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ABSTRACT

Seventy-five subjects were trained on a pursuit rotor for 10 trials, with ambient illumination from a strobe light flashing at frequencies of either 2,5,10,15, or 20 per second. A transfer trial followed, with a strobe flashing frequency of 10 per second for all subjects. Results supported hypotheses derived from Adams' closed-loop theory of motor learning that (a) performance would improve during training as a function of amount of visual feedback available, and that (b) if after training visual feedback was reduced, performance would be maintained to the extent that kinesthetic feedback had been learned to be relied upon as an alternate, compensatory, feedback loop. (Author)

Abstract

Seventy-five Ss trained on a pursuit rotor for 10 trials, with ambient illumination from a strobe light flashing at frequencies of either 2, 5, 10, 15, or 20/sec. A transfer trial followed, with a strobe flashing frequency of 10/sec for all Ss. Results supported hypotheses derived from Adams' (1971) closed-loop theory of motor learning that (a) performance would improve during training as a function of amount of visual feedback available, and that (b) if after training visual feedback was reduced, performance would be maintained to the extent that kinesthetic feedback had been learned to be relied upon as an alternate, compensatory, feedback loop.

Visual and Kinesthetic Components of Pursuit-Tracking Performance[1]

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Adams' (1971) closed-loop theory of motor learning postulates a perceptual trace which S develops as he receives error information in the form of sensory feedback from task performance. The theory predicts that the perceptual trace is what S uses as the reference against which to compare and modify subsequent movements on the basis of knowledge-of-results (KR) received. The theory also predicts that after a relatively large amount of training, performance can continue when KR is withdrawn, because S has built a perceptual trace as an internalized reference. It is consistent with the theory to assume that both visual and kinesthetic sensory feedback should contribute error information to the building of the perceptual trace.

The hypotheses of the study are two: (a) Performance will improve during training as a function of the amount of visual feedback available, and (b) That if after a relatively large amount of training the opportunity for visual feedback is reduced, performance will be maintained to the extent that a perceptual trace has been built with kinesthetic feedback as an alternate feedback loop.

Method

Procedure. On each of 12 one-min trials, S used a hinged stylus to track a target on a pursuit apparatus. Intertrial intervals of 20 sec were used to control for massed practice effects. The 12 trials included (a) pretest [trial 1], (b) training [trials 2-11], and

(c) transfer [trial 12]. The independent variable was the flash frequency of a strobe light during training, which provided the only source of target illumination.

The pretest was the same for everyone, with a strobe flash frequency of 40/sec. Training trials had one of five different flash frequencies (2, 5, 10, 15, or 20/sec). The transfer trial was the same for everyone, with a strobe flash frequency of 10/sec. The flash frequencies for pretest, training, and transfer were selected on the basis of findings from a pilot study conducted.

For all 12 trials, a 15 W red bulb was lighted as a source of KR whenever S's stylus contacted the target. The red light was positioned below and adjacent to the pursuit apparatus, and did not illuminate the target either directly or indirectly. Thus the present study was similar to past studies in which KR has been provided during the training stages of a tracking task (e.g., Williams & Briggs, 1962). It was different from past studies in that the KR was continued for the transfer trial, and was not removed. Instead on the transfer trial, the present study made the visual feedback loop more or less effective (relative to training) as a source of error information.

Subjects. Seventy-five paid undergraduate volunteers, both male and female, were divided randomly into five groups, with the constraints that there be 15 Ss per group, and approximately the same number of male and female Ss. Each group was assigned one of the five flash frequencies for training.

Apparatus. A General Radio 648-A Strobolux strobe-light was driven by a General Radio 631-BL Strobotac tachometer to produce the required flash frequencies. The duration of any single flash was 50 μsec. Durations of trials and intertrial intervals were regulated by two cycling Hunter timers. A Hunter Klockounter was used to record the dependent variable (time-on-target) in sec for each trial.

The strobe-light was positioned .3 m from the center of the pursuit apparatus. S stood behind the strobe-light and held his preferred arm over the top of the strobe-light box to perform the tracking task. To reduce reflected light, the walls and ceiling of the 1.35 by 2.2 m cubicle were covered with soft black flannel cloth, and the floor was covered with nonreflecting black rubber-coated fabric.

The target of the pursuit apparatus was an aluminum disk 2.5 cm in diameter, and was positioned 12 cm from the center of the 17 cm in diameter Prestwood platform of the pursuit apparatus. Throughout the experiment, the target was checked regularly for abrasion or pitting, and periodically polished. The platform of the apparatus rotated clockwise at 33 rpm, and its surface was 93 cm above the floor S stood on.

