LONG-TERM MEMORY FOR PRECONDITIONED ASSOCIATIONS AT 6 AND 9 MONTHS OF AGE

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ABSTRACT OF THE THESIS

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Recently, researchers found that immature human infants can form an association between two stimuli that were simultaneously preexposed in the initial phase of a sensory preconditioning (SPC) paradigm. How long such an association can remain latent before being successfully retrieved and used is still unknown. Because infants' new associations can be directly or indirectly linked with existing associations (Cuevas, Rovee-Collier, and Learmonth, 2006; Townsend, 2007) as well as with subsequent stimuli or events (Barr, Vieira, amd Rovee-Collier, 2001, 2002), how long a new association can remain latent but accessible defines the period in which it can be incorporated into the infant's expanding network of associations. In the present experiments with 6- and 9-month-old infants, the duration for which the memory of a simultaneous association between two preexposed hand puppets can remain latent before being forgotten was examined. The results indicated that, at both ages, the association can remain latent for as long as 2 to 3 weeks, but the length of this interval is determined by the preexposure regimen—in particular, by the number of sessions.

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Introduction

Since the time of Aristotle, associations have been a cornerstone of major theories of learning and memory. According to Aristotle, associations were formed between temporally contiguous events—a principle that has withstood the passage of time. Because associations are unobservable, or latent, behavioral scientists have developed a number of indirect means of confirming their formation. These methods are standard in studies of nonverbal learning (e.g., classical and operant conditioning) and verbal learning (e.g., paired-associate tasks). The sensory preconditioning (SPC) paradigm, a method introduced by Brogden in 1939 to assess association formation in animals, has enjoyed a revival of research attention over the last 2 decades. In Phase 1 of SPC, the experimental group is preexposed to two paired neutral stimuli (S1 + S2), while a control group is typically preexposed to the same stimuli unpaired. For both groups, Phases 2 and 3 are identical. In Phase 2, all subjects learn a distinctive response to one of the stimuli (S1→R1), and in Phase 3, all are tested with the other stimulus (S2→?). If the experimental group produces the distinctive learned response to the untrained stimulus (S2→R1) during the test, but the unpaired control group does not, then experimenters infer that a new association was formed between S1 and S2 in phase 1 and that this new association enabled the learned response to transfer from one stimulus to the other in Phase 3.

Until recently, it has been widely believed that very young human infants are incapable of associating stimuli or events that they merely see together, with no explicit reinforcement for doing so. Studies by Rovee-Collier and colleagues have demonstrated that this belief is incorrect (for review, see Rovee-Collier and Giles, 2009; Rovee-Collier and Cuevas, 2009). In fact, very young infants, both human and nonhuman, are particularly adept at associating two stimuli or events that occur simultaneously. The first study of SPC with human infants was conducted by Boller (1997) with 6-month-olds. In Phase 1, she preexposed a paired group to two distinctive cloth liners for a total of 1 hr on each of 7 consecutive days, and she preexposed an unpaired control group to the two liners equally long at different times of day. In Phase 2, all infants learned to kick to move a mobile in the presence of one of the liners, and all received a transfer test with the training mobile in the presence of the other liner 1 day later (Phase 3). At 6 months, infants cannot recognize their training mobile in a different context (Borovsky and Rovee-Collier, 1990). Presently, however, the paired preexposure group exhibited significant retention in the untrained context, while the unpaired preexposure group exhibited none. The paired group had associated the two liners (contexts) in Phase 1, and this association had enabled the transfer of conditioned responding to the test context.

Barr, Marrott, and Rovee-Collier (2003) adapted Boller's preexposure procedure to examine SPC using cues instead of contexts. Six-month-olds were simultaneously preexposed to two hand puppets (S1 and S2) for 1 hr daily on 7 consecutive days. One day after the last preexposure session, a sequence of three target actions (remove a mitten from the puppet's hand, shake the mitten, replace the mitten) was modeled six times (a total of 60 s) on puppet S1. Twenty-four hr later, infants received a transfer test for deferred imitation with puppet S2. An infant's imitation test score was the total number of target actions produced within 120 s. The unpaired (no-association) control group was preexposed to the two puppets for the same amount of time but at different times of day; otherwise, it was treated like the paired group. Finally, an age-matched baseline control group which had not seen the demonstration was tested with puppet S2. This group provided the baserate (0.13) at which 6-month-olds spontaneously produce the target actions.

As predicted, the paired preexposure group imitated the modeled actions on puppet S2, but the unpaired (no-association) control group did not. The same result was obtained when infants were preexposed to the paired puppets for 2 days instead of 7 days. To assess the specificity of the association, Barr et al. (2003) tested another paired preexposure group with novel puppet S3. This group failed to imitate the modeled actions on puppet S3, confirming that the association was specific to the paired cues that were preexposed in Phase 1.

Young infants are notorious for their rapid forgetting of associations that have been explicitly reinforced, and they forget more rapidly, the younger they are, (Hartshorn et al. 1998), but how long young infants might remember new associations that were not explicitly reinforced is unknown. Because young infants spend so much time exploring their visual environment, it seems likely that a major portion of their early learning results from merely noticing co-occurring stimuli rather than explicit reinforcement of a specific response. An important question then becomes how long can infants remember an association formed simply by contiguity, that is, how long can an association formed during Phase 1 of SPC remain latent before it is retrieved and used?

Because new associations can be linked with existing associations (Cuevas, Rovee-Collier, and Learmonth, 2006; Townsend, 2007) as well as with subsequent events (Barr, Vieira, and Rovee-Collier, 2001, 2002), how long a new association remains latent but accessible defines the period during which it can be incorporated into the infant's expanding network of associations. Even though a particular association might not be directly expressed, it may mediate or link other concepts that are (Townsend, 2007). Gaining some appreciation of the "window of opportunity" in which members of new associations can guide behavior and enter into other new associations at 6 and 9 months of age can offer new insight into how the early knowledge base is formed and expanded. The present study was designed to determine how long a newly formed simultaneous association can remain latent and still be successfully retrieved and used. In addition, because older infants remember learning tasks longer, both 6- and 9-month-olds were studied. (Twelve-month-olds were not studied because they do not form simultaneous associations in an SPC paradigm; Cuevas, 2009).

In Experiment 1, infants of both ages were preexposed to paired puppets for 1 hr on each of 2 consecutive days. In Experiment 2, infants were preexposed to the paired puppets for only 1 hr on 1 day, either continuously or in two distinct preexposure sessions lasting 30 min each. Because specific details of an event are usually forgotten before the general features (Rovee-Collier and Sullivan, 1980) Experiment 3 examined the specificity of the memory of the association after longer test delays.

Experiment 1:

Two Daily 1-hr Preexposure Sessions

In a preliminary study, Reynolds and Rovee-Collier (2005) simultaneously preexposed 6-, 9-, and 12-month-olds to puppets S1 and S2 for 2 consecutive days (Phase 1), modeled the target actions 1, 7, 14, or 21 days later on S1 (Phase 2), and tested infants with S2 1 day afterward (Phase 3). They expected older infants to remember the association longer, but such was not the case: Six- and 9-month-olds successfully imitated the actions 14 but not 21 days later, but 12-month-olds did not imitate on puppet S2 after any delay--not even 1 day after the demonstration. The latter result suggested that 12-month-olds did not form the association in the first place–a finding that has been subsequently replicated (Cuevas, 2009; Muentener, 2004).

Experiment 1 was designed to repeat the preliminary study with two major changes: A strict test response period was introduced and the daily preexposure session at each age was restricted to a single continuous period of time (previously, total preexposure time was accumulated throughout the day).

Independent groups were simultaneously preexposed to puppets S1 and S2 for 1 hr on each of 2 consecutive days (Phase 1). After a specified delay, a sequence of target actions was modeled on S1 (Phase 2), and infants received the deferred imitation test with S2 (Phase 3) 24 hr later. Imitation of the modeled actions on S2 would indicate that infants had formed the S1-S2 association in Phase 1 and remembered it in Phase 3, despite the intervening delay.

Method

Participants. The sample consisted of 63 infants at 6 and 9 months of age who were recruited from public birth announcements, commercial mailing lists, and by word of mouth. At each age infants were assigned to groups (*n* = 9) as they became available for study.

Six-month-old infants. The final sample contained thirty-six 6-month-old infants (15 boys, 21 girls) with a mean age of 191.1 days (*SD* = 8.6) on the first day of training. Participants were African-American (*n* = 1), Asian (*n* = 1), Caucasian (*n* = 31), and of mixed race (*n* = 3). Their parents' had a mean educational attainment of 15.8 years (*SD* = 0.6) and a mean rank of socioeconomic status (*SEI;* Nakao and Treas, 1992)[1] of 69.6 (*SD* =14.2).

Nine-month-old infants. The final sample contained twenty-seven 9-month-old infants (14 boys, 13 girls) with a mean age of 277.6 days (*SD* = 5.3) on the first day of training. Participants were Asian (*n* = 4), Caucasian (*n* = 16), Hispanic (*n* = 2), and of mixed race (*n* = 5). Their parents' mean educational attainment was 15.1 years (*SD* = 0.7), and the mean SEI was 56.8 (*SD* = 19.9).

Testing was discontinued on additional infants because of excessive crying (6 months, *n* = 2), failure to touch the puppet (6 months, *n* = 3; 9 months, *n* = 2), caregiver interference (6 months, *n* = 4; 9 months, *n* = 3), or equipment failure (6 months, *n* = 4; 9 months, *n* = 3).

Apparatus. Six hand puppets (a pink mouse, a gray rabbit, a black-and-white cow, a yellow duck, a pink rabbit, and a gray mouse) were constructed for this research and were not commercially available (see Figure 1). Infants do not spontaneously generalize between any of these puppets until they are at least 18 months of age (Hayne, MacDonald, and Barr, 1997; Learmonth, Lamberth, and

Rovee-Collier, 2004). The puppets were 30 cm tall and made of soft, acrylic fur. A removable felt mitten (8 cm x 9 cm) in a matching color covered each puppet's right hand. A jingle bell was pinned inside the mitten during the demonstration but removed during testing. Puppets were preexposed on a two-pronged wooden hat stand. A camcorder on a tripod was used to videotape the demonstration and test sessions for later review and scoring by independent coders.

