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A Systematic Investigation of Warning Stimulus Modality Effects on Two-Way Active Shuttle Avoidance Performance in Rats

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A SYSTEMATIC INVESTIGATION OF WARNING STIMULUS MODALITY EFFECTS ON TWO-WAY ACTIVE SHUTTLE AVOIDANCE PERFORMANCE IN RATS

by

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ABSTRACT

Three studies systematically investigated the hypothesis of Rosic, Frontali and Bignami (1969) that certain stimuli facilitate higher levels of avoidance performance (i.e., more correct responses) because of their ability to generate greater amounts of unconditioned motor activity during the stimulus presentation. Experiment I showed that buzzer, tone and light stimuli produce different amounts of unconditioned motor activity in rats, with the buzzer generating the most activity and the light generating the least. In Experiment II, the introduction of non-contingent shock resulted in a reduction in motor activity levels, but the buzzer still produced higher levels of activity than the light. Experiment III directly tested the effects of different motor activity levels in a two-way active shuttle avoidance situation. No significant relationship was shown between the unconditioned motor activity levels associated with warning stimuli and the corresponding avoidance performance. Surprisingly, all warning stimuli produced high levels of avoidance performance. It was suggested that stimulus modality effects still warrant further examination as a possible source of variance in avoidance experiments.

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INTRODUCTION

Most work in avoidance learning has been concerned with delineating numerous variables responsible for influencing avoidance performance. Variables such as CS-US interval, US intensity, CS intensity, intertrial interval and genetic strain, have been shown to influence the complex avoidance phenomenon. Recent evidence has suggested that an unconditioned motor response to the warning stimulus may be another important determiner of avoidance performance. This hypothesis has been proposed to explain a number of studies showing that avoidance performance varies according to the type of warning stimulus employed in the experimental paradigm.

One of the first studies to show warning stimulus differences in avoidance was a study conducted by Myers (1959). In either a bar-press or wheel-turn avoidance situation, a buzzer produced significantly better avoidance than a 4000 Hz tone. Myer's observations recorded during experimentation led him to attribute the superior performance of the buzzer group to startle responses elicited by the buzzer onset. Myers noted that when the manipulandum (either a bar or wheel) was not electrified during shock presentations, the rats continuously held the manipulandum between trials. With the onset of the buzzer, the rats made a startle response which was sufficient to operate the manipulandum and qualify as an avoidance response. However, when the manipulandum was charged during the shock presentation inorder to prevent the rats from holding it, suprisingly the avoidance performance remained comparable to that obtained with an uncharged manipulandum. Even with this additional data, Myers still hypothesized the startle response as the mediator of avoidance performance.

Whether the manipulandum was charged or uncharged, inferior avoidance performance was shown by the tone group in comparison to the buzzer group. Myers attributed this inferior performance to the tendency for rats to initially freeze in response to tone onset rather than to startle as with buzzer onset.

Smith, McFarland and Taylor (1961) discovered in pilot studies that rats failed to learn a wheel-turn avoidance response when a light served as a warning stimulus. When a buzzer was substituted for the light, the avoidance response was rapidly acquired. If overtraining with the buzzer occurred, the number of avoidances diminished and performance was soon composed entirely of escape responses. Thus it seemed possible that all avoidance performance exhibited with the buzzer could have been an artifact of pseudoconditioning or sensitization.

To test this hypothesis, Smith et al. (1961) compared two main groups of rats on a wheel-turn avoidance task. One group was trained using a standard buzzer-shock avoidance paradigm for 20 trials a day for 12 days. The other group served as a pseudoconditioned control group where the buzzer and shock were never paired in the same trial and either could be terminated by a wheel-turn. Both main groups were further subdivided into high (1.8 ma) and low (0.74 ma) shock intensity levels. At 0.74 ma shock, the pseudoconditioned group showed significantly better avoidance performance than the buzzer conditioned group. At 1.8 ma shock, no differences were present between groups. Smith et al. (1961) concluded that the buzzer groups' performance was due to pseudoconditioning since avoidance equal to or better than that of the buzzer group was obtained by the pseudoconditioned groups. However, the validity of the pseudoconditioning procedure as a control is questionable since the number of shocks received by the buzzer group was determined by their performance while the pseudoconditioned group always received 10 shocks per day.

In 1962, Myers attempted to determine whether the differential performance of a wheel-turn avoidance response to the buzzer and tone was due to stimulus-intensity effects produced by the buzzer being louder than the tone. The data revealed that 65 and 85 db buzzer intensity groups performed significantly better than either 60, 80 or 100 db tone intensity groups. Since the intensity levels were chosen on the assumption that the 100 db tone group would almost certainly be physically louder than the 65 db buzzer group, Myers concluded that stimulus-intensity effects were not involved in the differential avoidance performances. He stated that the difference was perhaps related to the particular quality of sound generated by the two stimuli, i.e., "their different frequency spectra".

