

Reinstatement versus Reactivation Effects on Active Memory in Infants

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Reinstatement and reactivation are procedurally different reminder paradigms used with infants and children, but most developmental psychologists do not distinguish between them. In 4 experiments with 102 three-month-olds, we asked if they differ functionally as well. Independent groups of infants received either a reactivation or a reinstatement reminder 3 days after training, when the memory is active, but its specific details have been forgotten. In Experiment 1, we measured retention after increasing delays until infants forgot altogether. A single reinstatement protracted retention twice as long after training as a single reactivation. In Experiments 2–4, whether the reminder was the original training stimulus or a novel one differentially affected the duration and specificity of memory in the 2 procedures as well. These data demonstrate that the distinction between reinstatement and reactivation is not artificial. In addition to differing procedurally, reinstatement and reactivation differ functionally, with different memory-preserving effects. © 2000 Academic Press

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Two reminder paradigms that are increasingly used in memory studies with infants and young children are reinstatement and reactivation. Whereas reactivation has been used primarily with infants between 2 and 18 months of age (Barr, 1997; Davis & Rovee-Collier, 1983; Fagen & Rovee-Collier, 1983; Hildreth & Rovee-Collier, 1999; Hill, Borovsky, & Rovee-Collier, 1988; Rovee-Collier, Sullivan, Enright, Lucas, & Fagen, 1980; Sheffield & Hudson, 1994), reinstatement has primarily been used with preschool- and school-aged children (Hoving & Choi, 1972; Hoving, Coates, Bertucci, & Riccio, 1972; Howe, Courage, & Bryant-Brown, 1993; Priestley, Roberts, & Pipe, 1999). Despite the

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fact that these reminder paradigms are procedurally quite different, both reminders protract retention so that it is exhibited after delays not otherwise possible, and most developmental psychologists do not distinguish between them (e.g., Howe et al., 1993; Hudson & Sheffield, 1998; Mandler, 1998). Howe et al. (1993) wrote, for example, that "the distinction between reinstatement and reactivation is . . . artificial in that both . . . have similar (if not the same) memory-preserving effects" (p. 855). Whether these two reminder procedures are really functionally equivalent, however, has never been investigated.

Campbell and Jaynes (1966) originally introduced the reinstatement paradigm, defining it as "a small amount of partial practice or repetition of an experience . . . which is enough to maintain an early learned response at a high level, but is not enough to produce any effect in animals which have not had the early experience" (p. 478). In their seminal study with weanling rat pups, they conditioned fear of the black side of a shuttle box by administering 30 inescapable shocks there while intermittently exposing the pups to the white (no shock, or safe) side. Over the next month, they gave half of the pups 3 shocks in the black side of the box as reminders—one on Day 7, one on Day 14, and one on Day 21—while they gave the other half of the pups no periodic reminders. During the long-term retention test on Day 28, they placed all pups on the black side of the box with the door open to the white side. The pups that had received periodic reminders spent significantly more time on the white than on the black side of the box, indicating retention of their conditioned fear, but the pups that had received no intervening reminders exhibited no retention of their conditioned fear, spending more time on the black (preferred) side. In addition, pups who had not been trained as weanlings but who had subsequently received the 3 periodic shocks also spent more time on the black side of the box during the test, confirming that the 3 periodic pairings of the shock and the black side of the box were insufficient to establish new learning.

Spear and Parsons (1976) also conditioned fear in weanling rats by pairing a flashing light (the conditional stimulus, or CS) with a shock in the white compartment of a shuttle box for 30 trials. During the long-term retention test, also given 28 days later, they placed rat pups in the white side of the box, lowered the partition separating the two compartments so that it formed a hurdle, and turned on the CS. By crossing the hurdle, the rat pups could escape from the white side and turn off the CS. Spear and Parsons distributed six reminders throughout the retention interval, and the test followed the last reminder by 4 days. However, they used four different reinstatement conditions—a complete conditioning trial (a CS–shock pairing), reexposure to the white compartment, reexposure to the white compartment and the CS, and reexposure to the shock in a different apparatus. Because so much new learning occurred during the six complete conditioning trials, the retention test data from this condition were uninterpretable. Of the remaining reinstatement conditions, the periodic shocks were highly effective, whereas the other reminders were no more effective than no reminders at all.

To test the possibility that the reinstatement effect resulted because periodic reexposures allowed the rapidly growing rat pups to perceptually accommodate to the conditioning situation, Spear and Parsons exposed another group to a single shock 24 h before the 28-day test—a procedure designed to eliminate any possibility of perceptual accommodation. As it turned out, exposing pups to a single shock at the end of the retention interval was as effective as exposing them to periodic shocks throughout the retention interval. To distinguish this procedure from the reinstatement paradigm, they referred to it as a “reactivation paradigm.”

The latter finding by Spear and Parsons suggested that the reinstatement and reactivation paradigms may have an equivalent effect on retention despite the procedural differences between them. In two recent studies with human infants, however, presenting a single reinstatement reminder at the end of a 3-week retention interval did not alleviate the forgetting of either 2-month-olds (Rovee-Collier, Hartshorn, & DiRubbo, 1999) or 3-month-olds (Galluccio & Rovee-Collier, in press), whereas presenting a single reactivation reminder after the same delay did. These studies led us to question whether these two reminder procedures truly are functionally equivalent. The present experiments were designed to answer this question.

EXPERIMENT 1: RETENTION AFTER A REMINDER

Although we have repeatedly found that a reactivation reminder can recover a memory after it has become inactive, on the two occasions when we presented either a single reactivation reminder or a single reinstatement reminder to 2- and 3-month-olds after the memory was inactive, the reactivation reminder alleviated forgetting, but the reinstatement reminder did not (Galluccio & Rovee-Collier, in press; Rovee-Collier et al., 1999). Because Campbell and Jaynes (1966) had shown that reinstatement *maintains* a memory throughout a long retention interval, whereas Spear and Parsons (1976) had demonstrated that reactivation *recovers* the memory after it was forgotten, we speculated that for a reinstatement reminder to be effective, the memory might have to be active when it is presented. In studies of reinstatement, multiple reminders are periodically presented throughout a retention interval. Presumably, each reinstatement reminder maintains the memory in an active state until the succeeding reinstatement reminder is presented, which again boosts the memory and keeps it active until the next reinstatement reminder is presented, and so forth—like periodically throwing a new log on a fire.

In Experiment 1, therefore, we asked whether reactivation and reinstatement reminders protract retention equivalently if they are presented when the memory is active. To answer this, we presented 3-month-olds with either a single reinstatement reminder or a single reactivation reminder of the same duration 3 days after training, when the memory is active (Rovee-Collier, Adler, & Borza, 1994; Rovee-Collier & Sullivan, 1980), and assessed how long each protracted retention. Because a reinstatement treatment presents the full complement of

training cues, whereas a reactivation treatment presents only a fraction of the same cues, we expected that a single reinstatement reminder would be as effective as a single reactivation reminder at the very least. Therefore, we began measuring the retention of infants who were given a reinstatement reminder at the point when infants who were given a reactivation reminder no longer exhibited any retention. If the two reminders are functionally equivalent, then infants' rate of forgetting after a single reinstatement reminder and their rate of forgetting after a single reactivation reminder should be the same. In all studies, we operationally defined "forgetting" as a failure to respond significantly above baseline on the long-term test and "recognition" as responding significantly above baseline on the long-term test.

