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BRIEF REPORT

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The mobile conjugate reinforcement paradigm in a lab setting

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Abstract

The mobile conjugate reinforcement task was administered to 4-month-old infants in a lab rather than a home setting where it is usually administered. Learning and retention patterns were comparable to those of infants tested in their homes, suggesting flexibility in where this task can be administered. These results pave the way for this task to be used with a broader range of infants for whom home visits are not practical or convenient (e.g., infants in child care). Developmental research conducted with a more diverse population of infants would facilitate our understanding of cognitive development very early in life.

KEYWORDS
assessment methods, infancy, learning, memory development

1 | THE MOBILE CONJUGATE REINFORCEMENT PARADIGM IN A LAB SETTING

The mobile conjugate reinforcement paradigm (Rovee & Rovee, 1969) is well-established as a reliable and valid measure of learning and memory in young infants (Domsch, Lohaus, & Thomas, 2009; Haley, Grunau, Oberlander, & Weinberg, 2008; Rovee-Collier & Hayne, 2000). In this task, one end of a ribbon is tied around an infant's ankle and the other end is connected to a mobile hanging over his/her crib. Through experience with this set-up, the infant learns the contingency between kicking and movement of the mobile. After a delay, the task is repeated, and retention is measured by examining whether the infant kicks more during the retention phase than at baseline (i.e., spontaneous kicking prior to the learning trials; Rovee-Collier, 1997). Developmental research using the mobile conjugate reinforcement paradigm has demonstrated that both the speed of learning and length of retention increase with age, and the use of reactivation treatments can enhance retention across even longer periods of time (Greco, Rovee-Collier, Hayne, Griesler, & Earley, 1986; Rovee-Collier, 1997). For example, by around 4 months of age, the age of the sample in the current study, infants typically learn the contingency quickly and remember it after a 24-hr delay.

Given that this task is usually administered in the familiar environment of children's homes, little is known about its usefulness when administered outside the home, such as in a lab setting. Studies of context effects on this measure have indicated that when the environment stays constant across learning and retention sessions, infants demonstrate typical memory patterns. It is only when the context (e.g., visual, auditory, or olfactory cues) differs between learning and retention sessions that young infants demonstrate reduced retention (e.g., Fagen et al., 1997; Rubin, Fagen, & Carroll, 1998). However, it is possible that infants may demonstrate decreased learning and memory performance when tested in a novel environment (Acredolo, 1979). Testing in a novel environment may be associated with distractions that interfere with infant learning and memory performance. Infant attention may be drawn to the new surroundings rather than the mobile and the task. Responses to novelty may also be expressed as negative emotional reactions, such as crying and fussiness (Kagan, 1997), which have been associated with decreased performance on the mobile conjugate reinforcement task (Singer & Fagen, 1992), even when the procedure is extended to extra learning sessions.

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Having flexibility in terms of where the task is administered would allow it to be used in a broader set of studies and with a broader range of participants (e.g., Willoughby, Blair, Wirth, & Greenberg, 2010), including those for whom home visits are not practical. The use of this task to examine early cognitive development in a more diverse range of participants would potentially yield results that are more generalizable to a broader population. While existing work indicates that socioeconomic status (SES) does not have significant influence on infant operant learning (Gerhardstein, Dickerson, Miller, & Hipp, 2012), logistical constraints associated with variability in demographic factors related to SES, such as families with one parent or caregivers who work outside the home, as well as significant variability in home environments that may preclude valid testing procedures and/or introduce "noise" into the data collection, may make home testing not possible or optimal. Accordingly, samples that only use this protocol in the home may not include a full spectrum of families and infants. Yet, to date, this task has almost exclusively been administered to infants in their homes. An exception is a study in which infants were tested on a contingent learning task using arm movements in a lab setting (Sullivan & Lewis, 1989). Results indicated a similar pattern of learning as compared to studies that have administered the mobile conjugate reinforcement paradigm in a home setting. No mention of the effect of the lab setting was made. As such, the goal of the present research was to investigate the performance of 4-month-old infants on the mobile conjugate reinforcement paradigm in a lab setting. Results were compared to those of previous studies to evaluate how closely they resembled learning and memory patterns of same-aged children tested in their homes.

