for attributes of the mobile such as color, pattern, form or context lasts. Results indicate that when aspects of the mobile are altered, the kicking response holds up across delays of 1–3 days without a retrieval cue, and across a period of at least 2- or 4-weeks, with a retrieval cue (e.g., Fagen, 1984; Hayne et al., 1987; Rovee-Collier & Sullivan, 1980). This ingenious method has yielded insight into infant memory and the conditions under which retrieval cues are effective in reactivating forgotten memories. However, the method also limits the questions we can ask to memory for a contingency and aspects of mobiles that can be manipulated.

The most popular method for investigating infant memory has been the novelty preference method (e.g., Fantz, 1964). It has been almost exclusively used to investigate memory for visual stimuli over short time periods in young infants. In this method the infant's interest in a novel stimulus serves as a basis for inferring memory for a previously familiarized stimulus. Infants are familiarized with a visual display for a brief period and then following a delay, their visual fixation to the familiar versus a novel display presented side by side is assessed. Infants have shown memory for numerous attributes

of visual displays including shape, color, facial configuration, geometric pattern, and 3-dimensional form by demonstrating a significant visual preference for the display with the novel attribute (e.g., Fantz, 1964; Fagan, 1971; 1978; Schwartz & Day, 1979; Rose, 1977). By imposing a delay between familiarization and the novelty preference test, visual recognition memory can be assessed over longer time periods. According to this method, young infants have been found to have excellent memory across intervals of minutes, hours, or sometimes days for all of the above mentioned attributes (e.g., Bornstein, 1976; Cohen, Deloache & Pearle, 1977; Cornell, 1979; Fagan, 1971; 1973; Rose, 1981). In one study visual recognition memory for faces held up across a 2-week period (Fagan, 1973). In this procedure, however, evidence of infant memory has been inferred exclusively by the infant's interest in novelty.

Recent studies, however, have challenged the view that novelty preferences are the best indicators of infant memory. Rather, under some conditions null preferences or preferences for familiar displays are obtained when memory is presumably accessible (Bahrick & Pickens, 1995; Hunter & Ames, 1988; Rose, Gottfried, Mellroy-Carminar, & Bridger, 1982; Spence, in press). Bahrick and Pickens (1995) recently found that young infants demonstrated evidence of very long-term memories by preferring to view the familiar display. For this reason, evidence of very long-term memory using the novelty preference method may have been limited. Understanding this shifting attention function may allow us to expand our research on infant memory and begin to bridge the gap between infant and child research in this area. Bahrick and Pickens' (1995) extension of the novelty preference method to investigations of very long-term memories in infancy opens the door to investigations that parallel those in the growing area of child event memory. The present study explores further the relation between memory and visual preference documented by Bahrick and Pickens (1995).

Bahrick and Pickens (1995) found that the direction of visual preferences shifted as a function of retention time, from novelty at short intervals, to familiarity at long intervals. Three-month-old infants showed memory for the motion of an object across a 3-month period by demonstrating a visual preference for a novel motion after a 1-minute delay, no significant visual preferences after delays of 1 day or 2 weeks, and a significant preference for the familiar motion after periods of 1 and 3 months. This pattern of results was replicated across two separate studies. This research thus revealed surprisingly long-lasting memory for dynamic events by young infants. A four-phase attention function was proposed as an explanation for the pattern of shifting attention, where visual preferences for novelty and familiarity interact with retention time. Novelty preferences decrease systematically with increasing retention time, and familiarity preferences emerge and remain stable for a lengthy period before the time when memory presumably becomes inaccessible. In phase 1 (e.g., evident at the 1-min delay in Bahrick & Pickens, 1995), recent or short-term memory is characterized by a novelty preference given

sufficient initial familiarization time. Phase 2 (e.g., 1-day and 2-week delays) is a period of transition where preferences shift from novelty toward familiarity and no significant preferences are apparent. However, during this period, memory is accessible while the relative interest value of novel and familiar stimuli are approximately equal. During phase 3 (e.g., 1- and 3-month delays), long-term or remote memory, a preference for more familiar stimulation emerges. Finally, in phase 4, memory presumably becomes inaccessible and is also characterized by no significant visual preferences. It is proposed that these phases reflect gradual shifts in preferences across retention time, rather than discrete or discontinuous shifts, and they are a function of changing memory accessibility.

Recently this shifting preference has been replicated in the domain of auditory event memory (Spence, 1996). Young infants (1 to 2 months) received multiple familiarization sessions with a nursery rhyme and retention was tested after delays of 1, 2, or 3 days. Results indicated changes in the direction of auditory preferences consistent with our four-phase attention function. They showed a novelty preference after 1 day, a null preference after 2 days, and a familiarity preference after 3 days. This comparison highlights the important influence of factors such as subject age, the complexity and type of target event, the modality of presentation, and the initial degree of familiarization with the events, in determining how quickly infant preferences progress through the four phases of the attention function. Further, given the converging results of Bahrick and Pickens (1995) and Spence (1997) it is important that null findings observed in the novelty preference method not necessarily be taken as evidence of forgetting or of lack of discrimination.

Only a few studies have previously reported using a reminder with the novelty preference method to reinstate a novelty preference following evidence of a null preference. Cornell (1979) found that infants who received brief exposures to visual patterns showed a significant novelty preference when tested immediately and no preferences after delays of a few minutes or 2 days. When they were given a brief reexposure to the patterns just prior to test, infants in both delay conditions showed a reinstatement of the novelty preference. Similarly, Fagan (1977) found that a brief refamiliarization reinstated a novelty preference for photos of faces following forgetting due to interference. These results are consistent with predictions generated by the four-phase attention function and suggest that novelty preferences can be reinstated by increasing memory accessibility.