Procedure. All infants were studied in their own homes at a time of day when they were likely to be playful, as reported by their caregivers. This time varied across infants but remained fairly constant across all sessions for a given infant. All sessions took place in the same room. The SPC procedure consisted of three phases:

Phase 1: Preexposure to S1-S2 (formation of the association). During Sessions 1 and 2, two puppets (S1, S2) were simultaneously exposed for 1 hr on each of 2 consecutive days (see Figure 2). Two puppets differing in both color and form were randomly assigned to each infant. The puppets were displayed side-by-side on a wooden hat stand in the infant's full view (see Figure 3). The caregiver who administered the preexposure sessions was provided with specific written instructions regarding when and how the puppets should be exposed (see Appendix A). During the exposure, infants were not permitted to touch the puppets. It was suggested that the preexposure occur during a mealtime while the infant was restrained in a high chair. The caregiver was encouraged to feed and/or play with the infant during the preexposure period, but asked not to direct the infant's attention to the puppets.

The experimenter provided each caregiver with a form on which to record the location, time of day, and what the infant was doing during each preexposure period (see Appendix A).

Phase 2: Demonstration of Target Actions (R1) on Puppet S1. Prior to the demonstration, the experimenter interacted with the infant for 5 min or until she elicited a smile. The infant was then seated on the caregiver's knees, the experimenter knelt in front of the infant, and held puppet S1 at the infant's eye level, approximately 80 cm from the infant's chest (out of the infant's reach). Phase 2 began when the experimenter removed the mitten from the puppet's right hand, shook it three times to ring the jingle bell inside, and replaced it on the puppet's hand. This sequence lasted 10 s and was repeated five more times (a total of 60 s) for 6-month-olds or two more times (a total of 30 s) for 9-month-olds. These demonstration durations were found to yield 24-hr retention at 6 and 9 months of age (Barr, Dowden, and Hayne, 1996; Learmonth et al., 2004).

Phase 3: Deferred Imitation Transfer Test with S2. Phase 3 occurred 24 hr after Phase 2. During the test, the experimenter held puppet S2 within the infant's reach, approximately 30 cm in front of the infant's chest (see Figure 4). Infants were allowed a response period of 90 s (9-month-olds) or 120 s (6-month-olds)[2] the time he or she first touched the puppet in which to imitate the modeled actions.

The independent variable was the interval that elapsed between Phase 1 and Phase 2. Retention of the S1-S2 association over that interval was measured 24 hr later during the deferred imitation test with S2 (Phase 3). The experimental strategy was to begin testing 7 days after the final preexposure session and then to increase or decrease the Phase 1-Phase 2 interval using the staircase method, depending on whether a delay group exhibited significant 24 hr retention or not, respectively. This strategy yielded four independent experimental groups at 6 months (intervals = 6, 9, 13, and 15 days) and three independent experimental groups at 9 months (intervals = 6, 13, and 17 days). If an experimental group's mean imitation score was significantly higher than the mean test score of an age-matched pooled baseline control group[2] (6 months: $M = 0.13$, $SE = 0.05$; 9 months: $M = 0.25$, $SE = 0.12$), then the experimental group exhibited significant retention; otherwise, it did not (see Appendix E).

Because retention was not measured until 24 hr after the Phase 1-Phase 2 interval, data from this and all succeeding experiments will be reported and interpreted in terms of the test delay at which they were collected (i.e., Phase 1-Phase 3 interval). In Experiment 1, for example, data are reported in terms of test delays of 7, 10, 14, and 16 days at 6 months and 7, 14, and 18 days at 9 months.

Results and Discussion

An imitation score was calculated by summing the number of target actions (remove the mitten, shake the mitten, attempt to replace the mitten on the puppet's right hand) that each infant produced during the test (range = 0-3). (Infants younger than 18 months rarely attempt to replace the mitten.) One observer coded 100% of the videotaped test sessions for timing and target actions. A second observer, who was blind to the infants' group assignments, independently coded 20% of the videotaped test sessions. Their interobserver reliability for the imitation scores, based on the number of exact agreements, was

96% (*kappa* = .92). When the two observers differed, the primary observer's score was assigned.

At each age, the mean imitation scores of infants in the experimental groups and an age-matched baseline control group were subjected to a one-way analysis of variance (ANOVA). Tukey's HSD was used to determine if any of the experimental groups differed from one another. The alpha level was set at p < .05 for both analyses. Directional Dunnett's t tests (p < .025 across multiple comparisons with the age-matched baseline control group) were used to determine whether the mean imitation score of any experimental group significantly exceeded the mean test score of the age-matched baseline control group. This test controls for Type I errors across multiple comparisons with a control group.

Six-month-old infants.

A one-way analysis of variance (ANOVA) indicated that the mean imitation scores of the four experimental groups and the pooled baseline control group differed significantly, $F(4, 65) = 6.80$, $p < .001$ (see Appendix E). Dunnett's t tests (p < .025) revealed that the mean imitation score was higher than the mean test score of the baseline control group after 7 and 10 days but not 14 or 16 days (see Figure 5).

Nine-month-old infants.

A one-way ANOVA indicated that the mean imitation scores of the three experimental groups and the pooled baseline control group differed significantly, $F(3, 50) = 5.67$, $p < .001$ (see Appendix F). Dunnett's t tests revealed that the mean imitation score was higher than the mean test scores of the baseline control group after 7 and 14 days, but not 18 days (see Figure 6). (The Tukey's HSD test indicated that the mean imitation test scores of the 14- and 18-day experimental groups differed significantly.)

These findings reveal that a new association can remain latent for a substantial period before it is retrieved and expressed. The S1-S2 association formed by simultaneously preexposing infants to two puppets for 1 hr per day on 2 consecutive days was remembered for 10 days at 6 months of age and 14 days at 9 months of age. The length of the interval over which infants remembered the association was surprising given that infants of these ages typically remember the demonstration when tested with the same puppet for only 24 hr. When 6-month-olds were exposed to the demonstration on 2 consecutive days, they exhibited significant imitation on the demonstration puppet after 10 days (Barr, Rovee-Collier, and Campanella, 2005). When an additional demonstration session was afforded, retention increased from 1 day to 10 days.

The latter data suggest that the number of preexposure sessions may be a critical determinant of the duration of retention. The effect of the number of preexposure sessions on retention in the SPC paradigm is unknown. In Experiment 2, therefore, this variable was examined.

Experiment 2a:
A Single 1-hr Preexposure Session

In Experiment 1, infants were simultaneously preexposed to S1 and S2 for 1 hr on 2 consecutive days. Barr et al. (2005) found that doubling the number of sessions in which the target actions were modeled on a puppet extended deferred imitation from 1 day to 10 days at 6 months of age. Similarly, Hsu (2007; Hsu and Rovee-Collier, 2009) found that 6- and 9-month-old infants remember an operant contingency two times longer after two sessions than after one. In Experiment 2a, therefore, how long infants could remember the S1-S2 association was examined after a single 1-hr preexposure session (see Figure 7). The same procedure was used as in Experiment 1.

Method

Participants. The sample consisted of 45 infants at 6 and 9 months of age who were recruited as before, and again assigned to experimental groups (n = 9) as they became available for study.

Six-month-old infants. The final sample consisted of twenty-seven 6-month-old infants (10 boys, 17 girls) with a mean age of 187.8 days (SD = 4.9) on the first day of training. Participants were African-American (n = 3), Asian (n = 2), Caucasian (n = 21), and other (n = 1). Their parents' mean educational attainment was 15.6 years (SD = 0.8), and their mean SEI was 61.6 (SD =19.1).

Nine-month-old infants. The final sample consisted of eighteen 9-month-old infants (11 boys, 7 girls) with a mean age of 281.7 days (SD = 5.5) on the first day of training. Participants were African-American (n = 3), Caucasian (n = 11), mixed race (n = 3), and NR (n = 1). Their parents' mean educational attainment was 15.7 years (SD = 1), and their mean SEI was 63.7 (SD = 15.8).

Testing was discontinued on additional infants because of failure to touch the puppet (6 months, n = 2; 9 months, n = 1), caregiver interference (6 months, n = 2; 9 months, n = 1), and equipment failure (6 months, n = 2; 9 months, n = 3).

Procedure. The experimental strategy was to begin testing 2 days after the preexposure session and then to increase the test delay to 3 days and, if infants remembered, to 7 days (these test delays corresponded to Phase 1-Phase 2 intervals of 1, 2, and 6 days, respectively). This strategy yielded three independent experimental groups at 6 months who were tested after delays of 2, 3, or 7 days and two independent experimental groups at 9 months who were tested after delays of 2 or 3 days. The two age-matched baseline control groups were also included in the analysis.

Results and Discussion

Six-month-old infants. A one-way ANOVA indicated that the mean imitation scores of the three experimental groups and pooled baseline control group differed significantly, $F(3, 56) = 7.70$, $p < .01$ (see Appendix G). Dunnett's *t* tests revealed that the mean imitation score was higher than the mean test score of the baseline control group after test delays of 2 and 3 days, but not 7 days (see Figure 8).

Nine-month-old infants. A one-way ANOVA indicated that the mean imitation scores of the two experimental groups and pooled baseline control group differed significantly, $F(2, 41) = 4.98$, $p < .001$ (see Appendix H). Dunnett's *t* tests revealed that the mean imitation score was higher than the mean test score of the baseline control group after a test delay of 2 days, but not 3 days (see Figure 9). A Tukey's HSD post hoc test indicated that the mean imitation scores of 6- and 9-month-olds did not differ at 3 and 2 days, respectively.

The results of Experiment 2a reveal that the S1-S2 association was formed within a single session and was remembered less than half as long after a single

1-hr session as after two 1-hr sessions on consecutive days (Experiment 1). The basis for the reduced retention, however, was unclear. In Experiment 2a, total preexposure time and the number of sessions were confounded. One possibility is that the reduced retention resulted from halving the preexposure duration in Experiment 2a (1 hr vs. 2 hr). Alternatively, the reduced retention could have resulted from halving the number of sessions in Experiment 2a. Individuals who are given two preexposure sessions are afforded an opportunity to retrieve the inactive memory of the association at the outset of the second session—an opportunity not provided by a single session. Experiment 2b, therefore, was designed to deconfound the effects of total preexposure time and number of preexposure sessions on retention.