2 | METHODS

As part of a longitudinal study in the northeastern region of the United States, healthy pregnant adolescents were recruited through a university-based medical center. Exclusion criteria included a lack of fluency in English, multiparity, or frequent use of nitrates, steroids, beta blockers, triptans, or psychiatric medications. Adolescents were also excluded for cigarette smoking or use of recreational drugs as assessed through self-report and one random urine toxicology screen. Mothers signed informed consents for their infants to participate in the study. All research procedures were approved by the Institutional Review Board of the university. Participants were 42 infants (19 male; 90% Hispanic/Latino) who ranged in age from 3.56 to 5.0 months (M = 4.26, SD = .52). Maternal age at infant birth ranged from 14.92 to 20.33 years (M = 18.58, SD = 1.39). Gestational age at birth ranged from 36.43 to 41.43 weeks (M = 39.52, SD = 1.22), and birth weight ranged from 2,475.00 to 4,250.00 g (M = 3,237.88, SD = 474.61). Eight additional infants were tested but excluded from analyses because they did not complete all of the learning periods or the short-term retention period on Day 1 due to crying, fussiness, or fatigue. This level of attrition is consistent with levels reported in previous studies (e.g., Gross, Hayne, Herbert, & Sowerby, 2002). There were no differences in age, sex, birth weight, or gestational age between infants who completed and did not complete the task.

Following the standard set-up matched to the age range of the infants in this study (Rovee-Collier, 1997; Rovee-Collier, Hartshorn, & DiRubbo, 1999), a seat was placed in a plain wooden crib to ensure that the infant did not roll over during the task and to guide attention to an overhead mobile with four brightly painted animals hanging from strings. The mobile was hanging from one of two L-shaped metal brackets above the lower portion of the crib, and the lowest animal figure was about 7 inches above the mattress. All of the objects on the mobile were within the infant's line of sight. Throughout testing, one end of a ribbon was tied around the infant's left or right ankle and the other end was attached to one of the metal brackets. The ribbon was taut so that a kick would promptly jiggle the overhead mobile when it was hanging from the connected bracket. Thus, infants could easily move their legs in the air and kick with immediate feedback.

Mothers brought their children to the lab on two consecutive days. Upon arrival, the mother was instructed to briefly play with her child as she usually does at home to help the infant become comfortable in the novel setting. Then, the infant was placed inside the seat located inside the crib to start the mobile conjugate reinforcement task, which was videotaped and the same on both days. Each 15-min session began with a 3-min non-reinforcement phase (baseline), followed by a 9-min reinforcement phase (three 3-min learning blocks), and a final 3-min non-reinforcement phase (immediate retention). During periods of non-reinforcement, the other end of the ribbon that was tied to the infant's ankle was attached to the metal bracket without the mobile hanging from it. In this arrangement, the mobile remained in full view, but any movement of the leg with the ribbon on it had no effect on the mobile. During periods of reinforcement, the mobile was moved to the same bar as the ribbon. Thus, kicking the leg with the ribbon attached to it caused the mobile to bounce. On Day 1, the initial 3-min period of non-reinforcement (baseline) provides a measure of the infant's baseline kick rate, and the final 3-min period of non-reinforcement provides a measure of the infant's immediate retention. On Day 2, kicking during the initial period of non-reinforcement (Day 2 baseline) reflects the infant's long-term (24-hr) retention of the contingency.

Trained coders used the videotapes to count the number of times per minute that an infant kicked the leg with the ribbon attached to it. A kick was defined as a linear or circular movement of the foot and leg retraced in a continuous motion back to the point of origin (Angulo-Kinzler, Ulrich & Thelen, 2002; Rovee & Rovee, 1969). A second trained coder independently coded 20% of the sessions. Inter-rater reliability was high (Spearman rank correlation = .95; range: .88–.99).

