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3. The EEG and EOG signals were monitored on a Beckman type R dynograph, simultaneously digitized with an analog-to-digital converter (Electrical Engineering Company of California, model 762) at the rate of 30 and 10 samples per second, respectively, and recorded on a Precision Instrument incremental digital recorder model 1167 F.
4. Infants were swaddled and buckled in a semiupright position in a plastic infant seat. The angle was adjusted so that the incline was approximately 45°. The stroboscope lamp was aligned so that the center was (i) perpendicular to the frontal plane of the face and (ii) directed midway between the eyes. The experimental room was dark. Photic stimulation was initiated only when the babies were quiet with eyes closed.
5. The tracing of each photic trial was inspected prior to and during stimulation to ensure a stable recording of ongoing activity: the nonstimulated peak-to-peak amplitude was scanned and used as a standard. If this criterion was grossly exceeded or if there was any departure from the test criteria for subjects or procedure, the trial was omitted.
6. Group 1 included 8 males and 11 females; group 2, 36 males and 42 females. Their ages range from 36 to 59 hours with a median of 46 hours; birth weights vary from 2466 to 4252 g with a median of 3203 g, with an average 1 minute Apgar score of 8 [V. Apgar, *Curr. Res. Anesth. Analg.* **32**, 260 (1953)].
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8. Since the characteristics of the EEG signals can vary with time (nonstationarity), the estimates of the spectra are not pooled across trials. They are estimated separately for each 4-second interval with use of the smoothed periodiogram method (*1*). The statistical test is based on the difference of the logarithms of the estimated spectrum of the 4 seconds immediately preceding stimulation and the estimated spectrum of the data during stimulation. The differences of the logarithms of the spectra are then summed over trials, giving a test that is not influenced by trial to trial nonstationarity.
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Multiphasic Retention Deficits at Periodic Intervals after Passive-Avoidance Learning

Abstract. *After one-trial passive-avoidance training, independent groups of rats tested promptly after training or at successive 6-hour intervals displayed a repetitive pattern of high then low retention scores. These results suggest that some physiological rhythm may interact with retention performance.*

We have evidence that the retention deficit found at intermediate intervals after avoidance conditioning, commonly called the "Kamin effect," may not represent a transitory phenomenon occurring only once after the training session. We found that rats tested for passive avoidance promptly (15 minutes) after a one-trial training procedure or at successive multiples of 12 hours after training displayed higher retention scores than did rats tested 6 hours after the training session or at successive multiples of 12 hours from this 6-hour interval.

The U-shaped retention curve of a partially learned avoidance response was first reported by Kamin (*1*) and has been replicated with a variety of procedures, including passive-avoidance tasks (*2–4*). The locus of the maximum retention deficit has been reported to vary from 1 to 8 hours after training. Such variations may have resulted from differences in procedure (such as stressing conditions and apparatus) or from an incomplete sample of training-testing intervals (TTI). Also, others have tended to omit testing for retention at intervals between 8 and 24 hours after training, between 24 and 48 hours after training, and so forth.

Several hypotheses have been offered as explanations for the Kamin effect, for example: (i) Memory consists of a multiple-stage process in which deficits at certain intervals after training may result from temporal disparities between stages (*5*). (ii) Decreases in fear or physiological processes underlying motivation for the avoidance behavior may occur during the intermediate TTI (*3, 6*). (iii) Increases in fear, inhibition, anxiety, or stress induced by the shock during training may be maximal during intermediate TTI's and thus interfere with avoidance behavior (*4, 7*). (iv) Stimulus generalization decrements or "state-dependent" effects may result from changes in the internal state of the organism between training and testing (*8, 9*). To our knowledge, in all suggested explanations for the Kamin effect it has been assumed, at least implicitly, that the retention deficit is transitory inasmuch as no impairment in retention is usually reported at 24 hours or successive multiples of 24 hours after training. The present experiment was designed to explore retention at intervals up to 24 hours and at intervals between multiples of 24 hours.

Subjects were 195 male albino rats (Sasco), weighing 314 to 376 g. All animals were housed in individual cages and given free access to food and water. They were placed on a light-dark cycle of 12 hours of light (0800 to 2000 hours) and 12 hours of dark (2000 to 0800 hours) at least 2 weeks before training began, and were maintained on this cycle throughout the experiment. Subjects were randomly assigned to one of 13 independent groups (15 animals per group). These groups received passive-avoidance training and testing and differed only in terms of TTI's. All groups were trained during the light cycle, with approximately equal numbers of subjects within each group trained in the earlier (1000 to 1345 hours) and later (1400 to 1715 hours) portions of the cycle. The 13 groups were designated by their TTI's, which were 15 minutes and 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, and 72 hours, respectively.