Method

Participants. Forty-eight 3-month-olds (28 boys, 20 girls) with a mean age of 94.6 days ($SD = 7.5$) on their first day of training were recruited from published birth announcements in local newspapers and randomly assigned to six experimental and two control groups ($n = 6$) as they became available for study. Infants were Caucasian ($n = 42$), Hispanic ($n = 1$), and not reported ($n = 5$). Their parents' mean educational attainment was 15.88 years ($SD = 0.50$), and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 66.33 ($SD = 20.14$). (Demographic information was available from 37.5% of the sample.) Additional infants were excluded from the final sample for failing to meet the learning criterion ($n = 3$), inattention ($n = 1$) or crying ($n = 3$) longer than 2 min in any of the four sessions, and equipment failure ($n = 1$).

Apparatus. Infants were trained with one of three highly detailed, hand-painted wooden mobiles composed of five objects (Nursery Plastics, Models 801, 804, and 809) and five 1/2-in. silver jingle bells. The mobiles were counterbalanced within groups. During each session, the mobile was hung from an aluminum L-shaped stand (BCS Machine Co., South Plainfield, NJ) clamped to the crib rail nearest the experimenter. An identical "empty" stand was clamped to the opposite rail, so that the suspension bar of each stand protruded over the infant's lower abdomen. A white ribbon, tied to the infant's ankle, was connected without slack to one of the suspension bars, depending on the phase of the session.

Procedure. Training took place in the infant's home crib at a time when the infant was likely to be playful. This time varied across infants but remained constant across all sessions for a given infant. All infants received two 15-min training sessions 24 h apart and a long-term retention test 7, 9, 14, 16, or 18 days later. The experimental groups received a single 3-min reminder 3 days after training was over, and the control groups received the same 3-min reminder immediately after training was over.

Each training session began with a 3-min nonreinforcement phase during which the mobile was suspended from one stand and the ankle ribbon was connected to the other. In this arrangement, the mobile was in view, but the infant was unable to move it by kicking. In Session 1, this was the *baseline phase*

during which the infant's unlearned kick rate (operant level) was measured. Next followed a 9-min reinforcement phase (*acquisition*) during which the ankle ribbon was connected to the same stand as the mobile. In this arrangement, kicks moved the mobile with an intensity commensurate with their rate and vigor ("conjugate reinforcement"). Finally, each session ended with a 3-min nonreinforcement period. At the end of Session 2, this was an *immediate retention test* during which the infant's final level of learning (kick rate) was measured. To qualify for the long-term retention test, infants were required to kick at a rate 1.5 times their baseline rate during 2 of 3 consecutive min during acquisition (the learning criterion). The *long-term retention test* was another 3-min nonreinforcement phase, identical to the baseline phase and the immediate retention test, when the infant's kick rate was measured again. Immediately after the long-term test, reinforcement was reintroduced as a motivational control procedure to ensure that infants who had responded poorly during the test were not ill, tired, or unmotivated on that particular day. None were—all responded to the contingency.

Infants in the experimental groups received a brief (3-min) reminder—either a reactivation or a reinstatement reminder—3 days after training was over. During the *reactivation reminder*, the ribbon was detached from the infant's ankle, but the other end was still connected to the same stand as the mobile. It was held by the experimenter, who pulled it to move the mobile noncontingently at the same rate that the infant had kicked to move the mobile during the last 3 min of acquisition in Session 2. During the *reinstatement reminder*, the ribbon was again strung from the infant's ankle to the mobile, as during training, so that kicks conjugately moved the mobile. When the 3 min timed out, the mother removed the infant from the crib, and the reminder treatment was over. Groups receiving a reactivation (*react*) reminder were tested either 7 or 9 days after training; groups receiving a reinstatement (*rein*) reminder were tested 9, 14, 16, or 18 days after training.

The reactivation and reinstatement control groups received the reminder immediately after the end of Session 2 and were tested 7 days later. These groups were included to ensure that infants' subsequent test performance was not simply due to their 3 additional min of familiarization with the reinforcer or overtraining, respectively.

Retention Measures

Retention was assessed in terms of two individual measures of relative responding that we have used in all previous studies of infant memory. The primary measure, the *baseline ratio*, is computed by dividing each infant's kick rate during the long-term retention test (LRT) by that same infant's baseline kick rate (B): LRT/B . A mean baseline ratio significantly greater than a theoretical population baseline ratio of 1.00 indicates significant retention (i.e., test performance above operant level). Conversely, a mean baseline ratio not significantly above 1.00 indicates no retention (i.e., test performance at the baseline level).

TABLE 1

Mean Baseline (BASE) and Immediate Retention (IRT) Kick Rates, Mean Baseline Ratios (BR), Mean Retention Ratios (RR), and Standard Errors (SE) of Groups in Experiment 1

Remind/test day	<i>M</i> BASE (<i>SE</i>)	<i>M</i> IRT (<i>SE</i>)	<i>M</i> BR (<i>SE</i>)	<i>M</i> RR (<i>SE</i>)
Reinstatement reminder				
rein/9	7.17 (1.57)	15.00 (2.88)	2.20 (0.41) ^a	0.88 (0.17)
rein/14	4.28 (0.68)	19.17 (2.68)	2.20 (0.31) ^a	0.60 (0.13) ^b
rein/16	10.89 (2.58)	20.95 (2.82)	0.62 (0.08)	0.32 (0.05) ^b
rein/18	10.73 (1.63)	22.17 (3.62)	1.15 (0.44)	0.36 (0.10) ^b
rein-con/7	5.01 (1.09)	21.12 (5.08)	0.80 (0.18)	0.27 (0.09) ^b
Reactivation reminder				
react/7	8.61 (1.80)	23.22 (5.17)	1.93 (0.04) ^a	0.74 (0.09) ^b
react/9	7.28 (1.89)	16.00 (2.89)	1.29 (0.21)	0.57 (0.10) ^b
react-con/7	7.67 (0.99)	13.50 (0.79)	1.14 (0.15)	0.65 (0.03) ^b

^a *M* BR significantly > 1.00 (significant retention).

^b *M* RR significantly < 1.00 (significant forgetting).

The baseline ratio indicates whether or not a group exhibits retention, but it is not informative about the degree of retention. This information is provided by the *retention ratio*, which is computed by dividing an individual infant's response rate during the long-term retention test by that same infant's response rate during the immediate retention test (IRT): LRT/IRT. The retention ratio describes the proportion of an infant's immediate retention (after zero delay) that still remains at the end of the retention interval. A retention ratio of 1.00 or greater indicates that performance did not decline over this period. A retention ratio significantly less than a theoretical population retention ratio of 1.00 indicates that significant forgetting took place over the retention interval. The degree of forgetting can be either partial (if the mean baseline ratio is significantly > 1.00) or complete (if the mean baseline ratio is not significantly > 1.00).