The four-phase attention function also complements recent findings relating immediate memory with length of familiarization or encoding time. A shifting preference from familiarity, to no preference, to novelty, as a function of increasing familiarization time has been observed following immediate memory tests (see Hunter and Ames, 1988; Rose et al., 1982; Wagner and Sakovits, 1986). According to these views, a period of transition has also been proposed, where infant memory is intact, yet no significant visual preferences are evi-

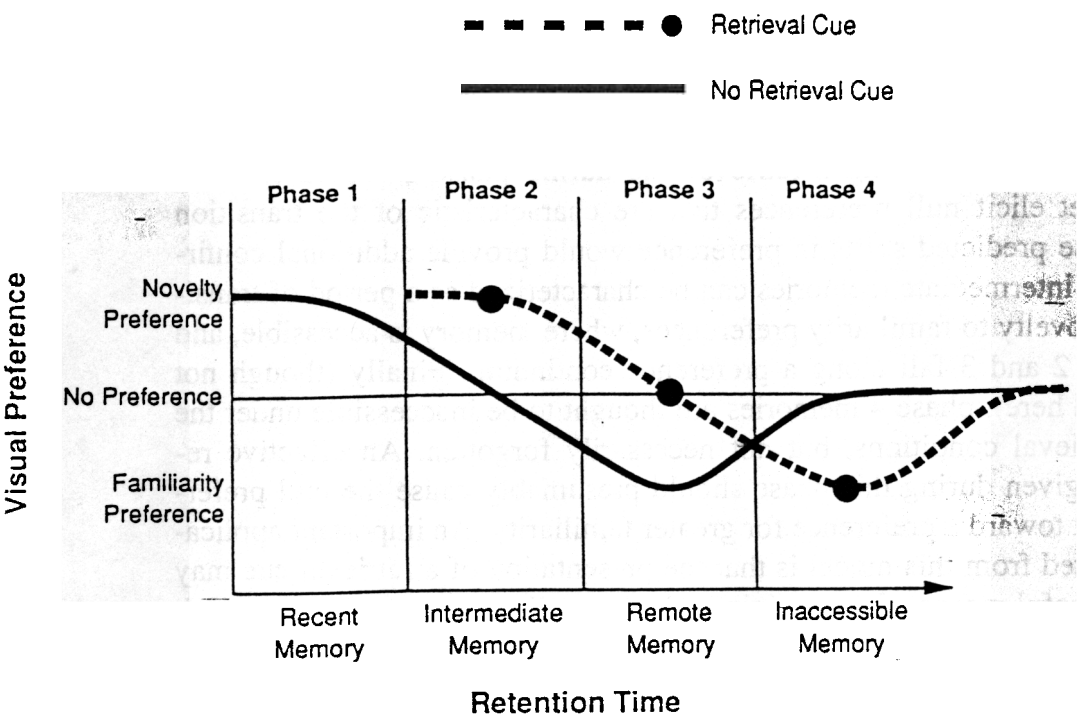

FIG. 1. Visual preferences as a function of retention time and effects of a retrieval cue given at different phases of the preference function as predicted by the four-phase model of infant attention.

dent. Intermediate familiarization periods which are too short to produce a novelty preference and too long to produce a familiarity preference are thought to elicit equal interest in novel and familiar stimuli and result in no significant preferences. Together, these lines of research increase our understanding of the factors that govern infants' attention to novelty and familiarity and will enable us to use visual preferences more effectively as a methodological tool for assessing memory and discrimination in infancy.

The present research was designed to test a priori predictions generated by Bahrick and Pickens' (1995) four-phase attention function. Further, it was designed to provide independent verification of our characterization of the transition phase (phase 2) as a period where memory is accessible, yet not manifested by a visual preference. By providing an appropriate retrieval cue such that infants are reexposed to a nontarget aspect of the familiar event just prior to the memory test (e.g., cueing with the static, familiar object and testing memory for its motion), memory accessibility should be enhanced, and attention should shift toward greater preferences for novelty. Figure 1 displays the four-phase attention function and the predicted effects of a retrieval cue given at different phases of the function. It is assumed that more recent memories are more accessible, and in phases 1–3 of the attention function, they should be expressed by increasingly greater preferences for novelty. Consequently, a retrieval cue should enhance preferences for novelty

in the first three phases where memory is accessible. Thus, it is expected that a retrieval cue given in phase 2, the transition period, should reinstate the novelty preference. It is further expected that a retrieval cue presented during phase 3 (where remote memory is expressed as a familiarity preference) should increase preferences in the direction of novelty, yielding a null preference. In essence, providing a retrieval cue during phase 3 would enhance memory, yet elicit null preferences that are characteristic of the transition phase. These predicted shifts in preference would provide additional confirmation that intermediate memories can be characterized as a period of transition from novelty to familiarity preferences, where memory is accessible, and that phases 2 and 3 fall along a preference continuum. Finally (though not investigated here), phase 4 memories are thought to be inaccessible under the current retrieval conditions, but not necessarily forgotten. An effective retrieval cue given during this phase should presumably cause the null preference to shift toward a preference for greater familiarity. An important application generated from this model is that the presentation of a retrieval cue may provide a useful means of determining whether null preferences are the result of accessible memories of phase 2 or of inaccessible memories of phase 4.