The tracking stylus had a wood handle 16 cm long, with a 16 cm long steel arm attached to it with a hinge. The end of the arm distal to the handle was bent into a loop 1.5 cm in diameter. In tracking, the loop at the end of the arm made contact with the target at a tangent to the loop's curvature. A special feature of the stylus was a mercury switch imbedded in its handle. Pilot study had shown that Ss sometimes tried to "ride" the target by holding the stylus sideways, which jammed the hinge and gave them advantage. The mercury switch was in a normally closed state when S held the stylus correctly. The mercury switch was connected in series with a monitor light in E's quarters in an adjoining room. If S did turn the stylus sideways, the circuit would open, and the monitor light would blink off. A second special feature of the stylus was a microswitch imbedded in the rear portion of the handle, with an activating level protruding above the top surface of the handle. Pilot study had shown that Ss sometimes would hold the stylus near the hinge so that they could bear down on the stylus arm with their index finger. S was required to depress the microswitch lever during tracking, to insure that he kept his hand at the end of the handle distal to the arm. The microswitch was in a closed state when S depressed the lever, and was connected in series with E's monitor light. If S did remove his hand from the rear of the handle, the circuit would open, and the monitor light would blink off.

S was instructed how to hold the stylus, informed about E's monitor light, and told that failure to hold the stylus as instructed would mean his expulsion from the experiment without pay. Ten Ss were expelled from the study for failure to hold the stylus as instructed, and were replaced.

Results

Each Ss cell score was the time-on-target out of each one-min trial. The *a priori* rejection region for all analyses conducted was $p = .05$. The results of the study are presented in Fig. 1.

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Insert Figure 1 about here

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Pretest. A one-way analysis of variance was conducted for the data of the five groups. There were no significant differences among groups [$F(4,70) = 1.16$].

Training. A 5 x 10 analysis of variance conducted with Groups and Trials being between- and within-subject variables respectively showed Groups [$F(4,70) = 43.22$], Trials ($F(9,630) = 28.99$], and Groups x Trials [$F(36,630] = 2.62$] to be statistically significant effects.

Groups were ordered from best to poorest in terms of time-on-target according to whether they were trained with flash frequencies of 20, 15, 10, 5, or 2/sec. Scheffé tests conducted on the means for trials 2 and 11 indicated that the significant Groups x Trials interaction was due to the fact that groups trained with flash frequencies of 20, 15, and 10/sec improved significantly over training trials, whereas groups trained with flash frequencies of 5 or 2/sec did not.

Transfer. A one-way analysis of variance conducted for the data of the five groups on the transfer trial indicated a significant effect for Groups [$F(4,70) = 7.52$]. Scheffé tests conducted on the individual means of the transfer trial indicated that in contrast to the group which received a flash frequency of 10/sec for both training and transfer trials, performance was as follows: (a) the group trained with a flash frequency of 20/sec dropped significantly lower, (b) the group trained with a flash frequency of 15/sec was not significantly different, (c) the group trained with a flash frequency of 5/sec was significantly lower, and (d) the group trained with a flash frequency of 2/sec was significantly lower.

Discussion

Training. Adams (1971) closed-loop theory of motor learning was supported, and extended to the domain of continuous motor skills. As hypothesized, performance did improve over training as a function of the amount of visual sensory feedback available. It is important to emphasize that the improvement occurred for groups receiving the three fastest flash frequencies (20, 15, and 10/sec), but not for the groups receiving the two slowest flash frequencies (5 and 2/sec). These findings suggest that a certain minimal amount of visual information is required before learning can occur under the conditions of the present study.

In addition to the learning effect observed, a marked performance effect was observed as a function of flash frequency, with differences observed between groups as early as the conclusion of the first training trial (trial 2).

Transfer. The results suggest three conclusions:

(a) Kinesthetic feedback will contribute to the development of the perceptual trace if that kinesthetic feedback can be correlated during training with visual information which has some degree of precision.

Greater positive transfer was demonstrated by the group trained with a flash frequency of 15/sec than the group trained with a flash frequency of 20/sec. The authors conclude that the flash frequency of 15/sec during training forced Ss to rely in part upon kinesthetic error information as an alternate, compensatory feedback loop. Thus when the transfer trial was encountered, their perceptual trace was built with kinesthetic error information as well as visual, and it served well to guide movements when visual feedback became a less reliable source of error information.

(b) A certain amount of visual feedback information is necessary to be correlated with kinesthetic feedback, in order for kinesthetic feedback to contribute to the building of the perceptual trace.

Groups trained with flash frequencies of 5 and 2/sec had the opportunity for kinesthetic feedback during training which could have contributed to the building of the perceptual trace if there had been sufficient visual feedback correlated with it. However, that sufficient visual feedback information was not available during training was indicated by (i) a lack of any significant learning during training, and (ii) by performance on the transfer trial for those two groups being about at the level of the first training trial (trial 2) of the group trained with a flash frequency of 10/sec.

(c) Ss will rely predominantly upon visual information during training if it is readily available with a high degree of precision, while neglecting kinesthetic information.