Prior to performing all analyses, we tested the baseline and retention ratios of each group for outliers. An outlier, defined as a ratio falling above the 90th percentile for a given group, was replaced with the next lowest baseline ratio or retention ratio within that group, and 1 *df* was subtracted (Tukey, 1977). None of the outlier corrections altered the outcome of any *t* test.

Results and Discussion

Separate one-way analyses of variance (ANOVAs) over the mean kick rates of the eight groups during the baseline phase and the immediate retention test yielded no significant differences either before training, $F(7, 40) = 2.13$, *ns*, or immediately afterward, $F(7, 40) = 1.06$, *ns* (see Table 1). Thus, any subsequent

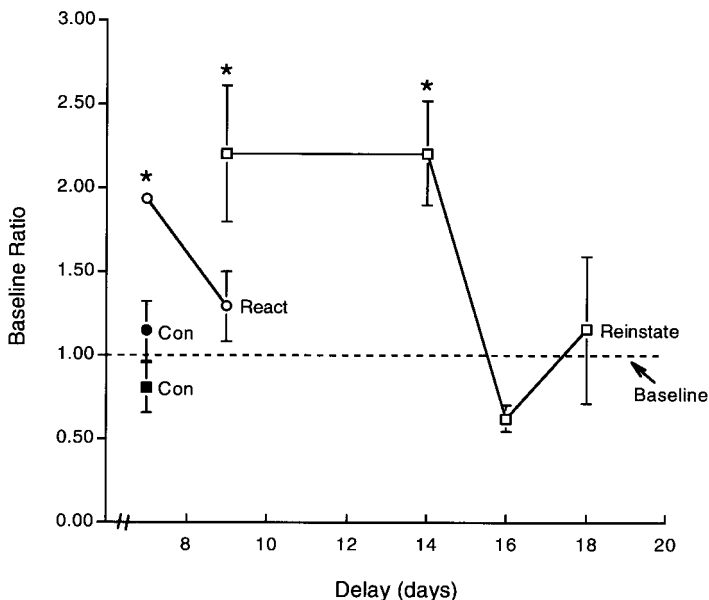


FIG. 1. Mean baseline ratios of independent groups of 3-month-old infants who received either a reactivation reminder (*open circles*) or a reinstatement reminder (*open squares*) 3 days after training and a long-term retention test 7 to 18 days after training. The reactivation control group (*filled circle*) and the reinstatement control group (*filled square*) received an identical reminder immediately after training and a long-term retention test 7 days later. Asterisks indicate significant retention (i.e., M baseline ratio significantly > 1.00); vertical bars indicate ± 1 SE (Experiment 1).

differences in retention could not be attributed to initial differences in unlearned activity or the final level of learning, respectively.

A one-way ANOVA revealed that the group baseline ratios differed significantly, $F(7, 36) = 4.42$, $p < .001$. A Duncan's multiple range test ($p = .05$) indicated that *group rein-9* and *group rein-14* had higher baseline ratios than all other groups (see Fig. 1). In addition, *group react-7* had a higher baseline ratio than *group rein-con* and *group rein-16*. An identical ANOVA revealed that the group retention ratios also differed, $F(7, 35) = 5.48$, $p < .0002$. A Duncan's multiple range test ($p = .05$) revealed that *group react-7* and *group rein-9* had higher retention ratios than *group rein-16*, *group rein-18*, and *group rein-con*; *group rein-14* also had a higher retention ratio than *group rein-con*. In addition, *group react-con* had a higher retention ratio than *group rein-con* and *group rein-16*.

To determine which, if any, groups exhibited significant retention, we used directional t tests to compare each group's mean baseline and retention ratios with the corresponding theoretical population ratios of 1.00 (no retention and no forgetting, respectively). These analyses revealed that the reactivation reminder

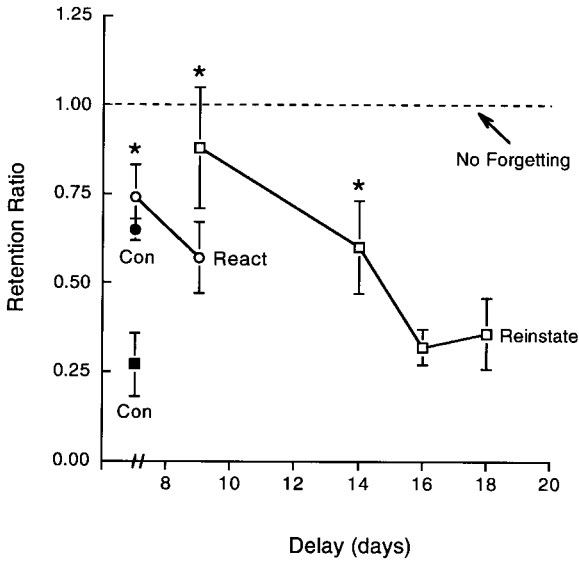


FIG. 2. Mean retention ratios of independent groups of 3-month-old infants who received either a reactivation reminder (*open circles*) or a reinstatement reminder (*open squares*) 3 days after training and a long-term retention test 7 to 18 days after training. The reactivation control group (*filled circle*) and the reinstatement control group (*filled square*) received an identical reminder immediately after training and a long-term retention test 7 days later. Asterisks indicate that a group exhibited significant forgetting during the long-term test (i.e., M retention ratio significantly < 1.00); vertical bars indicate $\pm 1 SE$ (Experiment 1).

produced significant retention 7 days after training but none 9 days afterward (see Figs. 1 and 2). *Group react-7* had a baseline ratio significantly greater than 1.00, $t(3) = 23.12$, $p < .0001$, and a retention ratio significantly below 1.00, $t(5) = 4.30$, $p < .004$, indicating that its retention was only partial. *Group react-9* had a baseline ratio not significantly greater than 1.00, $t(5) = 1.39$, ns , and a retention ratio significantly less than 1.00, $t(5) = 4.20$, $p < .004$, indicating that its forgetting was complete. Thus, 6 days after the reactivation reminder (9 days after training), forgetting was complete.

In contrast, the reinstatement reminder produced significant retention 9 and 14 days after training but not longer. *Group rein-9* had a mean baseline ratio significantly greater than 1.00, $t(5) = 2.94$, $p < .02$, and a mean retention ratio not significantly less than 1.00, $t(5) < 1$. *Group rein-14* also had a mean baseline ratio significantly greater than 1.00, $t(5) = 3.91$, $p < .006$, but its mean retention ratio was significantly less than 1.00, $t(5) = 3.03$, $p < .02$, indicating that its retention was only partial. The mean baseline ratios of *group rein-16* and *group rein-18*, however, were not significantly greater than 1.00, both $t(5) < 1$, and both groups had mean retention ratios significantly less than 1.00, $t(4) = 12.84$,

$p < .0001$, and $t(4) = 6.35$, $p < .0007$, respectively. Thus, 11 days after the reinstatement reminder (14 days after training), forgetting was complete.