In 1964, Myers extended his analysis of stimulus differences by testing a wider range of warning stimuli on two strains of rats in a discriminated operant avoidance procedure. Abandoning the previously used discrete-trials procedure, Myers used a bar-press avoidance situation where each bar press reset a 20 second timer so that shock was always due 20 seconds after the most recent response. If no bar press occurred within 15 seconds, a warning stimulus appeared 5 seconds before shock was delivered. Myers recorded as his dependent measure the proportion of responses having 15-20 second interresponse times, i.e., avoidance responses within the 5 second stimulus presentation interval preceding shock as compared to the number of interstimulus responses.

A significant Stimulus Condition main effect was obtained for the combined data of both strains of rats tested. Although no individual statistical comparisons were given showing where significance existed, Myers ordered the warning stimuli from most to least effective for avoidance performance in the sequence: Buzzer, Light, Noise, Tone, No Stimulus.

Statistical comparisons of the data from the individual rat strains were reported. In the Wistar rats, classified by Myers as an emotional strain, no differences were shown between Light and Buzzer, Noise and Light, and Tone and Noise. In the G-4 rats, an active strain of rat according to Myers, differences existed for all comparisons except that between Noise and Light.

The results corroborate Myers' previous findings (1959, 1962) that a buzzer elicits better avoidance performance than a tone. Whereas the buzzer and tone had yielded consistent differences across experiments the relatively good performance with the light stimulus was not typical of previous work by Smith et al. (1961) or unpublished work by Myers (1964). Also contrary to this finding were the data of Biederman (1967), who found that a light warning stimulus produced bar-press avoidance performance inferior to that elicited either by a noise or a combination of noise and light. Therefore it is unclear just how effective light and noise are in relation to tone and buzzer. Also,there exists the possibility that results will differ with the strain of rat tested.

Differential warning stimuli effects have been investigated by the previously mentioned studies only in bar-press and wheel-turn avoidance situations. Frontali and Bignami (1973) and Rosic, Frontali and Bignami (1969) have noted interesting differential warning stimuli effects in active-passive shuttle avoidance situations. Also called Go-No Go avoidance discriminations, these tasks require the subject to discriminate according to the stimulus presented whether or not an active or passive avoidance response should be emitted.

In their study of the ability of different stimuli to alter Go-No Go avoidance discriminations in rats, Rosic et al. (1969) found that active avoidance performance was better using a noise[1] than a light. All animals were trained in active avoidance with either a light or a noise until a criterion of 39 or more avoidance responses per session for two consecutive days was reached. Then, discrimination training commerced, with the groups receiving the pretrained stimulus as the Go signal and the other stimulus as the naive No Go signal (L+N- or N+L-). During discrimination training, the rats were punished for not emitting a shuttle response to the Go signal (called omission errors) and for emitting a shuttle response to a No Go signal (called commission errors).

The results showed that rats trained with noise as the Go signal and light as the No Go signal (N+L-) reached the avoidance performance criterion faster than rats trained under the reversed condition (L+N-). Rosic et al. (1969) attributed the results to the assumption that the buzzer provoked a stronger unconditioned motor response than the light. Hence the buzzer would tend to facilitate more motor activity than the light and increase the probability of a shuttle response being made. The authors supported this conclusion by citing the data which showed that more errors of omission, as well as commission, were made by the L+N- group than the N+L- group.

In 1971, Cicala, Masterson and Kubitsky investigated activity levels throughout a series of shock presentations in the absence of reinforcement provided by escape and avoidance contingencies. The authors discovered that the presentation of a 80 db noise warning stimulus consistently elevated the activity rate of rats as compared to the preceding 10 second intertrial interval. On the basis of these results, Cicala et al.(1971) have suggested that the warning stimulus may function as an excitor of activity. This conclusion is contrary to the generally accepted view that the warning stimulus when paired with shock will subsequently depress general activity (Rescorla and Solomon,1967; Weiss, Krieckhaus and Conte,1968). Such conclusions, as by Cicala et al.(1971), as well as the theoretical work of Bolles (1969) on species-specific defense reactions(SSDR) have stimulated an examination of the variables involved in the theoretical concepts of the prevailing avoidance theories.