In summary, if the four phases of the attention cycle reflect gradual shifts in preference across retention time, then enhancing memory accessibility with a retrieval cue should have different effects on visual preferences at different phases of the attention cycle. The retrieval cue should cause preferences to resemble those characterizing memories of a more recent phase.

EXPERIMENT 1

The present research tests the above hypotheses generated by the four-phase attention function by presenting a retrieval cue just prior to the novelty preference memory test and otherwise replicates conditions of Bahrick and Pickens (1995). Thus, infants were familiarized with an object moving in either a circular or horizontal trajectory. Then they returned after 1 day (phase 2) or 1 to 3 months (phase 3) for a retrieval cue. Fifteen minutes later they received the novelty preference test assessing memory for the object's motion. The familiar object was presented undergoing the familiar versus the novel motion side by side. In addition three groups of control subjects matched for age with infants who returned after delays of 1 day, 1 and 3 months, received identical retrieval cue and test procedures but no familiarization with the events. These groups were included to make certain that results were due to familiarization and memory for the object motions rather than unrelated variables. In the present research, the retrieval cue consisted of a presentation of the familiar object in a still pose, whereas memory was tested for object motion. Thus, subjects did not receive a reexposure to the object's motion and any effects of the retrieval cue on visual preferences will be the result of memory for motion information. Several a priori predictions regarding the effects of retrieval cues on visual preferences and memory were generated

on the basis of the four-phase attention function. (1) The visual preferences of phases 2 and 3 (1-day, 1-month, and 3-month delay conditions) should shift toward increased novelty as a result of presenting an appropriate retrieval cue. (2) This shift toward greater novelty preferences should result in a significant novelty preference in phase 2 (the 1-day retention interval) and a null preference in phase 3 (the 1- and 3-month retention intervals). (3) The no-familiarization control conditions should generate chance preferences if the effects of the retrieval cue are due to enhancing memory accessibility.

Method

Subjects

Eighty-nine normal, healthy, 3-month-olds participated in the study, 49 in the experimental condition and 40 in the no-familiarization control condition. Infants in the experimental condition were 100.03 days (SD = 8.1) at the time of familiarization, similar to those of Bahrick and Pickens (1995). Infants in the experimental condition were randomly assigned to the 1-day (N = 16), 1-month (N = 17), or 3-month (N = 16) retrieval cue and test conditions. They were also matched for age at test with the 3-month-olds who had participated in the Bahrick and Pickens (1995) study. Those in the 1-day delay condition were 101.75 days (SD = 9.17) at the time of the memory test, and all had a delay of 1 day between familiarization and test. Those in the 1-month delay condition were 129.8 days (SD = 8.82), with a delay of 30.47 days (SD = 4.03) between familiarization and test, and those in the 3-month delay condition were 195.5 days (SD = 11.5), with a mean delay of 93.5 days (SD = 7.46) between familiarization and test. Data for 44 additional experimental subjects were collected but rejected from the study due to excessive fussing during test (N = 7), experimenter error or equipment failure (N = 8), failure to return for the retrieval cue/test phase (N = 17), failure to meet minimum fixation criteria during familiarization (N = 2), behavioral abnormalities (N = 1), and excessive side preference during test (N = 9) (see procedure section for more detail regarding rejection criteria). Infants in the no-familiarization control conditions were tested at an age comparable to those of the experimental conditions. Thus controls for the 1-day delay condition (N = 12) were 102.42 days (SD = 6.13), those for the 1-month delay condition (N = 12) were 130.42 days (SD = 9.28), and those for the 3-month delay condition (N = 16) were 183.8 days (SD = 5.36). Data were collected for 8 additional control subjects, but rejected from the study due to excessive side preference during test (N = 3), fussiness (N = 2), experimenter error (N = 1), and external interference during test (N = 2). All subjects were recruited through the use of local birth records.

Stimulus Events and Apparatus

The stimulus events and apparatus were identical to those used by Bahrick and Pickens (1995). They consisted of videotaped displays of a single and a

compound object undergoing either a horizontal or a circular motion. The single object was a large, yellow, metal washer, and the compound object was a cluster of small, orange, metal nuts. Each was suspended from a small stick and moved in an erratic pattern. When the objects moved horizontally, they swung back and forth, striking a vertical wooden surface on one side of the display, with each motion. The natural impact sounds were audible. During the circular motion, the objects were pulled across a plastic surface in a circular path, creating a scraping sound. The events were videotaped with a Panasonic (WV 3170) color video camera.

Infants sat in an infant seat facing two side by side 19-inch video monitors (Panasonic BT S1900N), approximately 75-cm away. A strip of Christmas tree lights and a mechanical toy dog were positioned between the monitors, and were used to attract the infant's attention prior to each trial. The events were presented via two Panasonic video decks (NV 8500, AG 6300) and a Panasonic edit controller (NV A500). Video switch boxes allowed us to present a given display to either video monitor. Soundtracks presented only during familiarization emanated from a speaker centered between and just below the two video monitors.

Apertures in a poster board occluder were located between and to either side of the monitors. This allowed one or two trained observers to stand unseen, behind the display and monitor the subject's visual fixations throughout the procedure. They depressed one of two buttons to indicate fixation to the right- or left-hand displays. A permanent record of the visual fixations was created by a Rustrak strip-chart recorder connected to the button boxes.

Procedure

Experimental subjects were randomly assigned to one of two retention interval conditions, 1 day ($N = 16$), 1 month ($N = 17$), or 3 months ($N = 16$). The procedure was identical to that of the 1-day, 1-month, and 3-month retention interval conditions of the Bahrick and Pickens (1995) study, with the addition of a retrieval cue 15 min prior to the novelty preference memory test.