Neither control group exhibited significant retention 7 days later when the reminder immediately followed training. Both groups had baseline ratios that were not significantly above 1.00 [*group rein-con*, $t(4) < 1$; *group react-con*, $t(4) = 1.11$, *ns*], and both had retention ratios that were significantly below 1.00, $t(4) = 13.39$, $p < .0001$, and $t(4) = 8.34$, $p < .0002$, respectively. Their data confirmed that the retention advantage exhibited by the experimental groups was not simply due to additional exposure to the reinforcer (reactivation control) or additional training time (reinstatement control) but to the retention boost that resulted from retrieval of the training memory at the time of reminding.

The brevity of the delay after which Spear and Parsons (1976) measured retention following the single reactivation reminder—1 day—relative to the delay after which they measured retention following the last of six reinstatement reminders—4 days—may have contributed to the apparent equivalence of reactivation and reinstatement in their original study. Although subjects may have exhibited retention after 1 day whether they received only one shock reminder or several, they may have required *more* than a single shock reminder to exhibit retention after delays as long as 4 days (Spear & Parsons, 1976), much less 7 days (Campbell & Jaynes, 1966). Hayne (1990), for example, gave 3-month-olds one or two reactivation reminders when their training memory was inactive and found that all infants exhibited retention after 1 day irrespective of whether they received one reminder or two, but only infants who received two reminders exhibited retention after 7 and 14 days.

The present data reveal that the two reminder procedures, reinstatement and reactivation, are not functionally equivalent in protracting retention when the memory is active. Presenting a single reinstatement reminder to 3-month-olds when the original memory was still active protracted their retention twice as long after the end of training (7 days) as a single reactivation reminder of the same duration (14 days). Because the mobile was moving during both reminders, the only ostensible difference between them was the presence (reinstatement) or absence (reactivation) of the contingency. This factor, then, must have been responsible for the differential reminder effect. Given that a single reactivation treatment in Experiment 1 maintained retention for 7 days after training, but a single reinstatement treatment of the same duration and given after the same delay maintained retention for 14 days after training, we asked in what other ways these two reminder procedures might differ. The succeeding experiments were designed to answer this question.

EXPERIMENT 2: SPECIFICITY AFTER A REACTIVATION REMINDER

When tested 1 day after training, 3-month-old infants recognize the training mobile and discriminate a novel one. Over time, however, they increasingly

forget the specific details of the training mobile; 3 days after training, they remember only its general features and respond nonselectively whether tested with the training mobile or with a novel one (Rovee-Collier & Sullivan, 1980). When tested 1 day after a reactivation reminder that is given when the memory is inactive, this pattern is reversed. One day after a reactivation treatment, 3-month-olds respond nonselectively to the training mobile and a novel one, but 3 days later, they respond only to the training mobile and discriminate a novel one (Hayne & Rovee-Collier, 1995). The latter result was interpreted as reflecting the rate at which the two kinds of memory attributes were recovered by the reminder—memory attributes representing the general features of the training mobile were recovered first, and those representing its specific details were recovered last.

Even though infants generalize to a novel mobile 3 days after training, a generalized reminder cannot reactivate the training memory once it has been forgotten (Rovee-Collier, Patterson, & Hayne, 1985). Instead, an effective reactivation stimulus must be virtually identical to the original training mobile. Although exposing 3-month-olds to a novel moving mobile (a reactivation procedure) when the memory is active retroactively interferes with their recognition of the training mobile 1 day later (Rossi-George & Rovee-Collier, 1999; Rovee-Collier et al., 1994), how it affects what and for how long they ultimately remember is unknown. In the remaining experiments, therefore, we explored the specificity of the memory representation both during and after a reactivation or reinstatement treatment with either the same mobile or a novel one.

In Experiment 2, we asked if exposure to a single reactivation reminder when the training memory is still active produces the same specificity after long test delays. To answer this, we exposed infants to either the original or a novel mobile as a reactivation reminder 3 days after training—a delay when they have forgotten the specific details of the training mobile—and tested them with either the original or a novel mobile 7 days after training. In Experiment 1, this retention interval was the end point of their forgetting function after a reactivation reminder.

Method

Participants. Eighteen 3-month-olds (8 boys, 10 girls) with a mean age of 93.2 days ($SD = 8.3$) were recruited as before and randomly assigned to three groups ($n = 6$). All were Caucasian. (Socioeconomic data were not collected, but the sample pool was the same as before.) Three additional infants were excluded from the final sample for crying longer than 2 min in any of the four sessions. *Group react-7*, which received both a reactivation treatment and a test with the original mobile in Experiment 1, was also included in Experiment 2.

Procedure. The training, reactivation, and testing procedures were the same as in Experiment 1. Infants were exposed to a reactivation reminder—either the original mobile (A) or a novel mobile (B)—3 days after training was over and were tested 4 days later (7 days after training) with either the original mobile or

TABLE 2

Mean Baseline Kick Rates (BASE) and Immediate Retention (IRT) Kick Rates, Mean Baseline Ratios (BR), Mean Retention Ratios (RR), and Standard Errors (SE) of Groups from Experiments 2, 3, and 4

Group	<i>M</i> BASE (<i>SE</i>)	<i>M</i> IRT (<i>SE</i>)	<i>M</i> BR (<i>SE</i>)	<i>M</i> RR (<i>SE</i>)
Experiment 2: 7-day test (reactivation)				
react-A/A	10.22 (1.64)	23.17 (3.41)	1.93 (0.04) ^a	0.74 (0.09) ^b
react-B/B	7.72 (1.16)	15.33 (1.47)	0.92 (0.08)	0.37 (0.05) ^b
react-A/B	8.44 (2.24)	23.78 (5.08)	1.08 (0.08)	0.49 (0.01) ^b
react-B/A	8.61 (1.80)	23.22 (5.17)	2.09 (0.45) ^a	0.58 (0.09) ^b
Experiment 3: 14-day test (reinstatement)				
rein-A/A	4.28 (0.68)	19.17 (2.68)	2.20 (0.31) ^a	0.60 (0.13) ^b
rein-A/B	6.61 (1.28)	19.33 (1.30)	1.77 (0.31) ^a	0.46 (0.06) ^b
rein-B/B	19.13 (3.76)	30.69 (5.47)	0.69 (0.16)	0.51 (0.14) ^b
rein-B/A	5.32 (0.75)	19.72 (4.19)	0.90 (0.18)	0.23 (0.03) ^b
Experiment 4: 9-day test (reinstatement)				
rein-A/A	7.17 (1.57)	17.44 (3.04)	2.20 (0.41) ^a	0.88 (0.17)
rein-A/B	6.39 (1.53)	17.00 (3.85)	1.23 (0.25)	0.53 (0.16) ^b
rein-B/B	6.39 (0.88)	17.56 (2.55)	1.59 (0.16) ^a	0.67 (0.12) ^b
rein-B/A	6.00 (1.01)	21.44 (2.76)	1.27 (0.17)	0.34 (0.03) ^b

^a Significant retention (i.e., BR significantly > 1.00).

^b Significant forgetting (i.e., RR significantly < 1.00).

a novel one, forming four groups. *Group react-A/B* was reminded with the original mobile and was tested with a novel mobile; *group react-B/A* was reminded with a novel mobile and was tested with the original mobile; *group react-A/A* (*group react-7* in Experiment 1) was both reminded and tested with the original mobile; and *group react-B/B* was both reminded and tested with a novel mobile.