The passive-avoidance apparatus (*10*) was trough-shaped, consisting of a smaller, clear Plexiglas chamber (start box) illuminated by neon lamp (6 watts) and a larger, darkened, black Plexiglas chamber (shock box). The larger compartment was accessible to the subject through a circular opening in a black Plexiglas wall separating the two chambers. The floor of the chamber consisted of parallel stainless steel bars through which 5 seconds of 0.1-watt footshock (constant wattage) could be delivered. Latencies for entering the dark chamber, called step-through latencies (STL), were recorded with an electronic clock (accurate to 0.1 second) activated by photocell relays in the start box and stopped by a contact relay at the distal end of the shock box. One animal was placed in the start box facing the wall opposite the circular opening to the shock box (*11*); this simultaneously activated the STL clock. When the subject climbed through the opening and reached the rear of the shock box, the shock was delivered and the STL was recorded. All subjects returned to the start box within the 5-second shock period; no significant differences among groups were noted in latencies for escape from the shock box. During the training session, there were also no significant group differences ($P > .10$, Kruskal-Wallis one-way analysis of variance) on the STL measure; individual STL scores ranged from 1.2 to 46.9 seconds, and group STL means ranged from 11.9 to 17.9 seconds. After the training trial, the subject was returned to its home cage; no more than 20 seconds elapsed between the animal's escape from the shock box and its return to the home cage. The procedures for testing were equivalent to those for training, except that any subject failing to exit the start box within 300.0 seconds was removed from the apparatus and a STL of 300.0 seconds was recorded. The testing STL was the primary index of retention of the passive-avoidance response.

The results of the experiment are presented in Fig. 1. The mean STL yielded results similar to those for the median. However, skewness in the STL data rendered the median the more appropriate statistic. Analysis of testing STL's revealed no significant differences ($P > .10$, Kruskal-Wallis one-way analysis of variance) among the groups with TTI's of 15 minutes and 12, 24, 36, 48, 60, and 72 hours; these all showed perfect or near-perfect performance. Retention was impaired in the 6-, 18-, 30-, 42-, and 54-hour groups, with no significant impairment in the 66-hour group (*12*). The pattern of results was identical for those animals in each group receiving training in the earlier and later portions of the light cycle. As a control for unconditioned response tendencies, similar TTI groups (seven animals per group) were given training and testing sessions with no shock during training. No significant differences in testing STL ($P > .10$, Kruskal-Wallis one-way analysis of variance) among these control groups were noted; individual STL's ranged from 1.1 to 36.2 seconds, and group means ranged from 8.4 to 11.8 seconds.

We thus confirmed the existence of a deficit in retention of a passive-avoidance behavior at an intermediate interval after training (*13*). However, the occurrence of additional retention deficits at intervals between 12 and 24 hours, between 24 and 48 hours, and between 48 and 72 hours strongly suggests that the Kamin effect may not represent a transitory retention impairment. Instead, the alternating pattern of high and low retention every 12 hours suggests that some biological rhythmic factor (of unknown periodicity) may modulate fluctuations in the course of retention. While we cannot assert unequivocally that the same mechanism underlies the retention impairment in the various TTI groups, there is no obvious reason not to assume a common mechanism. We suggest at least three possible ways in which some rhythmic factor may operate to modulate retention performance: (i) The absolute levels of such a rhythmic variable—for instance, the peaks and troughs of the spontaneous activity cycle—may influence retention performance directly. (ii) The level of activity in such a rhythmic factor may define a "state" or class of internal stimuli present during training, and shifts away from the training level at certain TTI's may produce "state-dependent" retention failures. (iii) The exposure to shock during training may in some sense induce, trigger, or reset a rhythmic or oscillatory variation in some physiological process that interacts with retention performance (*14*). The first alternative appears to be the weakest, since no differences between the pattern of retention curves for animals trained early or later during the light cycle were found (*15*). Differences between animals trained early and late in the light cycle would be