The group trained with a flash frequency of 20/sec had every bit as much opportunity to build their perceptual traces with kinesthetic feedback as did the group trained with a flash frequency of 15/sec. Why then did the drop occur on the transfer trial for the group tr ned with a flash frequency of 20/sec? Adams (1971) stated that all feedback channels may not operate equally. One hypothesis is that Ss will attend to visual feedback at the exclusion of kinesthetic feedback if the visual feedback loop is sufficiently rich to maintain S's confidence in his performance at a maximum. Thus, confidence ratings should be obtained as an index of perceptual trace strength. However, the reason why Ss should rely upon rich visual feedback at the exclusion of kinesthetic feedback is unclear. If visual feedback is inherently a more potent variable for motor learning and performance, it may be because it provided more precise error information than kinesthetic error information, at least when flashing at a frequency of 20/sec. The faster the flash frequency, the more times per sec S would be able to observe any error between his positioning of the stylus and the target. And, at a flash frequency of 20/sec, visual error information was more precise than kinesthetic, and S's strategy was to rely upon it.

References

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Footnotes

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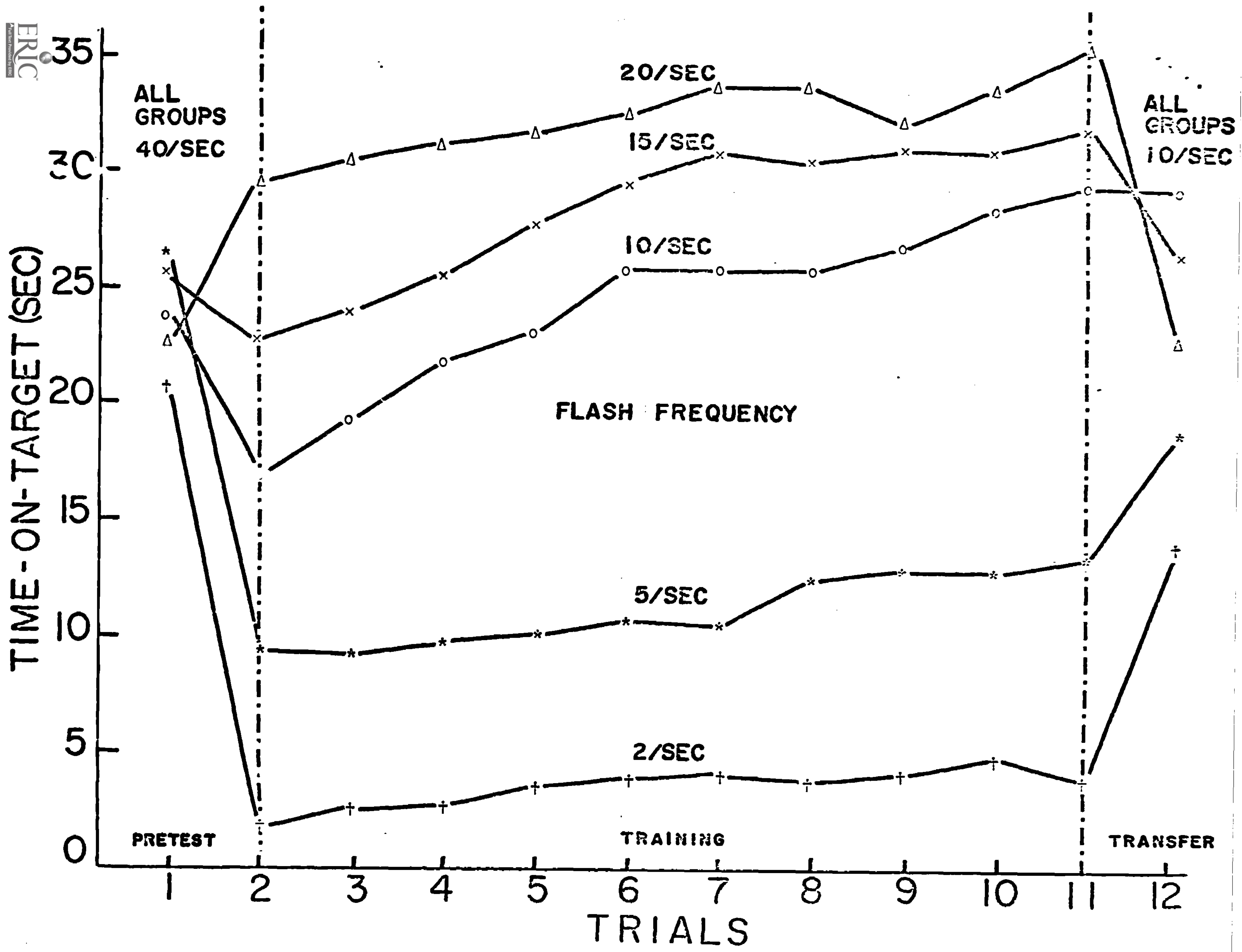
2. Now at the University of Illinois, Champaign, Illinois.

Figure Caption

Fig. 1. Rotary pursuit performance as a function of strobe-light flash frequency, and trials.


TIME-ON-TARGET (SEC)
35
30
25
20
15
10
5
0
ALL GROUPS 40/SEC
20/SEC
15/SEC
10/SEC
FLASH FREQUENCY
5/SEC
2/SEC
ALL GROUPS 10/SEC
PRETEST
TRAINING
TRANSFER
1
2
3
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TRIALS