Results and Discussion

Separate one-way ANOVAs performed on the mean kick rates of the four groups during the baseline and immediate retention test phases revealed that the groups did not differ either before or after training, both $F(3, 20) < 1$ (see Table 2, top). As a result, any subsequent group differences in long-term retention could not reflect differences in either unlearned activity or the final level of learning, respectively. Identical one-way ANOVAs indicated that the mean baseline ratios, $F(3, 16) = 4.89$, $p < .01$, and mean retention ratios, $F(3, 18) = 7.82$, $p < .001$, of the three groups differed significantly. A Duncan's multiple range test ($p = .05$) revealed that *group react-A/A* had a significantly higher

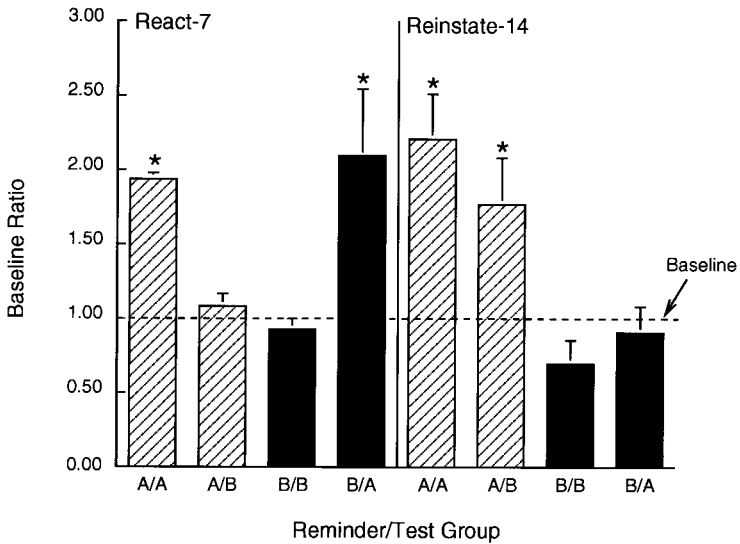


FIG. 3. Mean baseline ratios of 3-month-old infants who received either a reactivation reminder in Experiment 2 (left) or a reinstatement reminder in Experiment 3 (right) with either the training mobile (Mobile A: striped columns) or a novel mobile (Mobile B: filled columns) 3 days after training. After both reminders, infants were tested at the end point of their respective reforgetting function with either the original cue or a novel one; these delays corresponded to absolute retention intervals of 7 days (reactivation) and 14 days (reinstatement). In the group labels, the letter before the slash indicates the reminder mobile, and the letter after the slash indicates the test mobile. Asterisks mark groups that exhibited significant retention (i.e., M baseline ratio significantly > 1.00); vertical bars indicate $+ 1 SE$.

baseline ratio and retention ratio than *group react-B/B* and *group react-A/B*. In addition, *group react-B/A* had a significantly higher baseline ratio and retention ratio than *group react-B/B* and a significantly higher baseline ratio than *group react-A/B* (see Table 2, top).

Directional t tests were again used to compare each group's mean baseline ratio and mean retention ratio with the corresponding theoretical ratios of 1.00. The baseline ratio analysis revealed that both groups who were tested with the original training mobile recognized it irrespective of whether their reactivation stimulus was the original mobile or a novel one (see Fig. 3, left). *Group react-A/A* (*group react-7* in Experiment 1) had a mean baseline ratio significantly above 1.00, $t(3) = 23.12$, $p < .0001$, and a mean retention ratio significantly below 1.00, $t(5) = 4.30$, $p < .004$. Similarly, *group react-B/A* had a mean baseline ratio significantly above 1.00, $t(4) = 2.39$, $p < .05$, and a mean retention ratio significantly less than 1.00, $t(5) = 4.70$, $p < .003$, revealing that the retention of both groups was partial.

In contrast, neither group that was tested with the novel mobile generalized to it during the 7-day test. *Group react-B/B* had a mean baseline ratio not signifi-

cantly above 1.00, $t(4) = 1.06$, *ns*, and a mean retention ratio significantly below 1.00, $t(5) = 10.38$, $p < .0001$. Likewise, *group react-A/B* had a mean baseline ratio not significantly above 1.00, $t(5) = 1.01$, *ns*, and a mean retention ratio significantly below 1.00, $t(4) = 40.87$, $p < .0001$. The specificity of infants' memory at the time of testing was confirmed by the ANOVA, which showed that both reactivation groups who were tested with the original mobile had baseline ratios that did not differ and were significantly higher than the baseline ratios of both reactivation groups who were tested with the novel mobile, and whose baseline ratios also did not differ.

These data are particularly interesting because the reactivation treatment occurred at a point in time when infants typically treat a novel mobile as functionally equivalent to the training mobile, and these mobiles were functionally equivalent in protracting retention of the training memory for an additional 4 days as well (*groups react-A/A* and *react-B/A*). Because infants remembered only the general features of the training mobile at the time of reactivation, we speculate that the retention boost to the original memory that resulted from reactivation with the novel mobile was mediated by the general features that it shared with the training mobile. The fact that infants who were both reactivated and tested with mobile B (*group react-B/B*) failed to respond to it confirms that the remaining test groups had retrieved the original training memory and not the memory of the reactivation stimulus.

Apparently, the reactivation treatment "reset" the specificity of the memory and protracted it. Whereas infants typically *generalize* to a novel test mobile 3 days after training, *group react-A/B* still discriminated the novel test mobile 7 days after original training—4 days after reminding. Unless they had again remembered the details of the training mobile (*A*), the discrimination exhibited by infants in *group react-A/B* would not have been possible. In fact, their test data were identical to test data previously obtained from infants who had been reactivated with the training mobile 13 days after training, when the memory was inactive, and tested with a novel mobile 3 days later. Once the entire memory was forgotten, however, a novel mobile could not reactivate it (Hayne & Rovee-Collier, 1995).

EXPERIMENT 3: SPECIFICITY AFTER A REINSTATEMENT REMINDER

In Experiment 3, we asked if exposing infants to a single reinstatement reminder when their training memory is still active produced the same pattern of specificity that infants in Experiment 2 exhibited after exposure to a single reactivation reminder. To answer this, we again exposed infants to either the original or a novel mobile 3 days after training—this time using a reinstatement procedure—and tested them with either the original or a novel mobile. Because the magnitude of retention after reactivation and reinstatement in Experiment 1 was different after the same *absolute* delays, however, we

tested infants in Experiment 3 at the same *relative* point on their forgetting function as for infants in Experiment 2, namely, at the end point of their forgetting function. For infants receiving a reinstatement reminder in Experiment 1, this point was 14 days after training.