All experimental subjects received an identical familiarization procedure. As in the prior study, it consisted of four 40-s presentations of two identical video displays presented out of phase with one another, side by side. Type of object (single versus compound) and motion (horizontal versus circular) were counterbalanced across subjects within each retention interval condition such that approximately one-fourth of the infants received each object/motion combination. The natural soundtrack was played in synchrony with the motions of one of the events and out of phase with the motions of the other identical event on each trial. The lateral position of the sound synchronized event alternated across the four trials for each subject. A minimum fixation criterion (used previously) was imposed during this phase to insure uniform familiarization with the events across subjects. A total of 120-s fixation out of the possible 160 s was required for infants to participate in the next phase

of the study. The data from two subjects were rejected for failure to meet this attention criterion.

Experimental subjects returned to the lab after a retention interval of 1 day, 1 month, or 3 months to receive the retrieval cue and novelty preference memory test. The retrieval cue consisted of two still images of the familiar object presented side by side. Infants viewed these displays until they accumulated a total of 60 s fixation time. The images were neutral with respect to motion information. Subjects were then removed from the infant seat and test booth for a period of approximately 15 min and were returned to the seat for the memory test. Typically, during the 15-min interval, the parent took the infant into an adjacent waiting room and/or walked around in the nearby hallways. The novelty preference memory test, identical to that of the prior study, consisted of two silent 60-s trials of the familiar object displayed on two side by side video screens. (Infants in the 3-month delay condition, however, were given four 60-s trials to preserve the longer format used by Bahrick & Pickens (1995) for that interval). One display depicted the familiar object undergoing the familiar motion and the other depicted the familiar object undergoing the novel motion. Across subjects, each object and motion served approximately equally often as the novel versus the familiar display. From one trial to the next, the lateral positions of the novel and familiar motions were switched. The initial lateral position of the novel motion was counterbalanced across subjects within each object × motion condition.

As in the prior study, a minimum fixation criterion was imposed to eliminate the data of subjects who showed excessive "side bias" during the test. It was required that subjects fixate each video monitor at least 5% of their total looking time (typically 2–3 s per trial), thus insuring that subjects had in fact noticed that two different displays were presented and had time to attend to some details of the display on the least preferred side.

Infants in the three control conditions (3-, 4-, and 6-month-olds) received no familiarization phase. They participated only in the retrieval cue and novelty preference test phases. All procedures and counterbalancing were otherwise identical to those of the experimental subjects who were matched for age, including arbitrarily assigning half the subjects to a circular and half to a horizontal motion group even though they received no familiarization with the motions.

One or two trained observers, blind to the lateral positions of the novel and familiar displays, monitored subjects' visual fixations throughout the procedure. Observations of the second observer were used for calculating interobserver reliability.

Results and Discussion

Familiarization phase. The proportion of available looking time spent fixating either of the two identical displays was calculated and averaged across the four 40-s trials for each subject. Interobserver reliability was calculated

on the basis of these proportions for 11 of the 49 subjects (22%) and was .95 (SD = .11). This was derived by obtaining a Pearson product–moment correlation between the observations of the primary and secondary observers across the four trials for each subject and averaging across subjects.

Across conditions, subjects spent an average proportion of .86 (SD = .07) of the available time (136.1 out of 160 s) fixating the familiarization displays, .87 (SD = .05) in the 1-day group, .85 (SD = .08) in the 1-month group, and .86 (SD = .08) in the 3-month delay group. This amount of time is similar to that of subjects who participated in the same three retention interval conditions of the prior study, where looking proportions averaged .85 (SD = .07), .87 (SD = .06), and .88 (SD = .10) for the 1-day, 1-month, and 3-month groups, respectively. A one-way analysis of variance was conducted on the looking proportions to determine whether familiarization times differed across the three retention interval conditions. Results indicated no main effect of condition ($F(2,46) = .34$, $p > .10$). Thus, subjects showed no a priori differences across conditions in the amount of familiarization time to the displays.

Memory test phase. Across all groups, subjects spent a mean of 98.8 s (SD = 16.7) out of the total 120 s fixating the test displays, 95.9 s (SD = 17.6) for experimental subjects, and 102.5 (SD = 15.1) for control subjects.

For subjects in the experimental conditions, looking data were converted to proportions of total looking time (PTLT) subjects spent fixating the novel motion on each trial and were averaged across trials. For those in the control conditions, the arbitrary assignment of subjects to the two motion conditions dictated whether the horizontal or circular motion was the "novel" one. Thus, the PTLT to the "novel" motion could be calculated on each trial and averaged across trials in a manner similar to that of the experimental subjects.

Interobserver reliability was calculated on the basis of 27 of the 89 subjects (30%) by correlating the PTLTs derived from observations of the primary and secondary observers across three 20-s blocks of each trial and averaged .97 (SD = .05) across all subjects, .97 (SD = .05) for (N = 15) experimental subjects, and .97 (SD = .06) for (N = 12) controls.

