Table 1
Delayed Alternation with Equal or Differential Illumination of the Choice Doors

Illumination	Sessions	Percent Correct S33	Percent Correct S83	Rep. E/T*** S33	Rep. E/T*** S83
Equal*	1-3	49	35	0.66	6.15
Equal	18-20	56	44	0.15	0.49
Differential**	1-3	50	59	0.17	0.12
Differential	18-20	68	76	0.09	0.03
Equal	1-3	64	71	0.07	0.04
Differential	1-3	72	71	0.10	0.02
Equal	1-3	72	78	0.09	0.06

*Both choice doors illuminated by continuous lights.
**Illumination of right door by continuous, left door by 7-sec flickering light.
***Repetitive errors per trial.

the click. During several test trials, when the solenoid was inoperative, the monkey made more errors."

DISCUSSION

The development of strong positional habits by prefrontally ablated animals has also been reported by Konorski (1967), who observed that some dogs responded correctly on a locomotor delayed-response task by maintaining their body orientation toward the baited feeder during the delay period. Since the dogs then walked directly to the feeder, Konorski considered their behavior as a "pseudodelayed" response. In the present experiment, however, the monkeys were required to follow a complex sequence of motor responses involving several locomotor turns. The finding that prefrontal monkeys could walk through the maze with correct alternations, but failed on the task when their movements were briefly interrupted, suggests that prefrontal cortex is not essential to the execution of sequential motor acts per se. Konorski's formulation of prefrontal cortex as the locus for "kinesthetic gnosis" does not specify whether these neuronal structures function in the establishment of the relevant kinesthetic cues or in the execution of motor acts in accordance with such cues. The present findings point to the second interpretation as the more plausible. The interpretation is consonant with Luria's (1966) formulation of prefrontal cortex functioning as a guidance system for the execution of complex motor acts, in accordance with previous instructions. Whereas such guidance is mediated verbally by human Ss, it is dependent upon kinesthetic cues in the monkey In normal monkeys such cues are so subtle that they cannot be readily observed, whereas the present monkeys developed exaggerated positional habits that seemed to compensate for their prefrontal impairments.

REFERENCES

KONORSKI, J. *Integrative activity of the brain.* Chicago: University of Chicago Press, 1967.

LURIA, A. R. *Human brain and psychological processes.* New York: Harper & Row, 1966.

STAMM, J. S. Dorsolateral frontal ablations and response processes in monkeys. Journal of Comparative & Physiological Psychology, 1970, 70, 437-447.

Stimulus compounding and response summation with an instrumental running response

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A light and a tone each maintained a certain speed of an instrumental running response in a straight alley. When the light and tone were combined, their compound maintained a faster running speed than that maintained by either the light or tone alone. The results were interpreted in terms of summation of the response tendencies maintained by each stimulus and further demonstrated the wide generality of this phenomenon.

When two conditioned (CS) or discriminative (S^D) stimuli, each capable of maintaining a response, are combined, their compound may produce a response which is stronger than the response maintained by either stimulus alone. This effect has been described as summation of the response tendencies maintained by each stimulus. Summation of responding has been demonstrated to have generality over several conditioning paradigms and several measures of response strength: (1) Classical conditioning–a compound CS has been shown to elicit a greater magnitude of salivation (Pavlov, 1927) or galvanic skin response (Hull, 1940; Grings & O'Donnell, 1956) than the magnitude elicited by either CS alone. (2) Free-operant conditioning–Wolf (1963), Weiss (1964), and Miller & Ackley (1970) demonstrated that a compound S^D maintained a higher rate of response than the rate maintained by each S^D alone. (3) Conditioned suppression–Miller (1969a), Reberg & Black (1969), Van Houten, O'Leary, & Weiss (1970), and Cappell, Herring, & Webster (1970) found that when individual CSs, which each suppressed rate of leverpressing, were combined, this compound suppressed responding even more. (4) Discriminated instrumental avoidance–Miller (1969b) demonstrated that when a light and buzzer, which separately maintained a latency of avoidance response in a two-way shuttlebox, were combined, the latency to this compound was shorter than the latency to either single stimulus.