Cicala et al.(1971) further stated that underlying all theories of avoidance is the implication that "an animal must make several initial avoidance responses inorder to learn that an avoidance response produces positive consequences and is worth repeating". Therefore it seems possible that if the operant level of activity is elevated during the warning stimulus presentation, then the time required for the emergence of early avoidance responses would be reduced. This implies that activity may be an important determiner of overall avoidance performance.

The present series of experiments represent an attempt to delineate the effect of unconditioned motor activity on two-way active shuttle avoidance performance. First, the hypothesis suggested by Rosic et al.(1969) that certain warning stimuli generate different amounts of unconditioned motor activity was tested. Second, if motorigenic stimuli were found to exist, the effect of shock on the unconditioned motor activity levels was then determined. Finally, the effect of motorigenic stimuli on active two-way shuttle avoidance performance was investigated.

EXPERIMENT I

Several investigators have demonstrated in avoidance experiments that certain stimuli function as better warning stimuli than others in eliciting avoidance performance. Specifically, the buzzer has proven to be superior to either a light or tone (Myers 1959, 1964; Smith, McFarland, Taylor 1960; Rosic, Frontali, Bignami 1969). Rosic et al. (1969) hypothesized that the avoidance performance varied according to the amount of motor activity generated by the warning stimulus. This motor activity was assumed to be unconditioned and the buzzer was assumed to elicit the strongest unconditioned motor activity.

Experiment I was an attempt to determine whether warning stimuli generate different amounts of motor activity. Since motor activity was assumed to be unconditioned, it was hypothesized that the presentation of novel stimuli without any contingencies would produce differential levels of motor activity.

The experiment was designed to allow testing of high, medium, and low intensity levels for each stimulus to evaluate if an intensity level effect existed on the generation of motor activity.

METHOD

Subjects

Fifty naive, male Hooded rats, weighing 294-497 gm, were procured from Canadian Breeding Farm and Laboratories and housed individually in standard wire cages at the rat colony of Wilfrid Laurier University. The subjects were maintained ad libitum on food and water throughout the experiment.

Apparatus

A two-way active avoidance chamber, measuring 90 cm by 25.4 cm by 19 cm, was constructed of wood and painted black. The chamber was elevated 40 cm off the floor of a sound-attenuating converted refrigerator. Air circulation within the refrigerator was provided by a 60 CFM centrifugal fan (Dayton Model) located outside producing an ambient noise level inside of 46 db. A one-way mirror on the refrigerator door provided a partial view of the apparatus.

Each avoidance chamber compartment had a grid floor which butted at the center of the chamber and rested on two microswitches used to record shuttling responses. The 3.2 mm stainless steel grid rods, spaced 11.2 mm center to center, gave the appearance of one continous grid floor as no barrier separated the compartments. Each grid floor pivoted at the end of the chamber and was counterbalanced outside by 0.67 kgm weights. The minimum pressure required to activate the microswitches was 200 gms.

Six photo-electric relays, utilizing high speed photochopper cells (Clairex 703 CL), were located 5 cm above the grid floor. The chamber was divided into twelve 15.25 cm by 12.75 cm rectangles by an end positioned photo beam bisecting the other five side-mounted photocell beams. The ambient light level produced by the photo-relay light source (G.E. #44 bulbs) was 0.26 ft-c.

All stimulus presentations were delivered from below the grid floor in each compartment. A thin, free-standing partition was centered between compartments, 2.54 cm below the grid floor, to provide good separation of compartment stimuli. The light stimulus was the onset of a 40-W incandescent lamp (G.E. Lumiline) centered in a sheet metal reflector covered with frosted Plexiglas. The dimmer controlled lamps were calibrated with a photometer (Goffen Lumasix), held approximately 5 cm above the grid floor.

The tone and buzzer stimuli were presented by a 4 1/2 in. loudspeaker (Poly-Planar, Model P) centered beneath each compartment. Suspended gauze cloth prevented feces from falling on the speakers. A pure sine-wave tone generator(Eico Audio, Model 377) was the source of the 4000 Hz tone. The buzzer stimulus (Edwards Lungen, No. 18, size 1), as used by Myers (1973), was pre-recorded and played over a tape recorder (Uhrer, Royal Deluxe). The adjustable sound sources were calibrated by a sound level meter (General Radio, Type 1551-C) set at the "Slow" position, "A" level, with the microphone centered approximately 5 cm above the grid floor.

Activity counts, shuttle responses and time periods were recorded by a LVE Event Recorder. All experimental contingencies were programmed on standard 28V electromechanical modules situated in the experimental room.