Results of the novelty preference memory tests for experimental and control subjects are depicted in Fig. 2 along with those of the prior study where infants received no retrieval cue prior to test. A two-way analysis of variance was conducted on the PTLTs of subjects in the experimental and control groups of the present study and subjects of the prior study to determine whether there was a main effect of condition (retrieval cue, no-familiarization control, no retrieval cue) or of retention interval (1 day, 1 month, 3 months) or an interaction. Results indicated a significant main effect of condition ($F(2,130) = 5.50$, $p = .005$) and no significant main effect of retention interval ($F(1,130) = 2.09$, $p > .1$) or interaction effect ($F(2,130) = .702$ $p > .1$). Post hoc tests indicated that the PTLTs of infants who received the retrieval cue were significantly higher than those who received no-familiarization and those who received familiarization

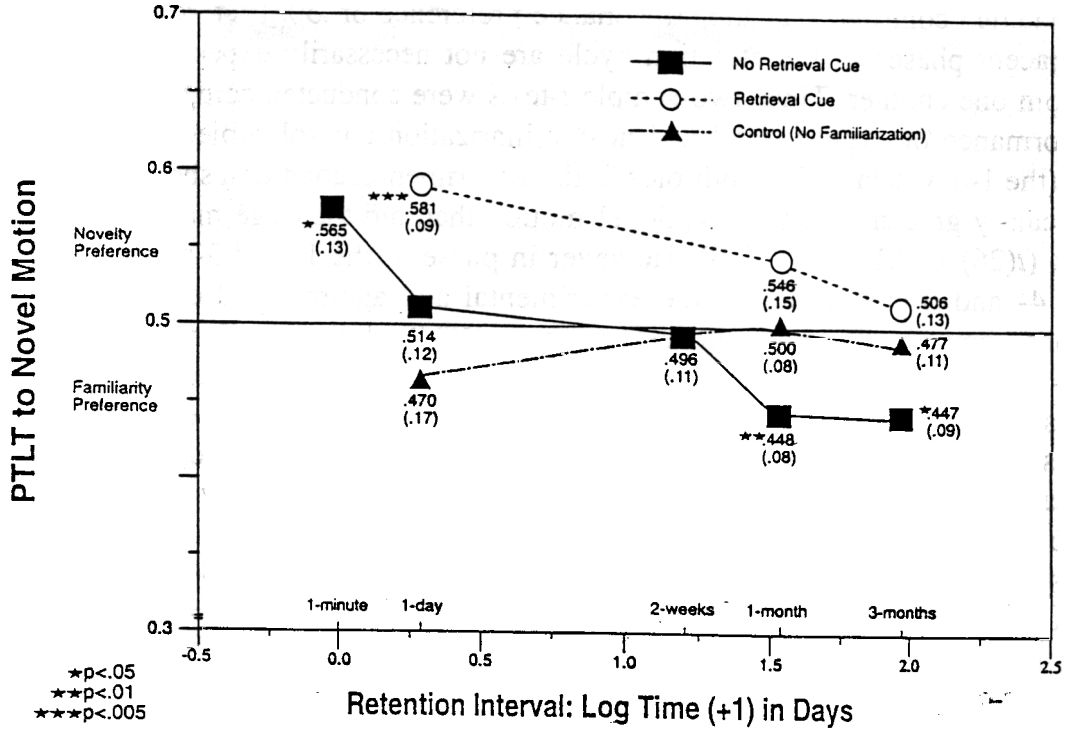

FIG. 2. Mean proportions of total looking time (PTLT) and standard deviations to the novel motion as a function of retention time for control subjects and those who received retrieval cues versus no retrieval cues.

and no retrieval cue ($p < .05$). These findings indicate an enhanced preference for novelty as a result of the retrieval cue.

To address the issue of whether the looking proportions of subjects in the experimental conditions of the present study were a result of their familiarization and memory for the object motions rather than to other extraneous variables, analyses were conducted comparing the performance of the experimental and no-familiarization control subjects. A two-way analysis of variance on the PTLTs to the novel motion with condition (experimental, control) as one factor and age (3, 4, and 6 months) as the other was performed. Results indicated a significant main effect of condition ($F(1,83) = 5.31$, $p = .024$) and no effect of age, or interaction ($p > .1$). Thus, the performance of experimental and control subjects differed and one may attribute the performance of experimental subjects to familiarization with the object motions rather than to unrelated factors.

To address the main research question regarding the direction of the visual preferences, analyses assessed the effects of the retrieval cue on visual preferences at phases 2 and 3 of the attention cycle (see Table 1). Because the different phases of the attention cycle are thought to reflect continuous shifts in preference rather than discrete phases, the significance and direction of visual preferences following the retrieval cue are best evaluated with respect

to age-matched controls or against the chance preference of .50. Preferences from adjacent phases of the attention cycle are not necessarily expected to differ from one another. Thus, two-sample *t*-tests were conducted comparing the performance of experimental and no-familiarization control subjects. In phase 2 (the 1-day delay), 3-month-olds in the experimental condition showed a significantly greater PTLT to the novel motion than did their age-matched controls, ($t(26) = 2.18$, $p = .038$). However in phase 3 (the 1- and 3-month delays), 4- and 6-month-olds in the experimental and age-matched control conditions showed no significant difference in PTLT to the novel motion ($t(27) = 1.01$, $p > .1$; $t(30) = .68$, $p > .1$, respectively). This pattern of results is similar to that obtained by comparing visual preferences of experimental subjects against the chance value of .50 at each age, according to single-sample *t*-tests. Results indicated that infants in the 1-day delay condition showed a significant novelty preference ($M = .581$, $t(15) = 3.52$, $p = .003$) as a result of the retrieval cue, whereas those in the 1- and 3-month delay conditions showed no significant preferences ($M = .546$, $t(16) = 1.24$, $p > .1$; $M = 506$, $t(15) = .19$, $p > .1$, respectively). Further, single-sample *t*-tests were conducted comparing the performance of control subjects against the chance value of 50% and revealed no significant departure from chance at either 3 months ($t(11) = .6$, $p > .1$), 4 months ($t(11) = .00$, $p > .1$), or 6 months ($t(15) = .85$, $p > .1$). These findings confirm predictions generated by the four-phase attention function that a retrieval cue given during phase 3 (remote memory) would elicit a null preference and that a retrieval cue given during phase 2 (intermediate memory) could reinstate a novelty preference.