The present study attempted to extend further the generality of compounding summation to a third measure of instrumental response strength, speed of running. Summation of response tendencies would predict that if two stimuli, which each maintained a certain speed of running, were combined, the speed maintained by the compound would be greater than the speed maintained by either single stimulus.

PROCEDURE

The Ss were four male albino rats about 150 days old. They were maintained at 80% of free-feeding weight for the course of the experiment. The apparatus was a 75 x 7 x 8 in. straight alley painted flat black and covered with screen. The runway

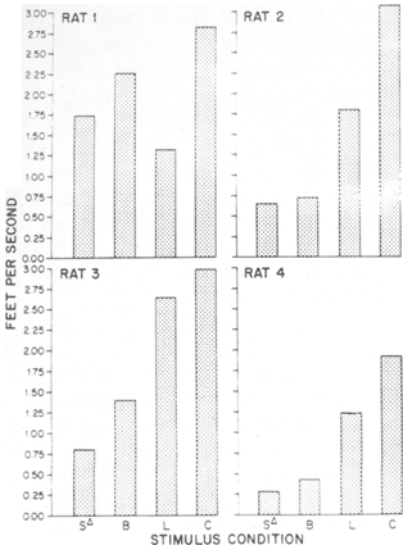

Fig. 1. Mean running speed under each stimulus condition for the 2 days of testing.

portion of the alley measured 60 in. long. Two Knight photocells were placed 52 in. apart in the runway. The distance from the startbox door to the first photo cell was the same as the distance from the second photocell to the goalbox door, 4 in. Running time from the first photocell to the second was measured with a Stoelting electric timer, accurate to .01 sec. The stimulus sources, a 150-W flood lamp and a 1,500-Hz tone emanating from a speaker, were positioned at the midline of the alley, 3.5 ft above the top of the alley.

Stimulus control over responding was established through discrimination training. Running down the alley was reinforced with a single 45-mg Noyes pellet in the presence of the light or tone (S^Ds) but was not reinforced in the absence of light or tone (S^Δ). Specifically, Ss were given 18 trials per day, six trials each to light, tone, and no light or tone. The order of presentation of the three conditions was randomly determined. Three different random sequences were used. On trials on which the light or tone was to occur, the stimulus was presented 1 sec before the startbox door was raised and was terminated when Ss entered the goalbox. On S^Δ trials only the startbox door was raised. Ss remained in the goalbox for 15 sec before being returned to the startbox for the next trial. If Ss did not run within 15 sec from the time the startbox door was raised, the trial was terminated and a running time of 15 sec was recorded. Training was continued in this manner until Ss had both attained a stable running time during S^D presentations and learned the discrimination. The criterion for discrimination was taken as a significantly longer running time on S^Δ trials.

Since the running times at the end of training were so brief, it was felt that Ss might be running at near their physical limit and that any effect of compounding might not be apparent. Therefore, compound testing was performed during extinction. The number of daily trials was reduced to 12, and Ss were run for 2 days, during which time they were not reinforced for running during light and tone presentations. At the end of the second day, running times had increased enough, so compound testing was programed on Days 3 and 4. Each of the four stimulus conditions of light, tone, S^Δ, and compounded light and tone occurred three .times according to a randomized sequence, for a total of six presentations of each stimulus condition for each S for the 2 days of testing.