Experimental Design

Independent Variables:

The design consisted of ten groups with 5 rats each. Nine of the groups received a stimulus presentation at a particular intensity level. The stimulus presentations were as follows: Buzzer High (BH), Buzzer Medium (BM), Buzzer Low (BL), Light High (LH), Light Medium (LM), Light Low (LL), Tone High (TH), Tone Medium (TM), Tone Low (TL). The tenth group served as a Control (C) group and received no stimulus presentation.

High, medium and low intensity levels were approximated from a review of the range of CS intensities stated in the avoidance literature of the Journal of Comparative and Physiological Psychology, 1970-1973.

Buzzer and tone intensity levels ranged from 60-100db. Light intensity levels, somewhat less determinable due to the variety and unspecificity of stimulus arrangements, ranged from approximately 6-15 W. The present experiment utilized the following intensity levels which were considered to be representative of the range of intensity levels used in the current avoidance literature.

	Buzzer	Tone	Light
High	100 db	100 db	100 ft-c (15 W)
Medium	72 db	72 db	8.1 ft-c (7.5 W)
Low	45 db	45 db	.26 ft-c (3 W)

Dependent Variables:

Throughout the experiment, gross motor activity was measured in the two-way active avoidance chamber. Motor activity was defined as the total number of photo-cell beams broken during a specified time period. To prevent inaccurate activity counts due to repetitive breaking of a photo-cell beam by a moving head or tail of a stationary rat, the following limitation was imposed on the photo-electric relays. When a photo-cell beam was broken a 1-count output was recorded. After that no further counts could be recorded from that relay until another beam had been broken.

Another variable measured was shuttling. It was defined as the movement of the rat from one grid floor to the other. To register a shuttle when crossing from compartment to compartment the rat had to commit a majority of its weight to the other grid floor in order to depress the microswitches and produce a 1-count output. Once this occurred, no further counts could be recorded from the grid floor occupied by the rat until the microswitches on the other grid floor were activated. This prevented inaccurate shuttling counts produced by the rat jumping on the grid floor.

Procedure

Prior to any experimental manipulations all rats were randomly divided among the experimental groups which in turn were randomly assigned to a testing day order. Two groups were tested per day.

On the day preceding the testing day, each rat was removed from the home cage and allowed 10 min. to explore the avoidance chamber. On the following test day, each rat was again allowed a 10 min. pretest acclimation period in the avoidance chamber, immediately after which the experimental test was initiated automatically.

The experimental test consisted of 20 trials. Each trial consisted of the stimulus presentation for 10sec. followed by a 60 sec. intertrial interval (ITI). Following the test, the rat was returned to the home cage.

RESULTS

Initial data presentation involved the computation of mean motor activity scores for each stimulus condition across the warning stimulus period and six successive ITI periods within four blocks of 5 trials each. The mean motor activity scores are presented in Table 1.

For formal analyses, total motor activity in blocks of 5 trials was computed for each S within the warning stimulus period and each successive ITI period. A 3x3x7x4 analysis of variance of these scores evaluated the effects of three stimulus types and three intensity levels on motor activity during seven 10 second time periods across four blocks of trials. The results are shown in Table 2.

Due to the significant interactions obtained for Block x Period x Intensity x Stimulus ($F = 1.45$, $df = 72/648$, $p<.025$), Block x Period x Stimulus ($F = 2.36$, $df = 36/648$, $p<.001$) and Period x Intensity x Stimulus ($F = 2.38$, $df = 24/216$, $p<.001$), and the rigorous task of discerning all effects present in these higher order interactions, it seemed warranted to inspect the data by use of a simpler and more meaningful measure. Therefore, a relative measure of stimulus motor activity was computed. This measure, formulated by subtracting a mean ITI period activity score from the warning stimulus period activity score, eliminated the between animal to animal variability in activity across the time periods. It was felt that the essence of the data could be obtained through the use of such a measure. More important, this analysis allowed for the inclusion of the control group by formulating ten equal stimulus groups.

Table 1 presents the mean relative motor activity scores within each stimulus group for either the individual blocks or the mean of the combined blocks. Ideally, the relative activity score for the control group should equal zero indicating comparable motor activity across all time periods. Figure 1 graphically presents the mean relative motor activity scores for the control group and all stimulus groups for the combined blocks of trials at each intensity level. It seems that the Buzzer stimulus quantitatively elicits more motor activity than either the Tone or Light stimulus at any intensity. Furthermore, it appears that the LH stimulus may inhibit motor activity during the stimulus presentation.

A 10 x 4 analysis of variance was computed on the relative motor activity score for each S within ten stimulus groups for four blocks of 5 trials each. The results are presented in Table 3.