As can be seen from Fig. 2, the preferences of experimental subjects also contrast with those obtained from infants in the same retention interval conditions of the prior study, where no retrieval cue was given. In the prior study preferences at the 1-day delay condition were at chance ($M = .52$, $p > .1$), whereas those of the 1- and 3-month delay conditions demonstrated significant familiarity preferences ($M = .45$, $p = .013$; $M = .45$, $p = .034$, respectively). A two-way analysis of variance was conducted on the PTLTs of subjects in the present study and those of the prior study for the 1-day, 1-month, and 3-month delay conditions to determine whether there was a main effect of condition (retrieval cue, no retrieval cue) or of retention interval (1-day, 1-month, 3-months), or an interaction. Results indicated a significant main effect of retrieval cue condition ($F(1,93) = 10.44$, $p = .002$), a significant main effect of delay condition ($F(2,93) = 3.15$, $p = .041$), and no interaction effect ($F(2,93) = .275$, $p > .1$). Thus, the performance of subjects in the present study differed significantly from that of subjects in the prior study as a result of the retrieval cue. Novelty preferences were significantly greater for the infants who received the reminder ($M = .54$, across all retention intervals) than those who received no reminder ($M = .47$).

Further analyses were conducted to assess secondary effects of type of motion or type of object on looking preferences for subjects in the present

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

Retention interval	Novel horizontal	Familiar horizontal	Difference	Novel circular	Familiar circular	Difference
1 Day						
Experimental						
M	.60	.44	16	.56	.40	16
SD	.09	.10		.10	.09	
N	9	7		7	9	
Control						
M	.535	.595	−.06	.405	.465	−.06
SD	.20	12		12	.20	
N	6	6		6	6	
1 Month						
Experimental						
M	.63	.53	10	.47	.37	10
SD	.13	.14		.14		
N	8	9		9	8	
Control						
M	.50	.51	−.01	.49	.50	−.01
SD	.10	.07		.07	.10	
N	6	6		6	6	
3 Months						
Experimental						
M	.56	.56	0	.44	.44	0
SD	.09	.16		.16	.09	
N	9	7		7	9	
Control						
M	.49	555	−.065	.445	.51	−.065
SD	.09	16		.16	.09	
N	8	8		8	8	

study. A four-way analysis of variance was performed with condition (experimental, control), age (3, 4, and 6 months), novel motion (circular, horizontal), and type of object (single, compound) as between subjects factors. Results indicated a main effect of novel motion $F(1,65) = 9.87$, $p = .003$) where subjects showed greater novelty preferences for the horizontal motion ($M = .56$) than the circular motion ($M = .47$) across conditions. Apparently infants found the horizontal motion more interesting than the circular motion. This contrasts with results of Experiment 2 of Bahrick and Pickens (1995) where infants found the circular motion to be more interesting than the horizontal one. There was also a condition × age × type of object interaction ($F(2,65) = 3.16$, $p = .05$) where subjects in the experimental condition at 3 months showed greater looking to the single, large object and those in the experimental condition at 4 months showed greater looking to the compound object,

whereas those in the other conditions showed no clear preferences for one object over another. An additional analysis was performed to determine whether infants showed any significant side preferences. The proportion of total looking time infants spent fixating the display on the right was calculated and averaged across trials. The mean proportion across age for experimental and control subjects was tested against the chance value of .50. Results indicated no significant preferences ($p > .1$).

Together these findings support the a priori predictions generated by the four-phase attention function (Bahrick & Pickens, 1995). They provide a greater understanding of phases 1–3 of the attention cycle and demonstrate that preferences shift across retention time from novelty, to null, to familiarity, while memory is still accessible.

EXPERIMENT 2

This study was conducted to replicate and further explore the shifting preference function. If the retrieval cue serves to increase memory accessibility and preference is a function of accessibility, then it was expected that providing more exposure to the retrieval cue might further increase memory accessibility and novelty preferences. Further, if the novelty and familiarity preferences lie along a preference continuum with the null preference interceding, then it should be possible to shift preferences for familiarity to novelty with sufficient exposure to a retrieval cue. In Experiment 1, one 60-s exposure to the retrieval cue caused the previously observed familiarity preferences of phase 3 to shift to null preferences. This study tested whether the familiarity preference observed in phase 3, after the 1-month delay, could be shifted to a novelty preference with additional exposure to the retrieval cue.

Method

Subjects

Sixteen infants, aged 3 months (103.5 days, $SD = 6.3$) participated. Data were collected for an additional 24 infants, but rejected from the study due to experimenter error ($N = 2$), fussiness ($N = 2$), equipment failure ($N = 2$), side bias during test ($N = 3$), failure to meet the minimum fixation criteria during familiarization ($N = 4$), and for failure to return for the 1-month memory test ($N = 11$).

Procedure

The stimulus events and procedures were identical to those of experimental subjects in the 1-month delay condition of the prior study with the exception that infants received two separate exposures to the retrieval cue. One month ($M = 35.9$ days, $SD = 5.0$) following familiarization, infants returned for a 60-cum s exposure to the retrieval cue, the still image of the familiar object. Then the next day they returned again for a second 60-cum s exposure to the

same retrieval cue, followed 15-min later by the novelty preference test assessing memory for object motion. During the memory test they received four 60-s trials of the familiar object undergoing the novel versus the familiar motions side by side.