RESULTS AND DISCUSSION

The results of compound testing for each S is presented in Fig. 1. Running times were converted to running speed. A running time of 15 sec would equal 0.29 ft/sec and a running time of 1 sec would equal 4.33 ft/sec. Each bar represents the mean of the six measures of running speed for the 2 days of testing for each of the four stimulus conditions. A Treatment by Subjects analysis of variance on the combined data of the four Ss revealed a significant effect of stimulus condition [$F(3,9) = 8.85$, $p < .01$]. Duncan's (1951) multiple-range comparisons test of treatment means showed that the light and compound maintained a significantly faster running speed than did S^Δ ($p < .05$ and $p < .01$, respectively), and that the compound maintained a significantly faster running speed than did either the buzzer or the light ($p < .01$ and $p < .05$, respectively). For S 1, three of the six running speeds during compounding exceeded the fastest running speed during the buzzer. For Ss 2, 3, and 4, the fastest running speed during the light was exceeded by 5, 4, and 2 running speeds during compounding, respectively.

Considering now the end of the extinction period, for S 1, the light maintained a slower speed than did S^Δ. For Ss 2 and 4, speed of running during the buzzer was only slightly greater than speed during S^Δ, indicating that responding in the presence of these particular S^Ds had undergone considerable extinction. Yet, when they were combined with the other S^D, summation was demonstrated. This result is consistent with results reported by Weiss (1964) and Miller (1969a), who found that even when responding in the presence of the individual S^Ds was extinguished, compounding of these S^Ds still produced summation.

The results of this experiment are in full accordance with a response summation interpretation and demonstrate the generality of the compounding-summation effect across a broad range of conditioning paradigms and measures of response strength. The possibility that the increased running speed to the compound was due to stimulus intensity effects from combining two stimuli was not directly controlled; however, Miller (1969a) and Weiss (1969) with the free-operant paradigm, Evans (1925) with the classical conditioning paradigm, and Winnick & Hunt (1951) with an instrumental running response have all presented evidence which indicates that stimulus intensity cannot account for the increase in response strength during stimulus compounding.

REFERENCES

CAPPELL, H. D., HERRING, B., & WEBSTER, C. D. Discriminated conditioned suppression: Further effects of stimulus compounding. Psychonomic Science, 1970, 19, 147-149.

DUNCAN, D. B. Multiple range and multiple F tests. Biometrics, 1951, 7, 1-16.

EVANS, C. A. L. *Recent advances in physiology.* London: Churchill, 1925.

GRINGS, W. W., & O'DONNELL, D. E. Magnitude of response to compounds of discriminated stimuli. Journal of Experimental Psychology, 1956, 52, 354-359.

HULL, C. L. Explorations in the patterning of stimuli conditioned to the G.S.R. Journal of Experimental Psychology, 1940, 27, 95-110.

MILLER, L. Compounding of pre-aversive stimuli. Journal of the Experimental Analysis of Behavior, 1969a, 12, 293-299.

MILLER, L. Stimulus compounding with an instrumental avoidance response. Psychonomic Science, 1969b, 16, 46-47.

MILLER, L., & ACKLEY, R. Summation of responding maintained by fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 1970, 13, 199-203.

PAVLOV, I. P. *Conditioned reflexes.* (Translated by G. V. Anrep) London: Oxford University Press, 1927.

REBERG, D., & BLACK, A. H. Compound testing of individually conditioned stimuli as an index of excitatory and inhibitory properties. Psychonomic Science, 1969, 17, 30-31.

VAN HOUTEN, R., O'LEARY, K., & WEISS, S. J. Summation of conditioned suppression. Journal of the Experimental Analysis of Behavior, 1970, 13, 75-81.

WEISS, S. J. Summation of response strengths instrumentally conditioned to stimuli in different sensory modalities. Journal of Experimental Psychology, 1964, 68, 151-155.

WEISS, S. J. Attentional processes along a composite stimulus continuum during free operant summation. Journal of Experimental Psychology, 1969, 82, 22-27.

WINNICK, W., & HUNT, J. McV. The effect of an extra stimulus upon strength of response during acquisition and extinction. Journal of Experimental Psychology, 1951, 41, 205-215.

WOLF, M. M. Some effects of combined S^Ds. Journal of the Experimental Analysis of Behavior, 1963, 6, 343-347.