Subsequent Newman-Keuls multiple comparisons on the stimulus groups across trial blocks for the significant Stimulus x Block interaction ($F = 3.27$, $df = 27/120$, $p<.001$) indicated that with increasing blocks of trials there was less difference between stimulus groups in the levels of motor activity generated. Specifically, as Figure 2 indicates, within the first block of 5 trials there was no difference between the BM and BH groups but they both generated a greater level of motor activity than any other group ($p<.05$). In Blocks 2, 3, and 4 only the BH group sustained a level of motor activity that was significantly greater from all groups ($p<.05$). Also, during the first block of trials, significantly less motor activity was generated by the LH group than any other group ($p<.05$). This difference was not present in the remaining trial blocks.

To assess the extent to which activity correlated with shuttling from one compartment to the other, a Pearson product-moment correlation was computed on the number of shuttles made during the warning stimulus period and the total motor activity recorded for that period for each group. The correlation ($r = +.71$) indicated that a fairly high relationship existed between the activity level and the probability of making an avoidance response by shuttling.

TABLE 1

MEAN MOTOR ACTIVITY AND MEAN RELATIVE MOTOR ACTIVITY SCORES FOR STIMULUS GROUPS

		MEAN MOTOR ACTIVITY							MEAN RELATIVE MOTOR ACTIVITY	
		TIME PERIOD							CS-$\overline{ITI}$	
STIMULUS GROUP	TRIAL BLOCK	CS	1	2	3	4	5	6	SEPARATE INDIVIDUAL BLOCKS	COMBINED ALL BLOCKS
BH	1	38.8	9.2	9.6	15.2	15.2	13.8	13.8	26.1	
	2	25.2	3.4	6.0	10.6	8.0	5.4	7.8	18.6	17.6
	3	21.6	2.8	5.8	6.4	8.8	9.4	9.8	14.5	
	4	20.2	8.2	9.4	6.8	8.6	10.2	10.6	11.2	
BM	1	42.0	7.0	19.8	16.2	14.0	12.8	15.2	27.8	
	2	20.0	14.0	13.8	13.2	9.6	13.2	15.8	6.7	10.8
	3	14.4	13.8	13.8	12.4	9.2	11.0	11.2	2.5	
	4	13.8	10.6	10.0	12.2	4.4	6.2	4.6	5.9	
BL	1	23.0	9.8	15.4	19.0	14.2	12.6	13.6	8.9	
	2	12.2	10.4	11.0	11.8	11.2	14.8	14.0	0.0	4.1
	3	15.2	9.8	11.0	12.2	10.6	12.6	12.8	4.0	
	4	10.6	6.8	5.2	6.4	8.6	5.6	8.6	3.73	
LH	1	12.8	25.4	20.4	25.8	21.8	26.2	18.6	-10.2	
	2	21.4	21.4	21.6	15.6	23.4	18.0	20.8	1.3	-2.4
	3	18.0	21.0	18.0	20.0	17.6	19.2	13.2	-0.2	
	4	16.6	24.8	17.2	16.6	15.6	13.0	15.4	-0.5	
LM	1	23.2	27.2	22.4	18.8	18.4	21.6	12.2	3.1	
	2	22.4	20.6	14.2	14.0	15.8	14.6	13.4	6.6	3.0
	3	18.0	21.2	12.2	13.6	13.4	16.4	16.4	2.5	
	4	12.2	13.6	11.6	10.4	8.0	17.4	13.8	-0.3	
LL	1	14.0	15.0	17.4	15.4	14.6	16.0	20.4	-2.5	
	2	20.0	17.6	14.6	13.4	19.8	12.6	16.6	4.3	1.4
	3	14.2	11.0	9.8	12.2	11.4	13.0	10.8	3.0	
	4	13.0	14.4	13.2	15.8	11.6	12.2	6.8	0.7	

TABLE 1 CONTINUATION

		CS	1	2	3	4	5	6		
TH	1	27.4	8.8	18.4	14.4	17.6	18.0	17.2	11.7	
	2	15.8	15.8	14.6	15.0	12.6	11.6	13.2	2.0	5.3
	3	15.2	12.0	10.0	15.4	11.0	8.8	13.8	3.4	
	4	16.8	10.8	12.2	15.6	12.0	14.4	10.6	4.2	
TM	1	33.6	16.6	20.2	25.4	15.0	17.2	18.4	14.8	
	2	21.6	12.6	15.2	14.8	19.6	16.4	14.4	6.1	6.5
	3	17.8	17.0	12.4	15.2	17.4	17.6	18.8	1.4	
	4	15.0	14.0	9.6	15.0	8.2	9.8	11.2	3.6	
TL	1	19.2	18.8	10.6	11.8	13.8	17.8	15.8	4.4	
	2	17.6	15.2	10.6	13.2	12.2	11.0	15.2	4.7	2.8
	3	14.0	13.6	12.2	12.6	15.8	12.0	11.2	1.1	
	4	16.6	19.4	13.6	17.0	13.0	15.8	16.2	0.7	
C	1	23.0	25.8	22.4	21.2	23.8	20.0	17.8	1.2	
	2	16.0	20.8	16.4	16.4	19.6	19.0	12.2	-1.4	-0.1
	3	14.4	15.6	12.8	08.4	12.2	12.6	16.2	1.8	
	4	11.8	11.0	13.6	17.6	13.0	14.8	13.2	-2.0	