Experiment 2b: Two 30-min Preexposure Sessions on 1 Day

In Experiment 1, infants had received a 1-hr preexposure sessions on 2 consecutive days, whereas in Experiment 2a, infants had received one 1-hr preexposure session on 1 day. The briefer retention of the S1-S2 association in Experiment 2a could have resulted from a decrease in session number, total preexposure time, or both. In Experiment 2b, therefore, infants received two sessions, as in Experiment 1, but the total preexposure time was 1 hr, as in Experiment 2a (see Figure 10)[3]. The minimum interval between the two preexposure sessions was set at 5 hr in order to ensure that no residual activation produced by the paired puppets during the first preexposure session would still be present when the second preexposure session occurred, and that the S1-S2 association would be retrieved (activated) from long-term memory (Hall, 2003; Lee, Gomberg, Cuevas, Hsu, and Rovee-Collier, 2008).

Method

Participants. The sample consisted of 72 infants at 6 and 9 months of age who were recruited and assigned to groups (*n* = 9) as before.

Six-month-old infants. The final sample consisted of thirty-six infants (18 boys, 18 girls) with a mean age of 187.0 days (*SD* = 5.1) on the first day of training. Participants were African-American (*n* = 1), Asian (*n* = 4), Caucasian (*n* = 28), Hispanic (*n* = 1), and of mixed race (*n* = 2). Their parents' mean educational attainment was 15.4 years (*SD* = 1.5), and their mean rank of SEI was 69.4 (*SD* = 21.9).

Nine-month-old infants. The final sample consisted of thirty-six infants (24 boys, 12 girls) with a mean age of 280.0 days (*SD* = 4.4) on the first day of training. Participants were Asian (*n* = 2), Caucasian (*n* = 24), Hispanic (*n* = 3), and of mixed race (*n* = 5). Their parents' mean educational attainment was 15.4 years (*SD* = 1.3), and their mean rank of SEI was 69.4 (*SD* = 17.9).

At both ages, testing was discontinued on additional infants because of failure to touch the puppet (9 months, *n* = 2), caregiver interference (9 months, *n* = 3), and equipment failure (6 months, *n* = 1; 9 months, *n* = 1).

Procedure. The procedure was the same as in Experiment 2a with the exception that infants were given two 30-min preexposure sessions, separated by a minimum of 5 hr. The experimental strategy was to begin testing 7 days after the final preexposure session and then to increase or decrease the Phase 1-Phase 2 interval delay according to the staircase method, depending on whether infants exhibited retention or not, respectively. This strategy yielded four independent experimental groups who were tested after delays of 7, 14, 21 or 28 days (i.e., Phase 1-Phase 2 intervals of 6, 13, 20, or 27 days, respectively) at both 6 and 9 months of age.

Results and Discussion

Six-month-old infants. A one-way ANOVA indicated that the mean imitation scores of the four experimental groups and the baseline control group differed significantly, $F(4, 64) = 10.70$, $p < .001$ (see Appendix I). Dunnett's *t* tests ($p < .025$) revealed that the mean imitation scores of the experimental groups were significantly higher than the mean test score of the baseline control group after 7, 14, and 21 days, but not 28 days (see Figure 11).

Nine-month-old infants. A one-way ANOVA indicated that the mean imitation scores of the four experimental groups and the pooled baseline control group differed significantly, $F(4, 59) = 3.19$, $p < .025$ (see Appendix J). Dunnett's *t* tests ($p < .025$) revealed that the mean imitation scores of the experimental groups were significantly higher than the mean test score of the pooled baseline control group after 7 and 14 days, but not 21 or 28 days (see Figure 12).

Cross-Experiment Analyses. Three basic questions were addressed in the cross-experiment analyses. First, did the preexposure regimen (defined in the analyses as "Group") significantly affect infants' mean imitation test scores, and did this effect vary by Age or Delay? Second, did the Delay or infant Age significantly affect mean imitation scores? And finally, did a three-way interaction over Group, Age, and Delay significantly affect infants' mean imitation scores?

To answer this, a Univariate Analysis of Variance was performed over Group, Age, and Delay. This analysis yielded a significant main effect of Group, $F(2, 233) = 3.71$, $p < .02$, and Delay, $F(8, 233) = 2.85$, $p < .01$, but not of Age, $F(1, 233) < 1$. The two-way interaction between Group and Age, $F(1, 233) = 3.24$, $p < .07$, $F(3, 233) < 1$, Group and Delay, $F(1, 233) < 1$, and Age and Delay, $F(4, 233) < 1$ were not significant. The Unianova also revealed no significant three-way interaction between Age, Group, and Delay, $F(1, 233) < 1$ (see Appendix K).

A post hoc analysis was run to determine which groups had mean imitation test scores significantly different from the mean test score of the baseline control group. Dunnett's *t* tests ($p <.025$) revealed that the mean imitation test scores of the 1 hr/2 day, 1 hr/1 day, and 1 hr/(2) 30 min/1 day were all higher than the mean test score of the baseline control group .

In summary, Age had no significant effect on infants' mean imitation test score, but Group (preexposure regimen) and Delay (Phase 1-Phase 3 interval) did. There were no significant interactions.

In Experiment 2b, even though total preexposure time was the same as in Experiment 2a, infants remembered the S1-S2 association seven times longer at both 6 months of age (21 days vs 3 days) and 9 months age (14 days vs 2 days). The absolute duration of retention at 9 months was the same in Experiment 1 (two daily 1-hr preexposure sessions) and Experiment 2b (two 30-min preexposure sessions on 1 day), clearly indicating that the number of sessions, not the total preexposure time, was the key factor affecting how long infants remember the S1-S2 association. This effect is attributed to the opportunity to retrieve the memory of the initial preexposure session at the outset of the second session.

Experiment 3: Specificity of the Memory for the Association at 6 Months

Shortly after training, the memories of young infants are highly specific to the stimuli that were present during the original event, but they increasingly generalize to novel test stimuli after longer delays (Bhatt and Rovee-Collier, 1996; Borovsky and Rovee-Collier, 1990; Hartshorn et al., 1998; Rovee-Collier and Sullivan, 1980). Experiment 3 was designed to determine if the memory of the association that infants formed between puppet S1 and puppet S2 in the preceding experiments remained specific to those puppets after longer test delays. Infants were tested with a novel puppet after the longest test delay that they had remembered the association in the preceding experiments, when they were most likely to have forgotten the specific details of the associated puppet (S2). Given that there were no age differences after any delay in the preceding ANOVAs, no significant age differences were found between groups, and because Learmonth et al. (2004) had found no generalization differences between these ages, only 6-month-olds were tested in Experiment 3. Specifically, infants in the three preexposure regimen groups were tested with a novel puppet (S3) after the longest test delay that they had remembered the association in Experiment 1, Experiment 2a, and Experiment 2b (see Figure 13).

Method

Participants. The final sample consisted of twenty-seven 6-month-old infants (15 boys, 12 girls), recruited as before and assigned to groups (*n* = 9) as they became available for study. They had a mean age of 186.7 days (*SD* = 4.8) on the first day of training. Participants were African-American (*n* = 2), Asian (*n* = 2), Caucasian (*n* = 19), Hispanic (*n* = 1), of mixed race (*n* = 2), or Not Reported (*n* = 1). Their parents' mean educational attainment was 13.4 years (*SD* = 1.6), and their mean SEI rank was 56.9 (*SD* = 9.3). Testing was discontinued on additional infants because of failure to touch the puppet (*n* = 1) and parental interference (*n* = 2).

Procedure. The procedure and apparatus used in Experiment 3 was identical to that used in the preceding experiments except that infants were tested with a novel puppet (S3). Three groups of infants were tested after the longest delay that corresponding groups of infants in the preceding experiments had remembered the association. Infants in Group 1 received the same preexposure regimen as infants in Experiment 1 (1 hr on 2 consecutive days) and were tested with S3 10 days afterwards. Infants in Group 2 received the same preexposure regimen as infants in Experiment 2a (1 hr on 1 day) and were tested with S3 after a 3-day delay. Infants in Group 3 received the same preexposure regimen as infants in Experiment 2b ((2) 30-min sessions on 1 day) and were tested with S3 after a 21-day delay (see Figure 12). In addition, the analyses included the three corresponding groups from Experiments 1, 2a, and 2b that were tested with the original associate (S2) and the baseline control group.

Results and Discussion

A one-way ANOVA indicated that the mean imitation test scores of Group 1, the corresponding Experiment 1 10-day test delay group, and the baseline control group differed significantly, $F(2, 47) = 18.58$, $p < .001$ (see Appendix L). Dunnett's *t* tests ($p < .025$) revealed that the mean imitation scores of the two experimental groups were higher than the mean test score of the baseline control group (see Figure 14). A Student's *t* test ($p < .05$) revealed that the difference between the mean imitation test scores of Group 1 and the corresponding 10-day delay test group only approached significance, $t(16) = 4.01$, $p < .062$.

A one-way ANOVA indicated that the mean imitation test scores of Group 2, the corresponding Experiment 2a 3-day test delay group, and the baseline control group differed, $F(2, 47) = 16.16$, $p < .001$ (see Appendix M). Dunnett's *t* tests ($p < .025$) revealed that the mean imitation scores of the two experimental groups were higher than the mean test score of the baseline control group. A Student's *t* test revealed no difference between the mean imitation scores of Group 2 and the corresponding 3-day test delay group, $t(16) = .001$, $p = 1.00$.

A one-way ANOVA indicated that the mean imitation scores of Group 3, the corresponding Experiment 2b 21-day test delay group, and the baseline control group differed, $F(2, 47) = 22.32$, $p < .001$ (see Appendix N). Dunnett's *t* tests ($p < .025$) revealed that the mean imitation scores of the two experimental groups were higher than the mean test score of the baseline control group. A Student's *t* test revealed no difference between the mean imitation test scores of Group 3 and the corresponding 21-day test delay group, $t(16) = 2.00$, $p < .176$.