Method

Participants. Eighteen 3-month-olds (8 boys, 10 girls) with a mean age of 93.5 days ($SD = 7.9$) were recruited as before and randomly assigned to one of three groups ($n = 6$). Infants were Caucasian ($n = 14$), African American ($n = 1$), Hispanic ($n = 1$), and not reported ($n = 2$). Their parents' mean rank of socioeconomic status (Nakao & Treas, 1992) was 61.03 ($SD = 20.45$) and mean educational attainment was 15.53 years ($SD = 1.33$). Additional infants were excluded from the final sample for failing to meet the learning criterion ($n = 1$) and for inattention ($n = 2$) or crying ($n = 1$) for 2 min in any of the four sessions. *Group rein-14*, which received both a reinstatement treatment and a test with the original mobile in Experiment 1, was also included in Experiment 3.

Procedure. All procedures were the same as in Experiment 1 except that infants received a reinstatement reminder with either the original mobile or a novel one and were tested 11 days later (14 days after training) with either the original mobile or the novel one. *Group rein-A/B* was reminded with the original mobile and was tested with a novel mobile; *group rein-B/A* was reminded with a novel mobile and was tested with the original mobile; *group rein-A/A* (*group rein-14* in Experiment 1) was both reminded and tested with the original mobile; and *group rein-B/B* was both reminded and tested with a novel mobile. These reminder/test groups correspond to the four reactivation/test groups in Experiment 2.

Results and Discussion

Separate one-way ANOVAs were performed over the mean kick rates of the four groups during the baseline phase and the immediate retention test (see Table 2). These analyses indicated that the kick rates of the groups differed prior to training, $F(3, 20) = 11.45, p < .0001$, but not immediately afterward, $F(3, 20) = 2.27, ns$. A Duncan's multiple range test ($p = .05$) indicated that *group rein-B/B* had a higher baseline than the other groups. Because the introduction of reinforcement during training eliminated this difference, however, any subsequent differences in retention of the training memory could not be attributed to group differences in absolute response rates.

Separate one-way ANOVAs indicated that the group baseline ratios differed, $F(3, 19) = 8.39, p < .0008$, but their retention ratios did not, $F(3, 18) = 2.53, ns$. A Duncan's multiple range test ($p = .05$) indicated that the groups whose reinstatement was with the original training mobile (*group rein-A/A* and *group rein-A/B*) had significantly higher baseline ratios than the groups whose reinstatement was with the novel mobile (*group rein-B/B* and *group rein-B/A*; see Fig. 3, right).

Directional t tests comparing each group's mean baseline and retention ratios with the corresponding theoretical population ratios of 1.00 revealed a different pattern of results than the pattern found in Experiment 2. In Experiment 3, irrespective of whether their test mobile was the original mobile or a novel one, infants responded to it only if they had been reminded with the original mobile. *Group rein-A/A* (*group rein-14* in Experiment 1) had a mean baseline ratio significantly above 1.00, $t(5) = 3.91$, $p < .006$, and a mean retention ratio significantly below 1.00, $t(5) = 3.02$, $p < .02$. Similarly, *group rein-A/B* had a mean baseline ratio significantly above 1.00, $t(5) = 2.53$, $p < .03$, and a mean retention ratio significantly below 1.00, $t(4) = 9.93$, $p < .0001$. These data confirmed the finding of Experiment 1 that reinstatement with the original training mobile protracted retention for 11 additional days.

In contrast, neither group whose reinstatement reminder was the novel mobile responded to it during the 14-day test regardless of the test mobile. *Group rein-B/B* had a mean baseline ratio that was not significantly greater than 1.00, $t(4) = 1.95$, ns , and a mean retention ratio that was significantly less than 1.00, $t(5) = 3.61$, $p < .008$. Likewise, *group rein-B/A* had a mean baseline ratio that was not significantly greater than 1.00, $t(5) < 1$, and a mean retention ratio that was significantly less than 1.00, $t(4) = 28.52$, $p < .0001$. These data demonstrated that a novel mobile was less effective than the original mobile in protracting retention.

The pattern of stimulus specificity in Experiment 3 was different from the pattern in Experiment 2: The specificity appeared at the time of reminding—not at the time of testing. This result was confirmed by the ANOVA, which showed that both groups whose reinstatement was with the original mobile had baseline ratios that did not differ and were significantly higher than the baseline ratios of both groups whose reinstatement was with the novel mobile, whose baseline ratios also did not differ.

The preceding experiments revealed that whether the training stimulus or a novel stimulus was used as the reactivation reminder (Experiment 2) and the reinstatement treatment (Experiment 3) had a different impact on infants' memory performance. This differential effect occurred despite the fact that infants typically give no indication that they can even distinguish between the original stimulus and a novel one 3 days after training, when they were reminded. Although whether the reminder or test mobile was novel affected reactivation and reinstatement differently, we were satisfied that we understood the basis of the specificity following reactivation (see Results and Discussion, Experiment 2). However, we still had no firm clue about the basis of the specificity associated with reinstatement. In Experiment 4, therefore, we assessed the specificity of infants' memory performance following reinstatement with either the original stimulus or a novel one after a shorter delay.

EXPERIMENT 4

Recall that 3-month-olds discriminate a novel mobile from the one they were trained with for 1 day after the end of training; after retention intervals of 3 days or longer, however, they generalize to a novel test mobile—presumably because they still remember the general features of the original mobile, which the novel mobile shares (Rovee-Collier & Sullivan, 1980; Rovee-Collier et al., 1994). In Experiments 2 and 3, therefore, we gave infants a reminder treatment with either the original mobile (Mobile A) or a novel one (Mobile B) 3 days after the end of training. In Experiment 3, infants whose reinstatement reminder was Mobile A had generalized to Mobile B when tested 14 days after training, at the *end* of their protracted forgetting function. We were unable to say, however, whether they had simply *continued* to generalize to a novel mobile from Day 3 through Day 14 or whether their original memory had been “reset” during their partial training trial (reinstatement) with Mobile A. If their memory had been reset, then we would expect them to discriminate Mobile B after a shorter delay in the same way that infants discriminate a novel mobile shortly after original training is over (Rovee-Collier & Sullivan, 1980). In addition, infants who had received a reinstatement treatment with Mobile B had failed to recognize either Mobile A or Mobile B during the 14-day test. Although these data suggested that a novel mobile was simply an ineffective reinstatement reminder, we thought that perhaps infants might recognize one of these mobiles after a shorter delay, particularly given that the reinstatement treatment was an abbreviated training trial.

In Experiment 4, therefore, we asked two questions: (1) What was the basis of infants’ generalization to Mobile B after reinstatement with Mobile A in the preceding experiment? and (2) Was the reinstatement treatment with Mobile B completely ineffective, or might its effect be seen after a shorter test delay? To answer them, we gave infants a reinstatement treatment on Day 3 with either Mobile A or Mobile B, as before, but this time we tested them with either Mobile A or Mobile B after a shorter delay—9 days after training.

Method

Participants. Eighteen 3-month-olds (10 boys, 8 girls) with a mean age of 95.9 days ($SD = 9.6$) on their first day of training were recruited from published birth announcements in local newspapers and randomly assigned to groups ($n = 6$) as they became available for study. Infants were African American ($n = 3$) and Caucasian ($n = 15$). Their parents’ mean educational attainment was 15.27 years ($SD = 1.35$), and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 71.76 ($SD = 15.16$). (Demographic information was available from 67.0% of the sample.) Additional infants were excluded from the final sample for crying longer than 2 min in any of the four sessions ($n = 7$) and because of a scheduling conflict ($n = 1$). *Group rein-9*, which was tested with Mobile A in Experiment 1, was also included in Experiment 4.