TABLE 2

ANALYSIS OF VARIANCE OF MOTOR ACTIVITY

SOURCE	df	SS	MS	F	p	ERROR TERM*
Blocks (4)	3	5841.81	1947.27	23.40	.001	2
Periods (7)	6	4714.17	785.69	19.87	.001	3
Intensity (3)	2	851.89	425.94	0.97	NS	3
Stimulus (3)	2	4205.15	2102.57	4.82	.025	1
BxP	18	1596.30	88.68	3.12	.001	4
BxI	6	991.40	165.23	1.98	NS	2
PxI	12	878.87	73.23	1.85	.05	3
BxS	6	527.26	87.87	1.05	NS	2
PxS	12	3710.28	309.19	7.82	.001	3
IxS	4	1689.81	422.45	0.96	NS	1
BxPxI	36	1219.91	33.88	1.19	NS	4
BxPxS	36	2410.31	66.95	2.35	.001	4
BxIxS	12	907.36	75.61	0.90	NS	2
PxIxS	24	2254.94	93.94	2.37	.001	3
BxPxIxS	72	2964.71	41.17	1.45	.025	4

*ERROR TERM	df	SS	MS
1	36	15699.22	436.08
2	108	8988.08	83.22
3	216	8539.07	39.53
4	648	18392.81	28.38

TABLE 3

ANALYSIS OF VARIANCE OF RELATIVE MOTOR ACTIVITY

SOURCE	*df*	*SS*	*MS*	*F*	*p*	ERROR TERM*
Groups (10)	9	5964.75	662.75	6.45	.001	1
Blocks (4)	3	1004.64	334.88	8.69	.001	2
GxB	27	3399.48	125.90	3.27	.001	2

*ERROR TERM	*df*	*SS*	*MS*
1	40	4107.24	102.68
2	120	4619.59	38.49

Figure 1. Mean relative motor activity levels for control and stimulus groups across intensities.