TABLE 1 Descriptive statistics for kicking rate (times/minute) and baseline ratio scores on the mobile conjugate reinforcement paradigm

	Kicking rate					Baseline ratio scores			
	N	*M*	SD	Range	Significance test[a]	*M*	SD	Range	Significance test[b]
Baseline	42	4.84	4.80	1–21	–	–	–	–	–
Learning block 1	42	7.68	5.96	1–16	$t(41)$ 4.27, $p < .001$	2.62	3.36	.15–16.6	$t(41) = 2.17$, $p = .04$
Learning block 2	42	11.32	9.51	1–38	$t(41)=5.09$, $p < .001$	4.56	8.63	.30–52.3	$t(41) = 2.30$, $p = .03$
Learning block 3	42	11.79	8.50	1–31	$t(41) = 6.94$, $p < .001$	4.84	7.37	.30–31.7	$t(41) = 2.94$, $p = .005$
Immediate retention	37	9.37	6.85	1–28	$t(36) = 4.87$, $p < .001$	5.75	13.08	.17–38.4	$t(36) = 3.25$, $p = .002$
Long-term retention	42	6.05	4.97	1–20	$t(41) = 2.56$, $p = .014$	3.07	5.52	.09–10.9	$t(41) = 2.43$, $p = .02$

[a]Mean kick rate during learning/retention blocks compared to baseline kick rate (paired *t* tests).
[b]Mean baseline ratio compared to 1.50 for learning blocks; compared to 1.00 for retention assessments (one-sample *t* tests).

3 | RESULTS

Demographics (age, sex, race/ethnicity) and birth variables (birth weight, gestational age) were not significantly associated with learning, immediate retention, or long-term retention ratio scores and thus were not controlled for in analyses. Kicking rate data were examined for outliers, defined as values greater than 2.5 standard deviations (SDs) from the mean. Each outlier was replaced with the highest respective value within 2.5 SDs from the mean. After Winsorizing, kicking data were normally distributed.

To assess learning, a repeated measures analysis of variance with Day 1 testing period (baseline, learning block 1, learning block 2, learning block 3) as the within-subjects factor was conducted on the mean number of kicks per minute. Results indicated a main effect for testing period, $F(3, 123) = 23.48$, $p < .001$, $\eta_p^2 = .36$. Mean kick rate during all three learning blocks was significantly higher than mean kick rate during baseline (see Table 1). Learning is also evaluated in terms of whether the ratio of kick rate during each learning block to baseline kick rate is ≥1.50 (the learning criterion is the same for all ages tested; Gross et al., 2002; Rovee-Collier, 1997). In total, 57%, 71%, and 71% of the infants had ratio scores ≥1.50 during learning blocks 1, 2, and 3, respectively. Nine infants showed increases in kicking during the learning blocks but the increases did not meet the critical value.

In analyses of immediate retention, mean kick rate during the immediate retention phase was significantly higher than mean kick rate during baseline (see Table 1). Also, the baseline ratio was calculated by dividing the mean kick rate during each retention block (either immediate or long-term retention) by the mean kick rate during Day 1 baseline. The mean baseline ratio for the immediate retention block significantly exceeded 1.00, which is the critical value (Gross et al., 2002; Hayne, Gross, Hildreth, & Rovee-Collier, 2000; Schroers, Prigot, & Fagen, 2007). In addition, 86% of infants had baseline ratio scores >1.00 during the immediate retention phase.

The mean kick rate during the long-term retention period (Day 2 baseline) was significantly higher than the mean kick rate during Day 1 baseline. Similarly, the mean baseline ratio for the long-term retention block significantly exceeded 1.00 (see Table 1). Also, 69% of infants had baseline ratio scores >1.00 for the long-term retention block. A retention ratio is traditionally used to evaluate forgetting from Day 1 immediate retention to Day 2 long-term retention. It is calculated by dividing infant kick rate during the long-term retention period by infant kick rate during the immediate retention period on Day 1. Retention ratios ≥1.00 indicate complete retention, while ratios <1.00 indicate partial retention. For this sample, the mean retention ratio was .84 (SD = 1.07), which did not differ significantly from 1.00, one-sample $t(36) = -.91$, *ns*.