Procedure. All procedures were the same as in Experiment 3 except that infants were tested 9 days after training. *Group rein-A/B* was reminded with the original mobile and was tested with a novel mobile; *group rein-B/A* was reminded with a novel mobile and was tested with the original mobile; *group rein-A/A* (*group rein-9* in Experiment 1) was both reminded and tested with the original mobile; and *group rein-B/B* was both reminded and tested with a novel mobile. In the group labels, the reinstatement mobile is indicated by the letter before the slash, and the test mobile is indicated by the letter after the slash.

Results and Discussion

Separate one-way ANOVAs over the mean kick rates of the four groups during the baseline phase and the immediate retention test (see Table 2) indicated that they did not differ either before training or afterward, $F_s(3, 20) < 1$. Identical analyses indicated that the baseline ratios of the four groups also did not differ significantly, $F(3, 20) = 1.21$, *ns*, although the difference in their retention ratios approached significance, $F(3, 20) = 3.01$, $p < .054$, due to the relatively high retention ratio of *group rein-A/A*.

When tested 9 days after training, infants recognized both Mobile A and Mobile B when the test mobile had been used as the reinstatement reminder, but they failed to recognize either Mobile A or Mobile B when the other mobile (Mobile B or Mobile A, respectively) had been used as the reinstatement reminder (see Fig. 4). Both *group rein-A/A* and *group rein-B/B* had baseline ratios significantly greater than 1.00, $t(5) = 2.91$, $p < .025$, and $t(4) = 3.80$, $p < .01$, respectively, indicating that both groups exhibited significant retention when tested with the same mobile that they saw during the reinstatement treatment. Whereas the retention ratio of *group rein-A/A* was not significantly less than 1.00, $t(5) < 1$, *ns*, the retention ratio of *group rein-B/B* was, $t(5) = 2.74$, $p < .025$, confirming that *group rein-A/A* exhibited no forgetting between training and testing, but *group rein-B/B* did. Its retention was only partial.

In contrast, neither *group rein-A/B* nor *group rein-B/A* had a baseline ratio significantly greater than 1.00, $t(5) < 1$, *ns*, and $t(5) = 1.59$, *ns*, respectively, and both groups had retention ratios significantly less than 1.00, $t(5) = 2.96$, $p < .025$, and $t(5) = 22.44$, $p < .001$, respectively. These two measures provide convergent evidence that infants did not recognize a test mobile that differed from the reinstatement mobile, whether they had been trained with it 9 days earlier (*group rein-B/A*) or not (*group rein-A/B*).

These results answered two important questions. First, did infants simply continue to generalize to novel mobiles once they had initially forgotten the specific details of their training mobile, regardless of whether their reminder was novel or familiar? The answer is “no.” The reinstatement treatment with Mobile A reestablished the specificity of the training memory because infants who were tested 6 days after reinstatement—9 days after training—again discriminated a novel test mobile from the training one. Whereas infants had remembered only

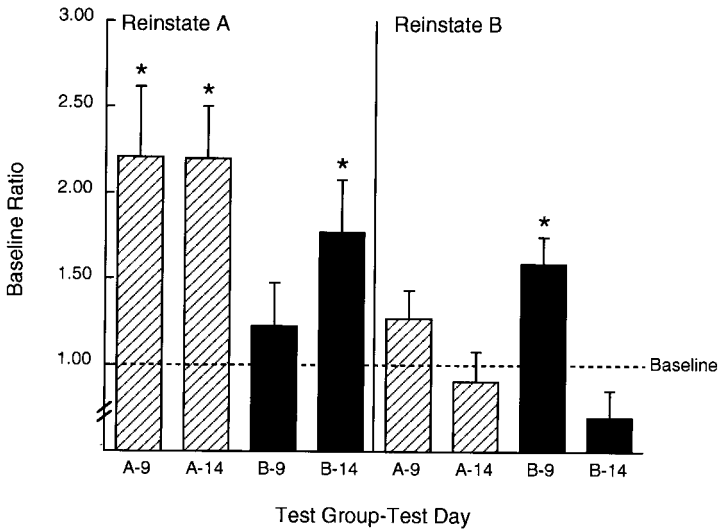


FIG. 4. Mean baseline ratios of 3-month-old infants who received a reinstatement treatment with either the training mobile (Mobile A: *left*) or a novel mobile (Mobile B: *right*) 3 days after training and were tested with either Mobile A (*striped columns*) or Mobile B (*filled columns*) either 9 days (Experiment 4) or 14 days (Experiment 3) after training. In the labels on the x axis, the letter before the dash indicates the test mobile, and the letter after the dash indicates the test day. Asterisks mark groups that exhibited significant retention (i.e., M baseline ratio significantly > 1.00); vertical bars indicate $+ 1 SE$.

the general features of the training mobile at the time of reminding, after a reinstatement treatment with the original mobile, they again remembered its specific details as well. Thus, although reactivation and reinstatement had initially appeared to have different effects on memory specificity (see Fig. 3), Experiment 4 revealed that both reminder procedures restored specificity at the time of testing.

Infants whose reinstatement reminder was Mobile B also exhibited specificity during testing 6 days later, responding differently to Mobile A than to Mobile B. They did so, however, for a different reason. The fact that they recognized only the novel reinstatement mobile and not the original training mobile suggests that the details of the reinstatement mobile (Mobile B) had been *substituted* for the forgotten details of the original mobile (Mobile A) in the training memory at the time of reminding.

Second, did infants' failure to respond to either mobile after 14 days when their reinstatement mobile was novel (Experiment 3) mean that the novel mobile was an ineffective reminder? Again, the answer is "no." In Experiment 4, *group rein-B/B* responded to the novel reinstatement mobile (Mobile B) 9 days after training, yet *group react-B/A*, which was reactivated with the novel mobile, had recognized the training mobile only 7 days after training (Experiment 2), and

group rein-con, which was *overtrained* with the original mobile for the same amount of time, had not recognized the training mobile even 7 days later (Experiment 1). Thus, the novel reinstatement mobile had boosted retention. Further, because 3-month-olds who received three 3-min reinstatements but were never initially trained exhibited no retention of the reminder mobile 6 days later (Galluccio & Rovee-Collier, in press), it is safe to conclude that the memory performance of *group rein-B/B* 9 days after training reflected retrieval of the modified training memory. Apparently, the additional 3 min of training during the reinstatement procedure boosted retention in *group rein-B/B* via the general features that Mobile B shared with Mobile A. Perhaps because the novel details that had replaced the original details in the training memory had themselves been trained for only 3 min during the reinstatement treatment, however, reinstatement with the novel mobile was insufficient to support retention after the longest test delay—14 days.