These data document that infants' memory of the association, which is highly specific after 24 hr (Barr et al., 2003), is generalized after the longest interval that they still remember it, irrespective of the preexposure regimen. These results indicate that infants had forgotten the specific details of the puppet over time but still remembered its general features. Had they forgotten the association altogether, they would have discriminated the test puppet (S3) from the puppet (S1) that was used during the demonstration 24 hr earlier and failed to imitate on it. The finding that infants forget the specific details before the general features of a stimulus or event after long delays has been obtained in studies of both SPC and operant learning (Barr et al., 2005; Bhatt and Rovee-Collier, 1996; Borovsky and Rovee-Collier, 1990; Campanella and Rovee-Collier, 2005; Hartshorn et al., 1998; Hitchcock and Rovee-Collier, 1996; Rovee-Collier and Sullivan, 1980).

General Discussion

Research using an SPC paradigm with young infants has found that they form associations between two stimuli on the basis of contiguity, without being explicitly reinforced for doing so (for review, see Rovee-Collier and Giles, 2009). The maximum period for which these associations can remain latent before being retrieved and potentially expressed is unknown. This information is important because it describes the period during which these associations can enter into other new associations, offering insight into how the early knowledge base is formed and expanded. Barr, Rovee-Collier, and Learmonth (under review) found that new associations formed in this way can be linked with subsequent events. In addition, Cuevas et al. (2006) found that new associations are also linked with existing associations.

The data from the present study reveal that how long the association can remain latent but accessible is determined by the preexposure regimen in the initial phase of SPC. After two 1-hr preexposure sessions, 6- and 9-month-old infants remembered the association for 10 and 14 days, respectively. After a single 1-hr preexposure session, infants of both ages remembered the association for only 2 and 3 days. After two 30-min preexposure sessions on 1 day, however, 6-month-old infants remember the association for 21 days, while 9-month-old infants remember the association for 14 days—the same duration as when they received preexposure sessions on 2 consecutive days. Despite age differences in the absolute retention benefit of administering two 30-min preexposure sessions instead of one 60-min preexposure session on a single day, the relative retention benefit at both ages was the same: Both 6-and 9-month-olds remembered the association seven times longer after two 30-min preexposure sessions. The longevity of the memory of the association after two sessions was surprising in light of conventional wisdom that infants' brains are too immature to encode and maintain memories over the long term until the end of the first year of life (e.g. Bauer, 2009; Jones and Herbert, 2006; Richmond and Nelson, 2007).

Why did two 30-min preexposure sessions afford such a huge retention benefit relative to one 60-min session at both ages, particularly when total preexposure time was the same in both conditions? What retention advantage did the second session provide? The retention advantage apparently resulted from the retrieval opportunity that was afforded at the outset of the second session. In studies with both adults and infants, human and nonhuman, a memory representation is strengthened by simply retrieving it (for review, see Bjork, 1988; Rovee-Collier, 1995; Schmidt and Bjork, 1992). Support for this conclusion comes from the data of 9-month-olds who received two preexposure sessions lasting 1-hr each on consecutive days. For them, the retention benefit of two sessions relative to one was the same whether the two sessions occurred on a single day or not.

This account, however, raises an additional question: Why did 6-month-olds remember more than two times longer after two 30-min preexposure sessions on 1 day than after two 1-hr sessions on 2 consecutive days? The answer probably lies in the consistent finding that infants who are older forget less rapidly, irrespective of task, than younger infants (for review, see Rovee-Collier and Hayne, 2005). Nine-month-olds, for example, exhibit significant retention of an operant task for 6 weeks, whereas 6-month-olds remember it for only 2 weeks (Hartshorn et al., 1998). Ebbinghaus (1885/1962) famously reported that the greatest proportion of forgetting occurred over the first 24 hr after training. It is reasonable to speculate, therefore, that 9-month-olds forget less over the 24-hr intersession interval than 6-month-olds. As a result, the shorter (5-hr) intersession interval would have benefitted 6-month-olds more than 9-month-olds, which is what the retention data suggest. Because there is no measurable behavior in the preexposure phase, however, how much infants forgot over 24 hr cannot be determined.

By the same token, the fact that 6- and 9-month-olds exhibited the same relative retention benefit from two 30-min sessions on a single day should be interpreted as a greater retention benefit for 6-month-olds. That is, because older infants are expected to remember longer, a manipulation that produces equivalent retention benefit at two ages actually produces a greater retention benefit for the younger age. This conclusion is consistent with prior evidence that younger infants benefit more than older infants from manipulations that facilitate retention. For example, Hsu (2007) found that 6-month-olds profited more than twice as much as 9-month-olds when she manipulated the interval between successive operant conditioning sessions. Administering a second training session at the end versus at the beginning of their respective forgetting functions prolonged retention by 136% at 6 months and by 67% at 9 months.

Finally, although infants remembered the association over a surprisingly long interval, what did they remember? The answer to this question was provided by 6-month-olds, who generalized imitation to a novel test puppet after the longest interval that they remembered the association, regardless of preexposure regimen. These results indicated that infants had forgotten the specific details of puppet S2 over time but still remembered its general features. Had they forgotten the association altogether, they would have discriminated the test puppet (S3) from the puppet (S1) that was used during the demonstration 24 hr earlier and failed to imitate on it.

The findings of the present study are consistent with recent evidence that human infants experience a period of exuberant learning during the first 9 postnatal months. During this period young infants rapidly form associations between simultaneously occurring events, whether related or not, and do so on a single occasion. For review, see Rovee-Collier and Cuevas (2009) and Rovee-Collier and Giles (2009). As a result of transfer studies (SPC, potentiation, and equivalence learning) with developing rat pups, Spear (1984) originally proposed that immature organisms of all species undergo an early period of exuberant learning during which they learn the critical relationships in their physical and social environment that permit them to adapt to each of a series of rapidly changing ecological niches. He found that an essential characteristic of this period of rapid learning was temporal contiguity: immature animals only learned to associate events that occurred simultaneously. According to Spear, because younger infants' attention is less selective than adults', they notice more about the same event and actually form more intra-event associations than adults. Chen, Lariviere, Heisey, Spear, and Spear (1991) subsequently found evidence that the period of exuberant learning ended at the end of the rat pups second postnatal week. Using a SPC paradigm, they found that the effective SPC preexposure regimen shifted developmentally over this period: Eight-day-old rat pups associated two odors that were preexposed simultaneously but not sequentially, 12-day-old rat pups associated two odors that were preexposed either simultaneously or sequentially, and 21-day-old rat pups associated two odors that were preexposed sequentially but not simultaneously. Cuevas (2009) documented a parallel developmental shift in the effective preexposure regimen with 6-, 9-, and 12-month-old human infants—ages that correspond to the ages of the infant rats tested by Chen et al. (1991). Six-month-olds associated two puppets that were preexposed simultaneously but not sequentially; 9-month-olds associated two puppets that were preexposed either simultaneously or sequentially; and 12-month-olds associated two puppets that were preexposed sequentially but not simultaneously. Thus, her data suggested that for human infants 9 months represented a transitional age after which the period of exuberant learning ends.

Evidence has suggested that the period of exuberant learning by human infants ends after 9 months of age—the same age at which the early period of experience-based perceptual tuning gives way to perceptual narrowing (Scott, Pascalis, and Nelson, 2007), and the explicit memory system presumably replaces the implicit memory system as the primary means for memory processing (Bauer, DeBoer, and Lukowski, 2007; Carver and Bauer, 2001; Carver, Bauer, Wiebe, Waters, and Nelson, 2003; Nelson, 1995; 1997; Richmond and Nelson, 2007). Evidence from the period of exuberant learning and the period of perceptual tuning is inconsistent with the neuromaturational model, which attributes learning and memory over the first nine months to an implicit memory system which cannot account for the variety of infants' early learning or the duration for which they remember it.

Given the close relation between perceptual development and memory processing, future memory research with infants will focus on how the perceived unit of analysis changes with age—or experience. Because younger infants readily form simultaneous, intra-event associations, but older infants do not, for example, it is reasonable to conclude that their perception of what constitutes a single event differs. This possibility can be examined with the present paradigm by systematically decreasing the interval between two 30-min preexposure sessions on a single day and determining the shortest intersession interval at which infants of different ages continue to treat them as two discrete sessions. Because retention is dramatically longer after two sessions than after one, the point at which two sessions are perceived as one should be obvious. Because older infants process information more rapidly, it seems likely that they would tolerate a shorter intersession interval before treating two sessions as one. More generally, the SPC paradigm offers a unique opportunity to reveal what otherwise would remain the hidden learning of young infants.

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Footnotes

[1]In the socioeconomic index (SEI), the recommended source for occupational status, ranks of occupations range from 1-100, with higher-paying occupations (e.g., physician and lawyer) being assigned higher ranks.

[2] The pooled baseline control group at 6 months contained 45 infants (19 boys, 26 girls) who had participated in spontaneous baseline control groups in previous imitation studies with the same stimuli (Barr, Marrott, & Rovee-Collier, 2003; Barr, Rovee-Collier, & Campanella, 2005; Barr, Muentener, Garcia, Fujimoto, & Chavez, 2007; Barr et al., 2001, 2002; Campanella & Rovee-Collier, 2005; Learmonth, Lamberth, & Rovee-Collier, 2004). Infants' mean age was 195.7 days (*SD* = 8.30). They were Caucasian (*n* = 30), Asian (*n* = 6), African-American (*n* = 3), Hispanic (*n* = 3), and of mixed race (*n* = 3). Their parents' mean educational attainment was 15.6 years (*SD* = 1.20) and mean SEI was 72.26 (*SD* = 18.89).

The pooled baseline control group at 9 months contained 45 infants (19 boys, 26 girls) who had participated in spontaneous baseline control groups in previous imitation studies with the same stimuli (Barr, Marrott, & Rovee-Collier, 2003; Barr, Rovee-Collier, & Campanella, 2005; Barr, Muentener, Garcia, Fujimoto, & Chavez, 2007; Barr et al., 2001, 2002; Campanella & Rovee-Collier, 2005; Learmonth, Lamberth, & Rovee-Collier, 2004). Infants' mean age was 195.7 days (*SD* = 8.30). They were Caucasian (*n* = 30), Asian (*n* = 6), African-American (*n* = 3), Hispanic (*n* = 3), and of mixed race (*n* = 3). Their parents' mean educational attainment was 15.2 years (*SD* = 1.20) and mean SEI was 67.16 (*SD* = 15.99).