Results

Familiarization phase. The proportion of available looking time spent fixating the two identical displays was calculated as before and averaged .87 (SD = .09). Interobserver reliability was calculated as before on the basis of these proportions for two of the 16 infants and averaged .995 (SD = .006).

Memory test phase. Infants spent a mean of 189.6 s (SD = 30.4) out of the total 240 s viewing one of the two visual displays, 79% of the available time. The PTLT to the novel motion was derived as before, across four 60-s memory test trials. Interobserver reliability was calculated on the basis of four subjects between observations of the primary and secondary observers and averaged .99 (SD = .01).

To address the main research question, whether a novelty preference could be elicited by presenting two exposures to the retrieval cue after a 1-month delay, a single sample t-test was conducted on the PTLT to the novel video against the chance value of .50. Results confirmed our prediction, indicating a significant novelty preference (M = .57, t (15) = 2.14, p = .049). Thus, in contrast with the null preference observed in the prior study following a 60-s exposure to the retrieval cue, a novelty preference was found for infants who had received two 60-s exposures to the retrieval cue.

Results of this study were also compared with those of the 1-month delay conditions of Experiment 1 (where only one retrieval cue was presented) and the prior study (Bahrick & Pickens (1995), where no retrieval cue was presented), as depicted in Fig. 3. A one-way analysis of variance with retrieval cue (no cue, 1 cue, 2 cues) as a main factor was conducted on the PTLTs of the infants in the 1-month delay condition. Results indicated a significant main effect of condition (F(2,48) = 4.64, p = .014).[1] A trend analysis also indicated a significant linear function (F(1,48) = 7.99, p = .007) relating increasing novelty preferences with increasing exposure to the retrieval cue. Thus, following a 1-month delay, memory is expressed as a familiarity preference, a null preference, or a novelty preference depending on the amount of exposure to the retrieval cue. This is presumably mediated by shifts in memory accessibility.

Secondary analyses were also performed to assess any effects of type of object or type of motion on looking preferences. A two-way analysis of

[1] This analysis was also conducted using the mean PTLT derived from test trials 1 and 2 (rather than trials 1–4) for the group with two retrieval cues to make the measures perfectly comparable across all three conditions. Results were comparable (F(2,48) = 3.96, p = .026).

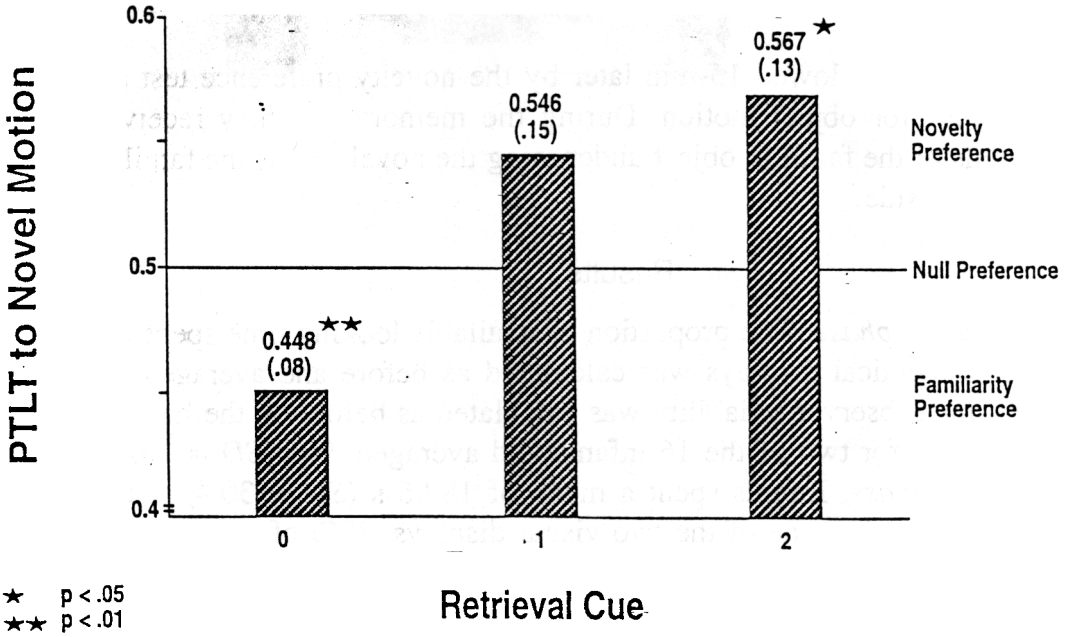

FIG. 3. Mean proportion of total looking time (PTLT) to the novel motion as a function of the number of presentations of the retrieval cue following a 1-month retention interval.

variance with novel motion (circular, horizontal) and type of object (single, compound) as between subjects factors was performed. Results indicated no significant effects of novel motion ($F(1,12) = 1.38, p > .1$) or type of object ($F(1,12) = .25, p > .1$). An analysis was also performed to determine whether subjects showed any side preferences. The PTLT spent fixating the display on the right was tested with a t-test against the chance value of .50. Results indicated no significant preference for one side over the other ($t(15) = .12$, $p > .1$).

GENERAL DISCUSSION

Results of the present studies complement those of the prior study in this series (Bahrick & Pickens, 1995) and provide clear support for the four-phase function relating infant attention with retention time. In the previous study where no retrieval cue was given, 3-month-old infants showed memory for object motion across a 3-month period by demonstrating a novelty preference after a 1-min delay, no preference after delays of 1 day and 2 weeks, and familiarity preferences after delays of 1 and 3 months. A four-phase model of infant attention was generated from these findings, suggesting that novelty and familiarity preferences interact with retention time, such that recent memories (phase 1) are expressed as a novelty preference, intermediate memories (phase 2) are expressed as a null preference, and remote memories (phase 3) are expressed as a familiarity preference (see Fig. 1).