GENERAL DISCUSSION

The present experiments reveal that reactivation and reinstatement, in addition to differing procedurally, differ functionally as well. A major factor in their relative efficacy as reminders appears to be the state of the memory—whether active or inactive—at the time of reminding. Previously, we found that a single reactivation reminder was effective in recovering a memory that was inactive at 2 and 3 months of age, but a single reinstatement reminder was not (Galluccio & Rovee-Collier, in press; Rovee-Collier et al., 1999). In free-operant studies, presenting the reinforcer as a reinstatement reminder requires that subjects respond at a rate sufficiently high to actually produce the reinforcing event that they had experienced during training. If they have forgotten the training memory at the time of reminding, however, infants do not respond above baseline—this is the *definition* of forgetting. As a result, they will produce an effective reinstatement reminder only if they are able to relearn the response–reinforcement contingency sufficiently early in the allotted reminding period to reap its full benefits.

This analysis is supported by recent evidence from 6-month-olds. Twenty days after training, when forgetting was complete (i.e., infants again responded at the baseline rate), we gave them a 2-min reinstatement treatment. As was the case with younger infants, it was not an effective reminder; infants failed to exhibit significant retention when tested 1 day later. When we instituted the requirement that infants must reattain the original learning criterion during the reinstatement treatment, however, infants whose reinstatement was given after the training memory was inactive exhibited significant retention not only 1 day later but for 4 weeks afterward (Sweeney & Rovee-Collier, 1999). This problem may be unique to free-operant studies in which exposure to the reinforcer during a reinstatement treatment is response-contingent. A similar problem does not arise during a reactivation treatment because exposure to the reinforcer is not re-

sponse-contingent but is under the control of the experimenter, who moves the mobile for the infant at the same rate that the infant had moved it at the end of training. Nor does it arise in classical conditioning studies (e.g., Campbell & Jaynes, 1966; Spear & Parsons, 1976) because exposure to the reinforcer (e.g., the shock) during both training and reminding also is not response-contingent but is under the control of the experimenter. As a result, subjects are reexposed to the reinforcing stimulus whether they respond or not.

We found that a reinstatement reminder was more effective than a reactivation reminder in protracting a memory that is still active. Whereas a reactivation reminder protracted retention for 4 additional days (1 week after training), a reinstatement reminder of the same duration and given after the same delay protracted retention for 11 additional days (2 weeks after training). This discrepancy may have resulted from the deleterious effect of giving a reactivation reminder when the memory is active. Both Gordon (Gordon, 1981; Gordon, Smith, & Katz, 1979) and Lewis (1979) proposed that memories can be modified only when they are active. When Gordon et al. (1979) gave adult rats a 15-s exposure to the CS+, their memory of active avoidance was reactivated; when the exposure duration was increased to 75 s, however, it was extinguished. The authors suggested that reactivation of the memory begins when the reactivation stimulus is initially exposed and that, once the memory has been reactivated, its continued presence without reinforcement leads to new learning (e.g., extinction).

Data from the present study are consistent with this analysis. In Experiment 4, infants whose reinstatement stimulus was a novel mobile (Mobile B) recognized Mobile B 6 days later. For these infants and infants in the corresponding groups in Experiment 2, the specific details of the novel reactivation mobile were apparently substituted into the memory for the details of the original mobile that had been forgotten. As a result, infants' original training memory, acquired with Mobile A, was buffered to some extent against extinction or other potentially subtractive effects at the time of reactivation, but, for the same reason, the modified memory was not boosted as much by the reminder procedure. The reactivation treatment with the original training mobile (Mobile A) was even less effective than reinstatement with a novel one. Although these infants failed to recognize the original mobile 9 days after training, they did recognize it 7 days afterward. Why was their retention benefit from a reactivation treatment with the training mobile, which reexposed all of the specific details that were in the original memory, not greater? We think that this was because they learned something during reactivation with Mobile A when the training memory was still active that partially *counteracted that benefit*, as Gordon (1981; Gordon et al., 1979) proposed.

Evidence supporting this analysis comes from two other reminder studies with 3-month-olds. In the first study, Hayne (1990) gave infants one, two, or three reactivation treatments after training was over—on Day 6, on Days 6 and 13, or

on Days 6, 13, and 20, respectively. One reactivation treatment protracted retention for 3 days but not for 1 week, whereas two reactivation treatments—each given after the memory was forgotten—protracted retention for 2 weeks but not for 3 weeks. Three reactivation treatments, however, were no more effective than one. Hayne hypothesized that the efficacy of the third reactivation treatment was reduced because it was given when the memory was still active after the second reminder. In the second study, Galluccio and Rovee-Collier (in press) tested this hypothesis. They gave infants either two or three reinstatement treatments on the same days as Hayne except that their first reminder was always on Day 3, when the memory was active, instead of on Day 6, when it was not. They found that two reinstatement treatments also protracted retention for 2 weeks; however, three reinstatement treatments—all given when the memory was active—protracted retention for 3 weeks.

At first blush, these studies seem to suggest that when both reminders are of the same duration, reactivation and reinstatement are functionally equivalent under certain circumscribed conditions, that is, if the reactivation treatment is given when the memory is *inactive* and if the reinstatement treatment is given when the memory is *active*. Such was the case, for example, when infants received two reinstatements (Days 3 and 13) when the memory was active (Galluccio & Rovee-Collier, in press) and two reactivations (Days 6 and 13) when it was not (Hayne, 1990). In another experiment in the same series, however, Hayne gave two reactivations (on Days 20 and 27), and infants remembered for the same length of time as infants who received three reinstatements in the Galluccio and Rovee-Collier study. Had Galluccio and Rovee-Collier given their third reinstatement on Day 27, when the memory was still active, infants might well have exhibited retention after an even longer delay. Unfortunately, this alternative was not possible because infants cannot be tested supine after they are 17 weeks old. Thus, although differentially manipulating the timing of reactivation and reinstatement can protract retention equivalently, this equivalence is a *psychophysical* effect—not a fundamental characteristic of the two reminder procedures. Differentially manipulating other temporal parameters (e.g., duration) of encoding and/or reminding, for example, might also produce equivalent retention following reactivation and reinstatement.

When the same temporal parameters are used for both procedures, reinstatement and reactivation protract retention for different durations. During a reinstatement treatment when the memory is active, the additional learning about the contingency in the presence of the original training mobile apparently *sums with* the prior learning achieved during original training to protract retention. During a reactivation treatment when the memory is active, however, the additional learning about the contingency apparently *subtracts from* any retention benefit initially achieved by retrieving the memory at the time of reminding (Rovee-Collier, 1995). As a result, when the memory is active and both reminders are of the same duration, reinstatement is substantially more effective than reactivation in protracting retention.

In addition to protracting retention for different durations, the specificity of the original memory is affected differently by reinstatement and reactivation treatments. Reinstatement with the original complement of cues resets the memory, reestablishing the same specificity of the memory that was seen shortly after original training (and prolonging it); only at the end of their protracted forgetting function do infants again remember only its general features. In contrast, after reactivation with the original training mobile, infants did not again generalize to Mobile B, even at the end of their protracted forgetting function.

This study demonstrates that the distinction between reinstatement and reactivation is not artificial. In addition to differing procedurally, reinstatement and reactivation differ functionally, with different memory-preserving effects. In economic terms, these two reminders are not substitutable.

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