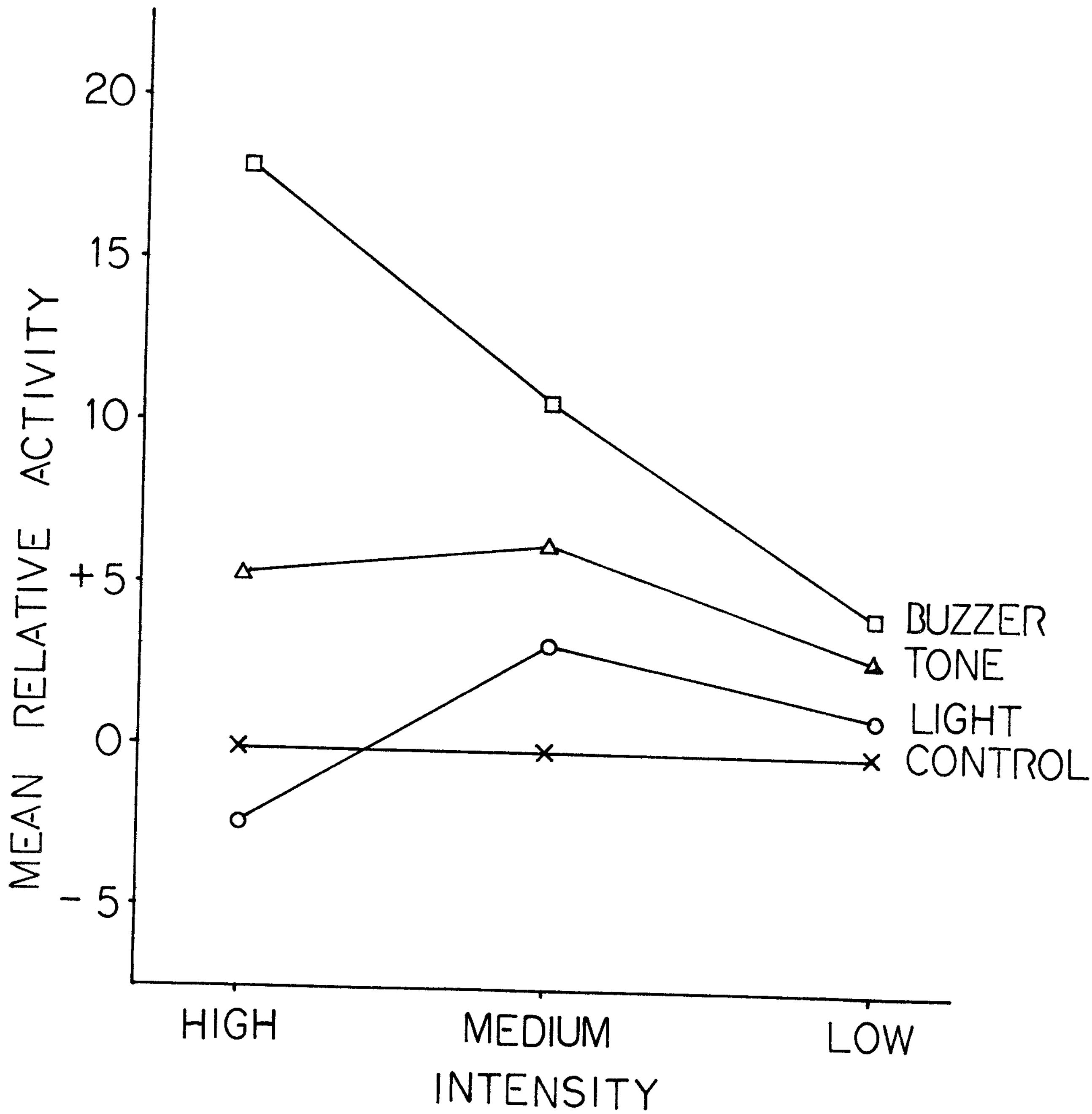
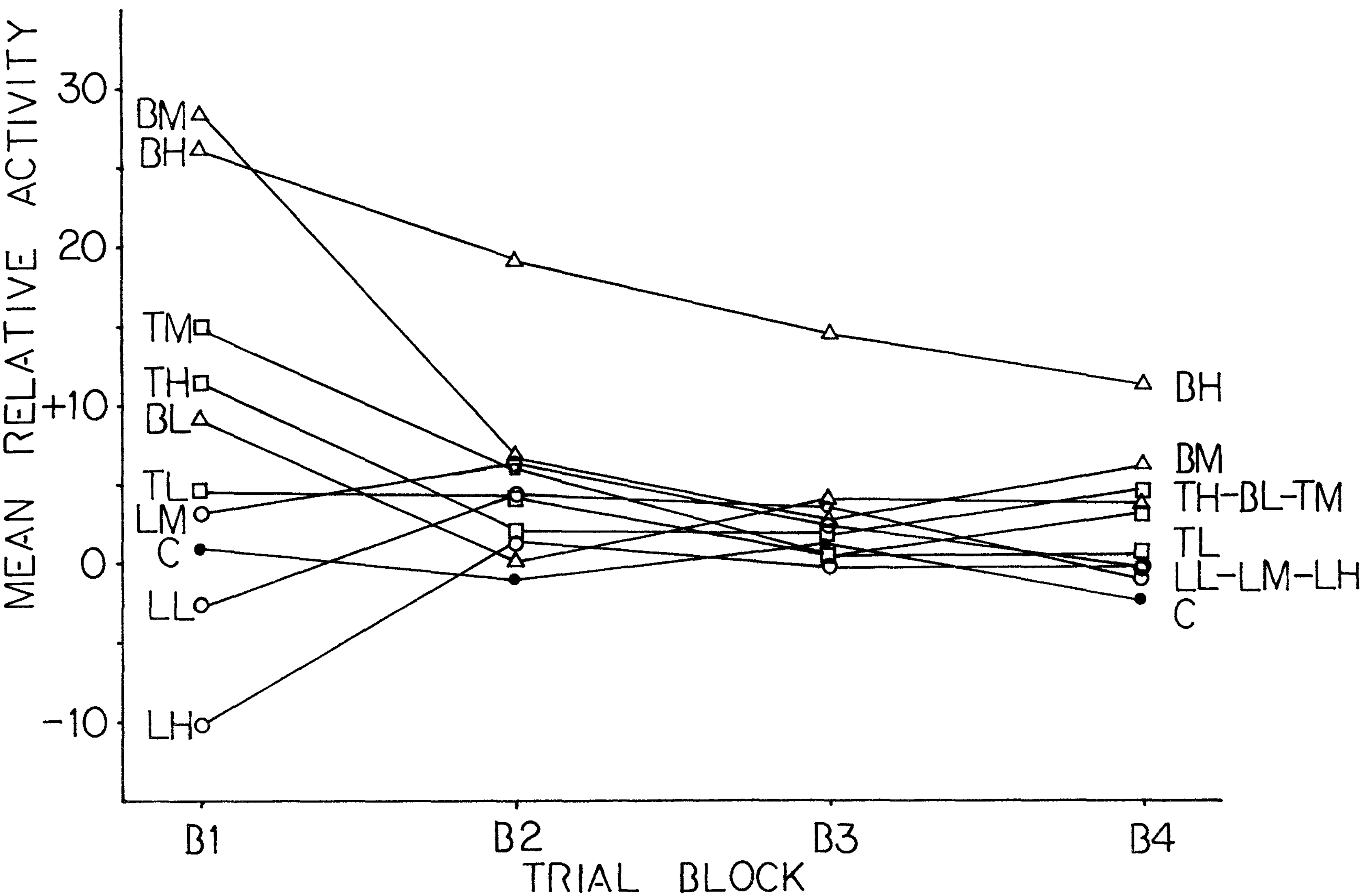