[3] The decision to administer two briefer sessions on a single day instead of two briefer sessions on 2 days was based on Barr et al.'s (2003) finding that 6-month-olds given two 1-hr preexposure sessions rarely attended to the paired puppets after the puppets had been exposed for 15 min in either session. Data from the Barr et al. study and unpublished data from our laboratory (Cuevas, Bullman, et al., 2008) indicated that 6-month-olds could form a simultaneous association between two puppets in less than 2 min.

Figure Captions

Figure 1. The six hand puppets, supported by wooden hat stand, that were used in experimental procedures. From left to right: The pink mouse, gray rabbit, black-and-white cow, yellow duck, pink rabbit, and gray mouse. Puppets were randomly assigned.

Figure 2. The timeline and the puppets used in Phases 1, 2, and 3 of Experiment 1.

Figure 3. The experimental arrangement used during a preexposure session (Phase 1), as pictured with a 6-month-old infant.

Figure 4. The experimental arrangement used during a deferred imitation test (Phase 3), as pictured with a 6-month-old infant.

Figure 5. The mean imitation test scores of independent groups of 6-month olds in Experiment 1. Featured in this graph are the mean imitation test scores of the 7-, 10-, 14-, and 16-day test delay groups. An asterisk indicates that a group's mean imitation test score was significantly higher than .013, the mean test score of the pooled, spontaneous production, baseline control group (dotted line).

Figure 6. The mean imitation test scores of independent groups of 9-month olds in Experiment 1. Featured in this graph are the mean imitation test scores of the 7-, 14-, and 18-day test delay groups. An asterisk indicates that a group's mean imitation test score was significantly higher than .025, the mean test score of the pooled, spontaneous production, baseline control group (dotted line).

Figure 7. The timeline and the puppets used in Phases 1, 2, and 3 of Experiment 2a.

Figure 8. The mean imitation test scores of independent groups of 6-month olds in Experiment 2a. Featured in this graph are the mean imitation test scores of the 2-, 3-, and 7-day test delay groups. An asterisk indicates that a group's mean imitation test score was significantly higher than .013, the mean test score of the pooled, spontaneous production, baseline control group (dotted line).

Figure 9. The mean imitation test scores of independent groups of 9-month olds in Experiment 2a. Featured in this graph are the mean imitation test scores of the 2- and 3-day test delay groups. An asterisk indicates that a group's mean imitation test score was significantly higher than .025, the mean test score of the pooled, spontaneous production, baseline control group (dotted line).

Figure 10. The timeline and the puppets used in Phases 1, 2, and 3 of Experiment 2.

Figure 11. The mean imitation test scores of independent groups of 6-month olds in Experiment 2b. Featured in this graph are the mean imitation test scores of the 7-, 14-, 21-, and 28-day test delay groups. An asterisk indicates that a group's mean imitation test score was significantly higher than .013, the mean test score of the pooled, spontaneous production, baseline control group (dotted line).

Figure 12. The mean imitation test scores of independent groups of 9-month olds in Experiment 2b. Featured in this graph are the mean imitation test scores of

the 7-, 14-, 21- and 28-day test delay groups. An asterisk indicates that a group's mean imitation test score was significantly higher than .025, the mean test score of the pooled, spontaneous production, baseline control group (dotted line).

Figure 13. The timeline and the puppets used in Phases 1, 2, and 3 of Experiment 3.

Figure 14. The mean imitation test scores of independent groups of 6-month olds in Experiment 3. Featured in this graph are the mean imitation test scores of generalization Groups 1, 2, and 3 (tested with S3), as well as their experimental counterparts (tested with S2) from preceding experiments. An asterisk indicates that a group's mean imitation test score was significantly higher than .013, the mean test score of the pooled, spontaneous production, baseline control group (dotted line).

Figure 1.

Figure 2.

24 hr

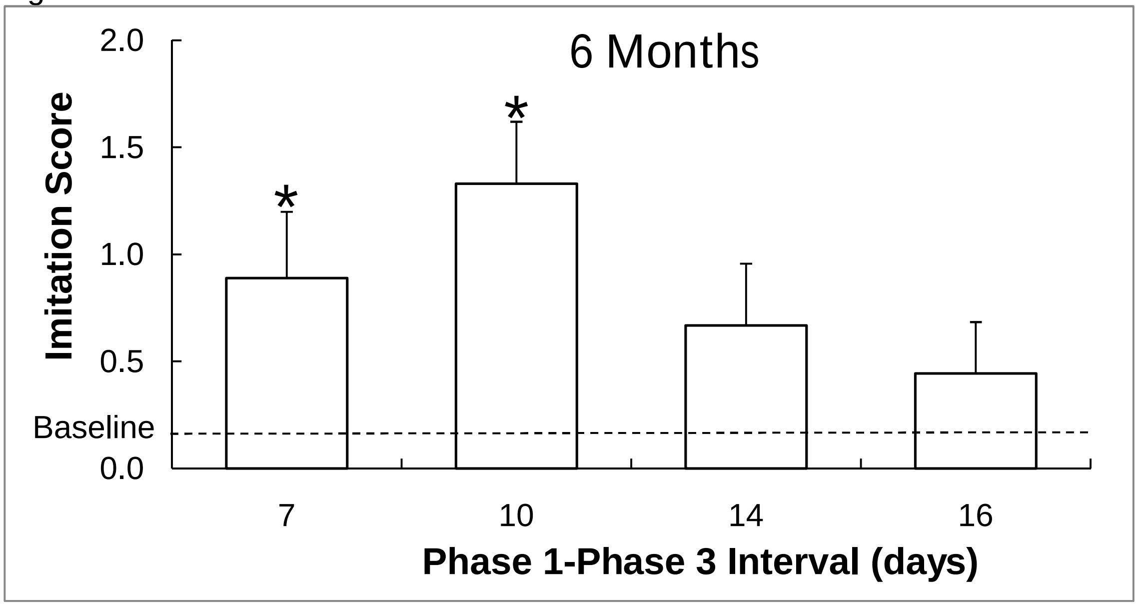
Phase 1	Phase 1-Phase 2 Interval	Phase 2	Phase 3
Preexposure to S1+S2 1 hr/ 2 days	**6-17 days**	Demonstration S1	Deferred Imitation Test S2

24 hr

Figure 3.

Figure 4.

Figure 5.



6 Months
Imitation Score
2.0
1.5
1.0
0.5
Baseline
0.0
*
*
7
10
14
16
Phase 1-Phase 3 Interval (days)

Figure 6.

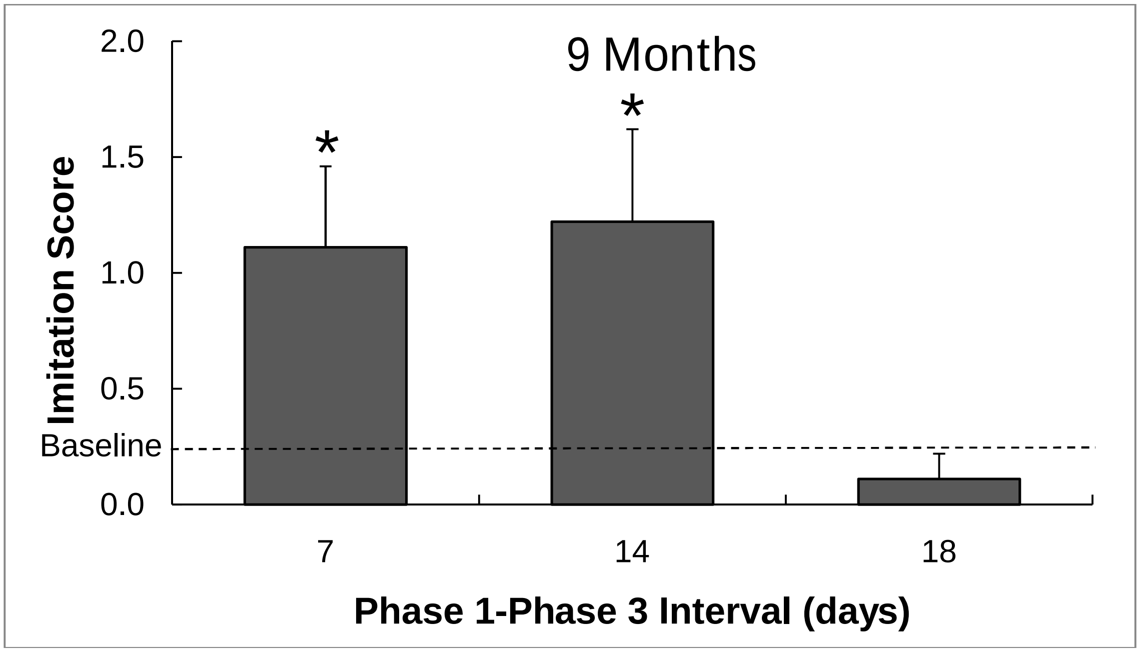

9 Months
Imitation Score
2.0
1.5
1.0
0.5
Baseline
0.0
*
*
7
14
18
Phase 1-Phase 3 Interval (days)

Figure 7.

Phase 1	Phase 1-Phase 2 Interval	Phase 2	Phase 3
Preexposure S1+S2 1 hr/1 day	**1-6 days**	Demonstration S1	Deferred Imitation Test S2

24 hr ⇨

Figure 8.