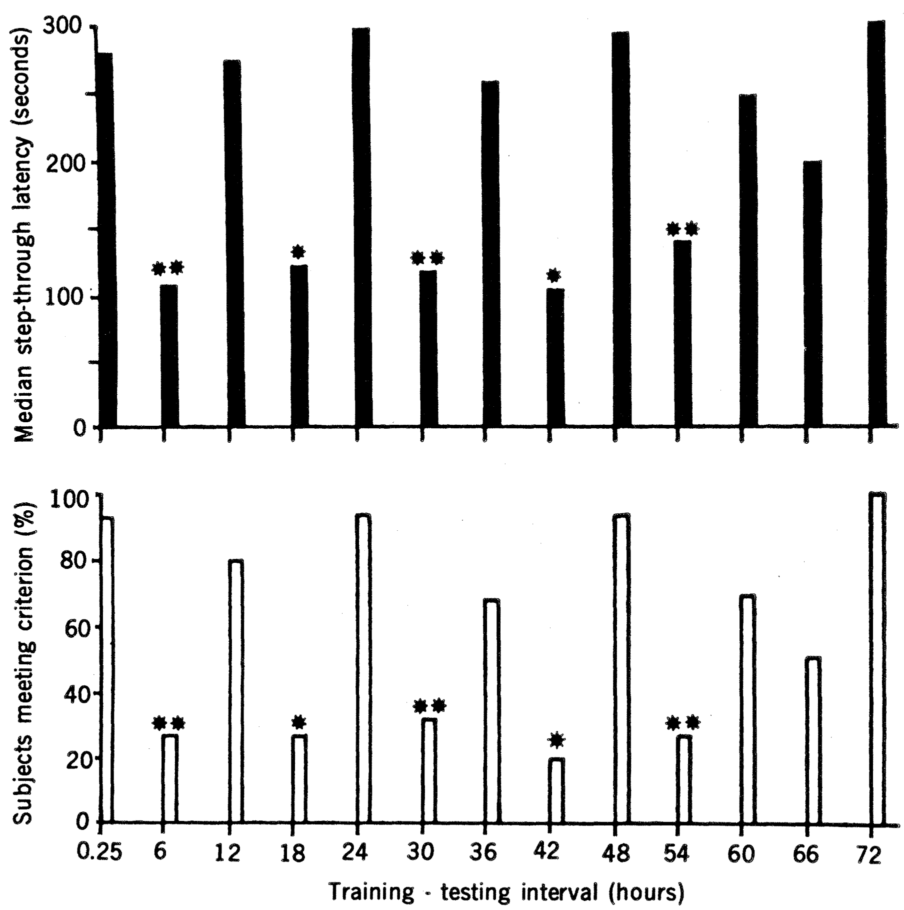

Fig. 1. Median step-through latencies (STL) at testing sessions (top) and percentages of subjects meeting the 300-second STL criterion at testing session (bottom). Successive paried group comparisons (*11*) for each measure are *, $P < .05$; and **, $P < .001$.

expected if retention failures were due to absolute levels of some rhythmic factor. The suggestion that the Kamin effect may represent a state-dependent phenomenon is not new (*8*, *16*). There is evidence that retention of conditioned suppression of operant responses is stronger when tested at the same "biological time" as training than when tested at any other time of the 24-hour cycle (*17*), a result similar to our results. Finally, we cannot completely exclude the possibility that something analogous to a stress response or some other psychophysiological reaction induced by the training procedure may itself become entrained to a rhythmic variable and interact with the retention performance.

Efforts to relate the Kamin effect to alterations (due to induced stress or biorhythms) in the activity of the pituitary-adrenal axis have largely been negative (*18*). However, scopolamine was recently reported to be effective in blocking the appearance of the Kamin effect (*19*). Since there also is evidence for a 24-hour cycle in acetylcholine levels of various parts of the rat brain (*20*), manipulation of central cholinergic activity may be a fruitful approach in understanding the fluctuations in retention found in the present study.

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Visual Temporal Order: A New Illusion

Abstract. *Brief visual stimuli presented in rapid sequence, one to the left and one to the right, appear to occur left first, then right, regardless of the actual order of presentation. This illusion persists under conditions of forced-choice testing and does not vary with presentation to the same or opposite retinal hemifields. A series of experiments suggests that this illusion may be the product of an internal mechanism that scans visual inputs in a left-to-right order.*

Two small targets, side by side in the visual field, are flashed in rapid succession. Observers tend to report that the left target flashed before the right target, regardless of the actual order in which they were presented. A series of experiments on this new illusion of visual temporal order demonstrates its persistence under a variety of conditions and suggests that it is the product of neither response bias nor hemispheric and hemiretinal asymmetries. Moreover, the results are consistent with an explanation based upon an internal mechanism that scans visual inputs in a left-to-right order.

The illusion was discovered during informal test sessions in which subjects sat, with nonpreferred eye occluded, 57 cm from a cathode-ray tube display. On each trial the following sequence of events occurred. (i) A horizontal matrix of dots (visual angle, 10° by 48′) appeared in the center of the screen. A vertical strip 36′ wide was left blank in the center of the matrix to provide a convenient fixation region. The matrix remained on for 1 second. (ii) At 100 msec after the offset of the matrix, two different letters appeared sequentially, with no delay between the offset of the first and the onset of the second, one 1° to the left of fixation and the other a like distance to the right. Each letter lasted 10 msec, had a visual angle of 48′ by 21′, and was chosen randomly from a set of 12 easily discriminable letters. (iii) At 100 msec after the termination of the second letter, the matrix of dots was again presented, for 1 second. On any trial a computer chose randomly which letter, the left or the right, would occur first, thus creating two different temporal sequences, left-right and right-left (*1*). The subject indicated on a teletypewriter his judgment of which letter was first and which was second. Subjects correctly identified about 60 percent of the left-right sequences but only 30 percent of the right-left sequences. In both cases they tended, when making an error, to reverse the sequence of presentation rather than to misidentify the letters (*2*).

Several plausible explanations for this illusion have been suggested, and we undertook an experimental program to choose among them (*3*). One hypothesis assumes that for an observer to identify the order of two stimuli, the neural representations of those stimuli must arrive at a single center in the nervous system (*4*). If this center were located in the right hemisphere, the arrival of stimuli appearing to the right of fixation would be delayed, because these stimuli project to the left hemisphere and their representations could reach the right hemisphere only after crossing the corpus callosum. Stimuli appearing to the left of fixation would not be handicapped in this manner, because they project more directly to the right