In the present studies, using procedures identical to those of the prior study, infants were given a retrieval cue to increase memory accessibility and observe the effect on the direction of their preferences. It was hypothesized that if attention shifts gradually from novelty to null, to familiarity preferences as a function of memory accessibility, then enhancing memory accessibility with a retrieval cue should shift attention in the direction of novelty. In Experiment 1 infants received a retrieval cue 15-min prior to the novelty preference memory test, 1 day, 1 month, or 3 months following familiarization. Results indicated that the retrieval cue significantly enhanced novelty preferences with respect to the preferences obtained for the comparable retention interval conditions of the prior study. The null preference previously observed at the 1-day delay (phase 2) shifted to a novelty preference, whereas the familiarity preferences previously observed at the 1- and 3-month delays (phase 3) shifted to null preferences. Further, control subjects who received only the retrieval cue and memory test phases, but no familiarization, showed chance preferences and their performance differed significantly from that of the experimental subjects. Thus, without the familiarization, there was no benefit of the retrieval cue. These changes in preference as a result of the retrieval cue were most likely mediated by increases in memory accessibility for the object's motion. This pattern suggests that enhancing memory with a retrieval cue at a given phase reinstates preferences characteristic of a prior phase. Thus, the effects of increasing retention time on memory can in effect be reversed by aiding memory with a retrieval cue, and these two factors produce reciprocal effects on the direction of visual preferences.

Further, in Experiment 2, infants were given two exposures to the retrieval cue following a 1-month retention interval (remote memory). It was hypothesized that this additional exposure to the retrieval cue would further increase memory accessibility and might cause a remote memory, typically expressed as a familiarity preference, to resemble a recent memory, typically expressed as a novelty preference. Results confirmed our expectation and indicated that the original preference for familiarity was shifted to novelty by the additional exposure to the retrieval cue. These findings highlight the close relation between attention and retention time. They suggest that the novelty, null, and familiarity preferences lie along a continuum and reflect different degrees of memory accessibility.

Together, these findings support the characterization of phase 2, generated by results of Bahrick and Pickens (1995), as a period where preferences are in transition from novelty to familiarity, while memory is intact. This view is supported by the finding that preferences of one phase can be experimentally shifted to those of a prior phase by increasing memory accessibility with a retrieval cue. During phase 2, memory is of intermediate accessibility, while preferences for novelty are decreasing and preferences for familiarity are increasing. A null preference is observed because novel and familiar stimuli compete for attention. The confirmation of this transition phase underscores

the need for using caution when interpreting results of novelty preference tests. Null findings may not be the result of forgetting, rather they may be the result of shifting preferences where memory is of intermediate accessibility.

The present research suggests that in addition to factors that affect encoding (e.g., amount of familiarization time; see, Hunter & Ames, 1986; Wagner & Sakovits, 1988) factors that affect retrieval such as retention time and retrieval cues also influence memory accessibility and the direction of visual preferences. Further, these factors interact with the age of the infant and the type, modality, and complexity of the target event in determining the speed through which infant preferences progress through the novelty, null, and familiarity preference phases. Together, findings from this area of research point out the need for understanding more about the interaction of visual preferences with a number of factors, in order to improve theories of attention and more effectively use this response system as a tool for assessing discrimination and memory in infants.

Results of the present research also complement those of Rovee-Collier and her colleagues (e.g., Rovee-Collier & Fagen, 1981; Rovee-Collier, 1984). Their research demonstrates that a retrieval cue (a noncontingently moving mobile) can effectively reinstate a memory that is otherwise inaccessible. According to the present model this would be characterized as a phase 4 memory. In contrast, the present findings demonstrate that in the novelty preference method, a retrieval cue can effectively reinstate a novelty preference for an accessible, phase 2, memory that is otherwise expressed as a null preference.

Results of Bahrick and Pickens (1995) along with the present findings add to our knowledge about infant memory for dynamic displays and provide converging evidence for a four-phase function relating infant attention to retention time. They demonstrate that memory for object motion lasts at least 3-months in infants 3 months of age, and is expressed as a novelty preference (phase 1), a null preference (phase 2), a familiarity preference (phase 3), and then presumably a null preference (phase 4) as retention time is extended. The four phases of the attention cycle are thought to reflect gradual shifts in preference as a function of retention time, that can be experimentally manipulated by enhancing memory accessibility with retrieval cues.

Further research is needed to determine whether the null results hypothesized to characterize phase 4, inaccessible memory, would also be enhanced by a retrieval cue. If so, memory should then first be expressed as a familiarity preference rather than a novelty preference. Without such a test, it cannot be determined from a novelty preference test given at a single retention interval whether null findings are the result of a transition period where memory is accessible or of phase 4 where memory is inaccessible. The use of retrieval cues may provide an expedient method for interpreting null results observed in the two-choice preference procedure.

This series of studies provides one avenue for narrowing the gulf in the

literature between research in the areas of infant and child memory. By increasing our understanding of the relation between infant preferences for novelty and familiarity and memory accessibility we open the door to new methods for assessing infant memory. The present research has delineated a way to expand these methods to include tests of very long-term memory for a variety of naturalistic events in infancy. With this approach, we can begin to ask questions of infants that parallel those asked of young children regarding the nature and extent of long-term event memory.

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