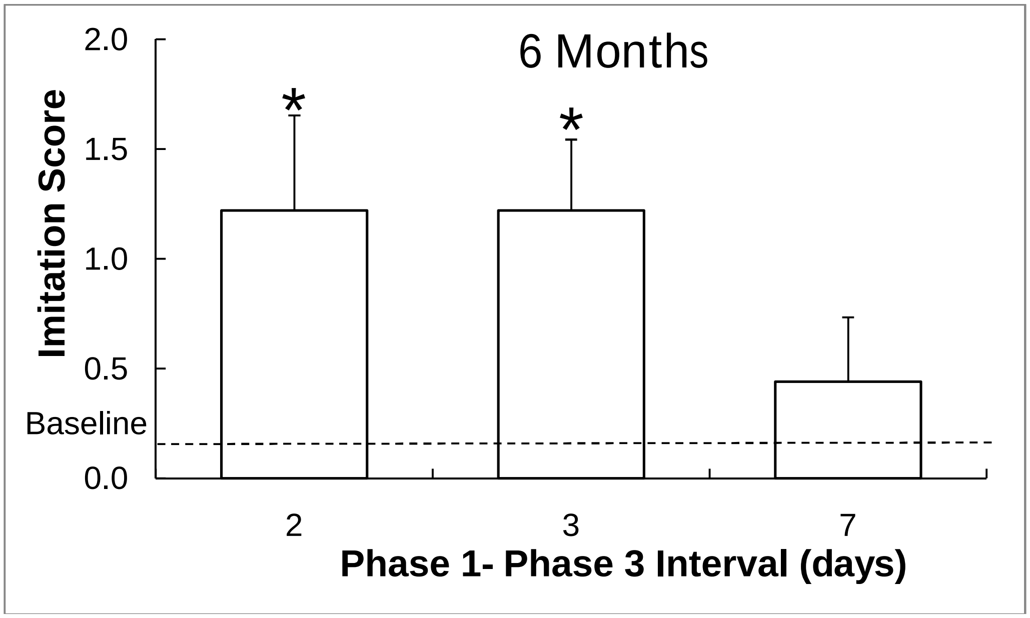
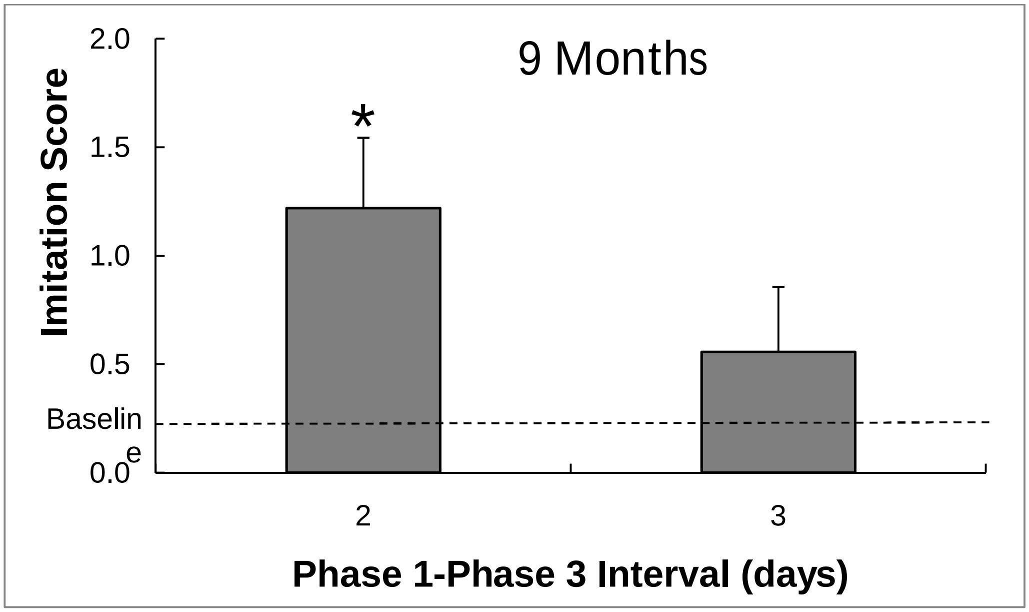

6 Months
Imitation Score
2.0
1.5
1.0
0.5
0.0
Baseline
*
*
2
3
7
Phase 1- Phase 3 Interval (days)

Figure 9.



9 Months
Imitation Score
2.0
1.5
1.0
0.5
Baseline
0.0
*
2
3
Phase 1-Phase 3 Interval (days)

Figure 10.

Phase 1	Phase 1-Phase 2 Interval	Phase 2	Phase 3
Preexposure S1+S2 1 hr/ (2) 30 min/1 day	**6-27 days**	Demonstration S1	Deferred Imitation Test S2

24 hr ⇨

Figure 11.

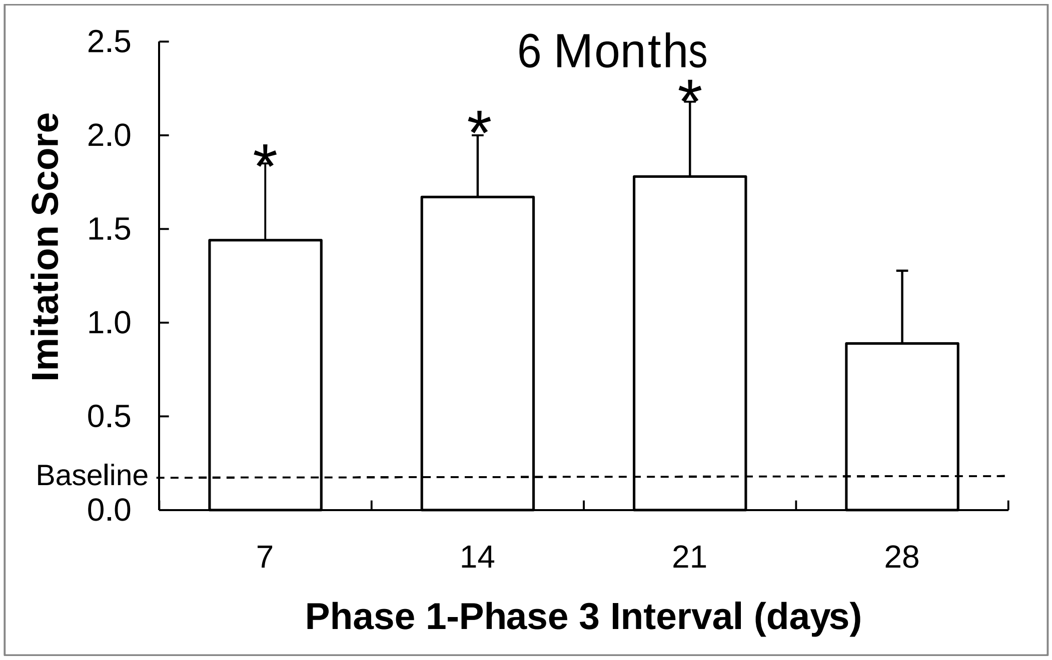

6 Months
Imitation Score
2.5
2.0
1.5
1.0
0.5
Baseline
0.0
*
*
*
7
14
21
28
Phase 1-Phase 3 Interval (days)

Figure 12.

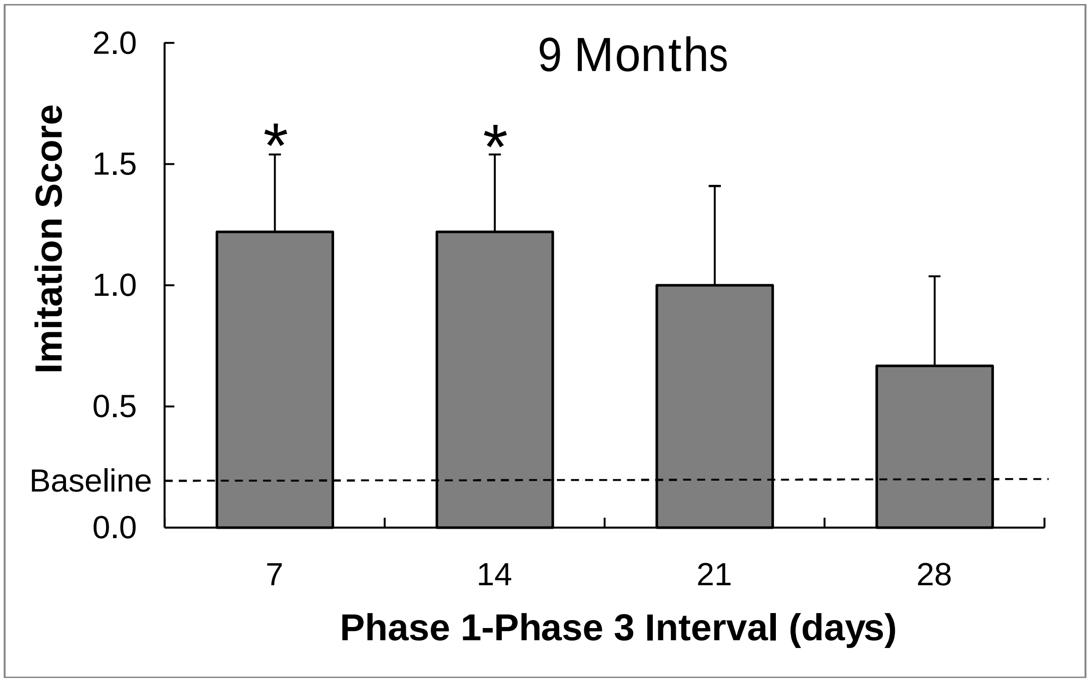
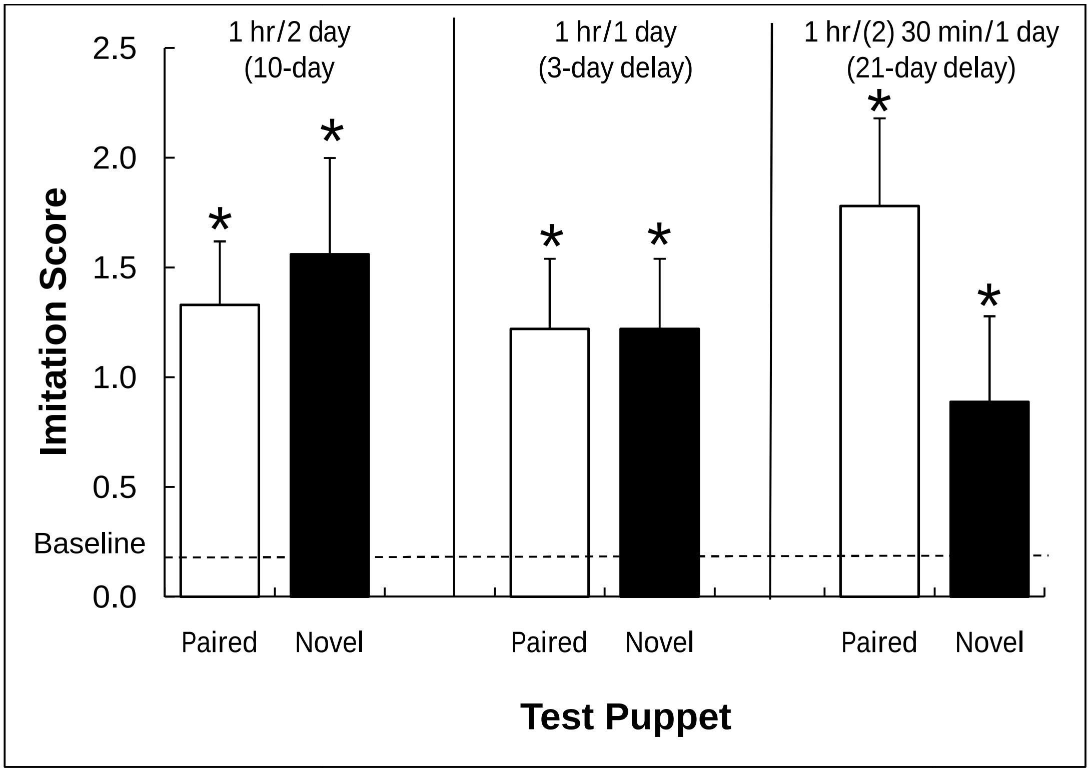