To supplement these results, immediate and long-term retention data were re-analyzed using only infants who met the learning criterion (79% of the sample; Rovee-Collier, 1997). Mean kick rate during immediate retention was significantly higher than mean kick rate during baseline, paired $t(29) = 4.92$, $p < .001$. The mean kick rate during long-term retention was higher than mean kick rate during baseline, paired $t(32) = 1.91$, $p = .07$. Six infants who did not reach learning criterion (but increased their kicking during learning) showed long-term retention. Finally, we re-ran all analyses excluding infants <37 weeks and/or <2,500 g at birth, older than 5 months, and who did not complete immediate retention on Day 1. Results were the same.

4 | DISCUSSION

The goal of this study was to determine whether learning and retention patterns of 4-month-old infants tested on the mobile conjugate reinforcement paradigm in a lab setting paralleled such patterns in previous studies conducted in home settings. In this study, attrition was not different compared to previous studies (Gross et al., 2002; Haley et al., 2008); most infants were able to complete the task even though it was administered in the lab. Infants showed strong learning and retention of the contingency between kicking and movement of the mobile, similar to results of previous studies of infants in this age range (Rovee-Collier, Schechter, Shyi & Shields, 1992). Specifically, the majority of infants learned the contingency and retained it over a 24-hr delay.

Typically, this task has been administered to infants in their homes to reduce the possibility that negative reactions to a novel environment might interfere with task performance. Context has been found to be important in studies using the mobile conjugate reinforcement task, especially for younger infants. Changes in infants' surroundings from learning to retention periods can reduce their ability to retain information (e.g., Fagen et al., 1997; Rubin et al., 1998). We compared our findings to Rovee-Collier, Patterson, and Hayne (1985) who tested infants in a home setting using the same kind of mobile and the same procedure. Comparing the two studies, mean kicking rate during learning trials differed by around three kicks in two of the learning blocks; the other blocks showed smaller differences. Our findings indicate that infant learning and retention can be reliably assessed in a novel (lab) environment when it is kept constant between learning and retention periods.

Although the infants in our study had adolescent mothers, often an at-risk group, they were a healthy group with the majority having normal birth circumstances. Thus, results for learning and retention are consistent with other studies examining children without any birth complications (e.g., Rovee-Collier et al., 1985; Shields & Rovee-Collier, 1992). Future research should examine whether infants tested in a lab setting demonstrate retention of the contingency over longer intervals (e.g., 4–5 days) and whether this ability increases with age.

This study has some limitations that should be taken into account when interpreting the results. Although we had a low attrition rate, it is not known how the inclusion of those infants would have affected the results. Also, previous studies using the conjugate kicking procedure have laid young infants flat on their backs in the crib; however, a seat is often used either to keep infants from rolling over during the procedure (rolling from back to belly occurs around 5 months of age) or to implement a reactivation component and minimize random kicking activity (a desirable effect that potentially minimizes noise in the data; see Rovee-Collier, 1997). The use of a seat in this study was not observed to make kicking difficult for infants. Nonetheless, results should be interpreted keeping in mind seat use during task administration in the present and other studies with younger and older infants.

The mobile conjugate reinforcement paradigm is feasible within months of birth, thus making it one of the earliest behavioral tools that can be used to examine learning and memory development. Findings from this study suggest that this task can be administered to infants in contexts beyond just home settings without biasing infant performance. Thus, these results pave the way for this task to be used with a broader range of infants for whom home visits are not practical or convenient (e.g., infants in child care). Developmental research conducted with a more diverse population of infants would facilitate our understanding of cognitive development very early in life, a goal we share with Carolyn Rovee-Collier and her colleagues (Fagen, Ohr, & Boller, 2016).

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