9 Months
Imitation Score
2.0
1.5
1.0
0.5
Baseline
0.0
*
*
7
14
21
28
Phase 1-Phase 3 Interval (days)

Figure 13.

Phase 1	Phase 1-Phase 2 Interval	Phase 2	Phase 3
Preexposure S1+S2 1 hr/ 2 day	**9 days**	Demonstration S1	Deferred Imitation Test S3
Preexposure S1+S2 1 hr/1 day	**2 days**	Demonstration S1	Deferred Imitation Test S3
Preexposure S1+S2 1 hr/(2) 30 min/1 day	**20 days**	Demonstration S1	Deferred Imitation Test S3

Figure 14.


1 hr/2 day
(10-day
1 hr/1 day
(3-day delay)
1 hr/(2) 30 min/1 day
(21-day delay)
Imitation Score
2.5
2.0
1.5
1.0
0.5
Baseline
0.0
Paired
Novel
Paired
Novel
Paired
Novel
Test Puppet

Appendix A

Preexposure Diary Form: Completed by caregiver administering preexposure

Puppet Diary

Please use the chart below to record details regarding your child's experience. Thank you for participating!

	Session 1	Session 2
Time of day puppets were shown to child		
Location in home that puppets were shown		
Description of child's actions while observing the puppets.		

- Place the puppets on display for 2 continuous 30-min sessions on:
- Please put the puppets away immediately following each session, and keep them hidden until we return.
- Allow your infant to view the puppets in the same room for both sessions.
- Please do not let your child touch or play with the puppets, and do not allow anyone else to touch or refer to the puppets in front of your child.
- Please separate Sessions 1 and 2 by at least 5 hours.

Please call with any questions or problems.

Laboratory (732) 445-4819

Amy's Cell Phone (908) xxx-xxxx

Appendix B

Sex, Race, Age (in days), and Imitation Score (IS). (6-month-olds, excluding standardized control).

Condition	S	Sex	Race	Age	IS
2d / 7dd	1	F	C	184	2
	2	F	M	179	0
	3	M	C	191	1
	4	M	C	193	0
	5	F	C	191	0
	6	M	C	187	1
	7	M	C	194	2
	8	F	AA	189	0
	9	F	C	180	1
2d / 10dd	1	M	C	199	1
	2	M	C	199	2
	3	F	C	212	0
	4	M	C	201	2
	5	F	C	212	0
	6	F	C	207	2
	7	F	C	182	2
	8	F	C	184	1
	9	F	C	184	2
2d / 14dd	1	M	C	192	1
	2	M	A	186	0
	3	F	C	187	0
	4	F	C	192	2
	5	F	C	186	0
	6	F	C	192	0
	7	M	C	186	2
	8	M	M	179	1
	9	F	C	190	0

Note: AA = African American; A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race.

Appendix B (continued)

Sex, Race, Age (in days), and Imitation Score (IS). (6-month-olds, excluding standardized control).

Condition	S	Sex	Race	Age	IS
2d / 16dd	1	F	C	186	0
	2	F	C	198	0
	3	M	M	181	0
	4	F	C	195	0
	5	F	C	186	0
	6	M	C	205	1
	7	M	C	190	2
	8	M	C	186	1
	9	F	C	195	0
1d / 2dd	1	M	AA	190	3
	2	M	AA	190	0
	3	F	C	189	0
	4	M	C	187	3
	5	M	C	187	2
	6	F	C	187	0
	7	M	C	198	0
	8	M	C	190	2
	9	F	C	192	1
1d / 3dd	1	M	C	183	0
	2	M	C	189	2
	3	M	C	197	2
	4	M	A	186	0
	5	F	C	181	2
	6	F	C	182	0
	7	F	C	191	2
	8	F	C	188	1
	9	M	C	185	2
1d / 7dd	1	M	C	184	2
	2	M	AA	182	2
	3	F	C	182	0
	4	M	C	182	0
	5	M	C	183	0

Appendix B (continued)

Sex, Race, Age (in days), and Imitation Score (IS). (6-month-olds, excluding standardized control).

Condition	S	Sex	Race	Age	IS
1d / 7dd	6	F	A	185	0
	7	M	O	191	0
	8	F	C	198	0
	9	M	C	191	0
1d ss / 7dd	1	M	A	182	2
	2	M	C	190	2
	3	F	C	185	2
	4	F	C	186	3
	5	F	AA	188	0
	6	F	C	181	1
	7	M	C	177	0
	8	M	C	193	3
	9	F	C	190	0
1d ss / 14dd	1	M	C	188	3
	2	F	C	190	2
	3	M	M	199	1
	4	F	A	189	2
	5	F	C	191	0
	6	F	C	191	1
	7	M	C	192	3
	8	M	M	183	2
	9	M	C	189	1
1d ss / 21dd	1	F	A	189	0
	2	F	C	184	2
	3	F	C	188	3
	4	M	C	184	2
	5	F	C	187	3
	6	M	C	183	3
	7	F	C	197	0
	8	M	H	197	1
	9	F	C	183	2

Note: AA = African American; C = Caucasian; H = Hispanic; M = Mixed Race; O = Other Race.

Appendix B (continued)

Sex, Race, Age (in days), and Imitation Score (IS). (6-month-olds, excluding standardized control).

Condition	<u>S</u>	Sex	Race	Age	IS
1d ss / 28dd	1	F	C	193	3
	2	F	H	190	2
	3	F	C	185	0
	4	M	C	186	0
	5	M	A	195	0
	6	F	C	194	1
	7	F	C	184	0
	8	M	C	187	2
	9	M	C	183	0
2d / 10 dd GEN	1	F	C	193	3
	2	F	H	190	0
	3	F	C	185	3
	4	M	C	186	2
	5	M	A	195	2
	6	F	C	194	0
	7	F	C	184	0
	8	M	C	187	1
	9	M	C	183	3
1d / 3dd GEN	1	F	C	185	2
	2	F	C	188	0
	3	M	C	185	0
	4	M	M	184	0
	5	M	M	194	1
	6	M	C	190	2
	7	M	C	189	2
	8	M	C	200	2
	9	M	H	196	2

Note: AA = African American; A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race; NA = Native American; O = Other Race.

Appendix B (continued)

Sex, Race, Age (in days), and Imitation Score (IS). (6-month-olds, excluding standardized control).

Condition	S	Sex	Race	Age	IS
1d ss / 21dd GEN	1	F	C	196	2
	2	F	C	196	0
	3	F	C	189	1
	4	F	C	195	1
	5	M	M	196	1
	6	M	M	183	0
	7	F	C	179	0
	8	F	C	179	1
	9	M	C	192	2

Note: AA = African American; A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race.

Appendix B (continued)

Sex, Race, Age (in days), and Imitation Score (IS). (9-month-olds, excluding standardized control).

Condition	S	Sex	Race	Age	IS
2d / 7dd	1	F	C	279	1
	2	M	M	281	3
	3	F	A	268	0
	4	F	O	280	1
	5	M	M	265	0
	6	M	A	280	2
	7	F	C	276	0
	8	F	H	274	2
	9	M	A	273	1
2d / 14dd	1	M	C	282	0
	2	M	C	286	2
	3	M	H	282	2
	4	M	C	280	2
	5	M	C	274	0
	6	F	C	278	2
	7	M	C	275	0
	8	F	M	287	0
	9	F	C	280	3
2d/ 18dd	1	F	C	271	0
	2	F	M	287	0
	3	M	C	278	0
	4	M	C	280	1
	5	F	C	279	0
	6	M	M	272	0
	7	F	C	275	0
	8	F	A	274	0
	9	M	C	280	0

Note: AA = African American; A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race; O = Other Race.

Appendix B (continued)

Sex, Race, Age (in days), and Imitation Score (IS). (9-month-olds, excluding standardized control).

Condition	S	Sex	Race	Age	IS
1d / 2dd	1	F	C	285	2
	2	F	C	277	2
	3	M	M	278	2
	4	M	C	290	3
	5	M	M	281	0
	6	M	C	280	0
	7	M	C	274	0
	8	M	M	290	1
	9	F	C	280	1
1d / 3dd	1	F	C	281	2
	2	M	AA	279	0
	3	F	AA	279	0
	4	F	AA	281	2
	5	M	C	291	0
	6	M	C	276	0
	7	M	C	289	1
	8	M	C	273	0
	9	F	C	286	0
2d/ 2dd UPCTRL	1	F	C	282	0
	2	M	C	273	1
	3	M	C	283	0
	4	M	C	271	0
	5	M	C	274	0
	6	M	M	273	2
	7	F	C	287	0
	8	F	C	280	0
	9	M	H	274	2

Note: AA = African American; A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race; O = Other Race.

Appendix B (continued)

Sex, Race, Age (in days), and Imitation Score (IS). (9-month-olds, excluding standardized control).

Condition	S	Sex	Race	Age	IS
1d ss/ 7dd	1	M	C	278	2
	2	M	C	273	0
	3	F	C	281	1
	4	M	C	284	1
	5	M	C	277	1
	6	F	A	275	3
	7	M	C	269	2
	8	F	M	281	0
	9	M	M	284	1
1d ss/ 14dd	1	M	C	280	3
	2	M	M	282	1
	3	M	C	280	1
	4	F	C	278	1
	5	M	H	276	2
	6	M	C	280	0
	7	F	C	287	2
	8	M	C	281	1
	9	M	AA	281	0
1d ss / 21dd	1	M	C	277	0
	2	M	C	286	3
	3	M	A	277	0
	4	M	C	272	0
	5	F	C	282	0
	6	M	H	273	2
	7	M	AA	276	2
	8	M	AA	276	2
	9	F	C	273	0

Note: AA = African American; A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race; O = Other Race.

Appendix C

Sex, Race, Age (in days), and Imitation Score (IS). (Standardized control: 6-month-olds).

Standardized Control	S	Sex	Race	Age	IS
	1	M	H	201	1
	2	F	C	201	0
	3	F	C	197	0
	4	M	C	184	0
	5	F	C	209	1
	6	F	AA	202	0
	7	M	A	200	0
	8	F	C	183	0
	9	M	C	178	0
	10	F	C	209	0
	11	M	C	202	0
	12	-	-	-	0
	13	-	-	-	0
	14	-	-	-	0
	15	-	-	-	0
	16	F	C	183	1
	17	F	C	193	0
	18	M	C	203	0
	19	F	A	210	1
	20	F	C	199	0
	21	F	AA	197	0
	22	F	-	197	0
	23	M	C	190	0
	24	F	C	220	0
	25	M	C	197	0
	26	M	C	190	0
	27	M	M	199	0
	28	F	A	205	0
	29	F	M	193	0
	30	F	M	203	0

Note: AA = African American; A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race.

Appendix D

Sex, Race, Age (in days), and Imitation Score (IS). (Standardized control: 9-month-olds).

Standardized Control	S	Sex	Race	Age	IS
	1	M	C	297	0
	2	F	C	290	0
	3	F	C	288	0
	4	M	C	292	1
	5	M	H	292	0
	6	M	C	-	0
	7	M	C	295	2
	8	F	C	293	0
	9	M	C	280	0
	10	M	C	289	0
	11	F	C	286	0
	12	M	C	279	0
	13	M	C	279	0
	14	M	A	278	1
	15	M	A	278	0
	16	F	M	286	0
	17	F	C	281	0
	18	F	C	286	0
	19	M	O	282	0
	20	F	C	294	2
	21	M	H	292	0
	22	M	C	273	0
	23	M	A	285	0
	24	F	C	295	0

Note: A = Asian; C = Caucasian; H = Hispanic; M = Mixed Race; Other Race.

Appendix E
Experiment 1: 6-Month-Olds, 1 hr/2 day SPC

ANOVA Table for Imitation Score (*p* < .05)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	4	11.256	2.814	6.799	.001*
Residual	61	25.244	.414		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
7d delay	9	.778	.833	.278
10d delay	9	1.333	.866	.289
14d delay	9	.667	.866	.289
16d delay	9	.444	.726	.242
Baseline Control	30	.133	.346	.063

Dunnett's *t* (> control, *p* < .025)

Delay Group	vs.	Mean Difference	*p* Value
7d delay	Baseline Control	.644	.020*
10d delay	Baseline Control	1.200	.001*
14d delay	Baseline Control	.533	.060
16d delay	Baseline Control	.311	.315

Appendix F
Experiment 1: 9-Month-Olds, 1 hr/2 day SPC

ANOVA Table for Imitation Score ($p < .05$)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	3	10.794	3.598	5.668	.002*
Residual	47	29.833	.635		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
7d delay	9	1.111	1.050	.351
14d delay	9	1.222	1.200	.401
18d delay	9	.111	.333	.111
Baseline Control	24	.250	.669	.212

Dunnett's *t* (> control, $p < .025$)

Delay Group	vs.	Mean Difference	*p* Value
7d delay	Baseline Control	.861	.012*
14d delay	Baseline Control	.972	.004*
18d delay	Baseline Control	-.139	.924

Appendix G
Experiment 2a: 6-Month-Olds, 1 hr/1 day SPC

ANOVA Table for Imitation Score (*p* < .05)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	3	13.411	4.470	7.692	.001*
Residual	53	30.800	.581		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
2d delay	9	1.222	1.301	.434
3d delay	9	1.222	.972	.324
7d delay	9	.444	.882	.294
Baseline Control	30	.133	.346	.063

Dunnett's *t* (> control, p < .025)

Delay Group	vs.	Mean Difference	*p* Value
2d delay	Baseline Control	1.089	.001*
3d delay	Baseline Control	1.089	.001*
7d delay	Baseline Control	.311	.339

Appendix H
Experiment 2a: 9-Month-Olds, 1 hr/1 day SPC

ANOVA Table for Imitation Score (*p* < .05)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	2	6.198	3.099	4.979	.012*
Residual	39	24.278	.623		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
2d delay	9	1.222	1.090	.364
3d delay	9	.556	.882	.294
Baseline Control	24	.250	.669	.212

Dunnett's *t* (> control, *p* < .025)

Delay Group	vs.	Mean Difference	*p* Value
2d delay	Baseline Control	.972	.003*
3d delay	Baseline Control	.306	.281

Appendix I
Experiment 2b: 6-Month-Olds, 1 hr/(2)30 min/1 day SPC

ANOVA Table for Imitation Score (*p* < .05)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	4	32.352	8.088	10.694	.001*
Residual	61	46.133	.756		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
7d delay	9	1.444	1.240	.412
14d delay	9	1.670	1.001	.333
21d delay	9	1.780	1.200	.400
28d delay	9	.889	1.170	.389
Baseline Control	30	.133	.346	.063

Dunnett's *t* (> control, *p* < .025)

Delay Group	vs.	Mean Difference	*p* Value
7d delay	Baseline Control	1.311	.001*
14d delay	Baseline Control	1.533	.001*
21d delay	Baseline Control	1.644	.001*
28d delay	Baseline Control	.756	.048

Appendix J
Experiment 2b: 9-Month-Olds, 1 hr/(2) 30 min/1 day SPC

ANOVA Table for Imitation Score ($p < .05$)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	4	10.572	2.643	3.187	.020*
Residual	55	45.611	.829		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
7d delay	9	1.222	.972	.324
14d delay	9	1.222	.972	.324
21d delay	9	1.001	1.225	.408
28d delay	9	.667	1.190	.373
Baseline Control	24	.250	.669	.212

Dunnett's *t* (> control, $p < .025$)

Delay Group	vs.	Mean Difference	*p* Value
7d delay	Baseline Control	.9722	.016*
14d delay	Baseline Control	.9722	.016*
21d delay	Baseline Control	.7500	.071
28d delay	Baseline Control	.4167	.353

Appendix K
Cross-Experiment Analysis

Unianova Table for Imitation Score (*p* < .05)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	2	6.222	3.111	3.706	.026*
Age	1	.448	.448	.534	.466
Delay	8	19.124	2.391	2.848	.005*
Group * Age	1	2.722	2.722	3.243	.073
Group * Delay	1	.056	.056	.066	.797
Age * Delay	4	1.819	.455	.542	.705
Group*Age*Delay	1	.222	.222	.265	.607

Dunnett's *t* (>control, *p* < .025)

Delay Group	vs.	Mean Difference	*p* Value
7d delay	Baseline Control	.644	.020*
10d delay	Baseline Control	1.200	.001*
14d delay	Baseline Control	.533	.060
16d delay	Baseline Control	.311	.315

Appendix L
Experiment 3: Specificity of the Memory of the Association at 6 Months: Group 1

ANOVA Table for Imitation Score ($p < .05$)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	2	19.561	9.781	18.579	.001*
Residual	47	43.250	.526		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
Group 1	9	1.556	.866	.444
Exp. 1 Test Group	9	1.333	1.33	.289
Baseline Control	30	.133	.346	.063

Dunnett's *t* (> control, *p* < .025)

Group	vs.	Mean Difference	*p* Value
Group 1	Baseline Control	1.422	.001*
Exp. 1 Test Group	Baseline Control	1.200	.001*

Student's *t* Test Table

df	*F* Value	*p* Value	*t* Value	Mean Difference	S.E. of Diff
16	4.010	.062	-.419	-.222	.530

Appendix M
Experiment 3: Specificity of the Memory of the Association at 6 Months: Group 2

ANOVA Table for Imitation Score (*p* < .05)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	2	13.339	6.669	16.155	.001*
Residual	47	31.917	.413		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
Group 2	9	1.222	.972	.717
Exp. 2a Test Group	9	1.222	.972	.717
Baseline Control	30	.133	.346	.063

Dunnett's *t* (> control, *p* < .025)

Group	vs.	Mean Difference	*p* Value
Group 1	Baseline Control	1.089	.001*
Exp. 2a Test Group	Baseline Control	1.089	.001*

Student's *t* Test Table

df	*F* Value	*p* Value	*t* Value	Mean Difference	S.E. of Diff
16	.001	1.000	.001	.000	.459

Appendix N
Experiment 3: Specificity of the Memory of the Association at 6 Months: Group 3

ANOVA Table for Imitation Score (*p* < .05)

	df	Sum of Squares	Mean Square	*F* Value	*p* Value
Group	2	19.756	9.878	22.324	.001*
Residual	47	39.667	.442		

Means Table for Imitation Score
Effect: Group

	n	Mean	S.D.	S.E.
Group 3	9	.889	.782	.261
Exp. 2b Test Group	9	1.778	1.20	.401
Baseline Control	30	.133	.346	.063

Dunnett's *t* (> control, *p* < .025)

Group	vs.	Mean Difference	*p* Value
Group 1	Baseline Control	.756	.001*
Exp. 2a Test Group	Baseline Control	1.644	.004*

Student's *t* Test Table

df	*F* Value	*p* Value	*t* Value	Mean Difference	S.E. of Diff
16	2.000	.176	1.860	.889	.478