MEAN RELATIVE ACTIVITY
20
15
10
+5
0
-5
BUZZER
TONE
LIGHT
CONTROL
HIGH
MEDIUM
LOW
INTENSITY

Figure 2. Mean relative motor activity levels for control and stimulus groups across trial blocks.


MEAN RELATIVE ACTIVITY
30
20
+10
0
-10
BM
BH
TM
TH
BL
TL
LM
C
LL
LH
BH
BM
TH-BL-TM
TL
LL-LM-LH
C
B1
B2
B3
B4
TRIAL BLOCK

DISCUSSION

The results of Experiment I support the experimental hypothesis that different warning stimuli generate different amounts of gross motor activity and that motor activity is an unconditioned response to the stimulus. Specifically, a buzzer stimulus generates more motor activity than does a light stimulus, while motor activity generated by a tone stimulus was intermediate to that generated by light and buzzer stimuli.

The motor activity generated by the buzzer and tone was greatest during the stimulus presentations and was not sustained across succeeding intertrial interval periods. In contrast, the light stimulus recorded the greatest motor activity during the first intertrial interval period. Although motor activity diminished across succeeding ITI periods, it remained low when the light stimulus was presented. These findings suggest that certain stimuli, such as a buzzer or tone, may augment activity levels during their presentations while other stimuli, such as light, may inhibit activity. The relative measure of stimulus activity portrays quite clearly the inhibiting effect of light on motor activity as compared to the buzzer. The Buzzer High, Buzzer Medium and Tone Medium were all significantly greater in the motor activity generated than the Light High group.

The results failed to confirm any systematic difference in motor activity between high, medium or low intensities across stimuli. However within the buzzer stimulus, motor activity was greater with each increasing intensity. In the Light stimulus, the least motor activity was shown by the high intensity while no difference existed between the low or medium intensities. No differences were shown across intensities with the Tone stimulus.

The findings of Experiment I show that different stimuli elicit different amounts of unconditioned motor activity. If avoidance performance varies according to the amount of motor activity present during the warning stimulus period, then the findings demonstrate that the necessary condition for the hypothesized relationship exists. However, it must be remembered that the response measure employed (the number of photo-cell beams broken) is not directly analogous to that obtained in an avoidance learning situation where only the first shuttle response is measured. A question relevant to shuttle avoidance learning is whether or not a shuttle response occurs to the warning stimulus on a given trial. In an attempt to assess this, the number of shuttles and the total activity recorded during the warning stimulus period were correlated. A fairly high correlation of +0.71 was obtained reaffirming the common-sense notion that the greater the motor activity, the greater the probability of a shuttle response occurring.

EXPERIMENT II

As a logical step in the evaluation of the effect of unconditioned motor activity on shuttle avoidance, Experiment II was designed to determine the effect of shock on the unconditioned motor activity levels shown in Experiment I.

METHOD

Subjects

Fifty-four male Hooded rats, all but four previously tested in Experiment I, were housed in individual standard wire cages at the rat colony of Wilfrid Laurier University. The Ss weighing approximately 300-500 gm, were maintained ad libitum on food and water for the duration of the experiment.

Apparatus

The apparatus was identical to that described for Experiment I except that a shock generator (Grason-Stadler, Model 700) was added. Every second grid rod was wired in series with the option of delivering shock separately to each compartment. For the present Experiment, connections were made between grid floors so that shock could be delivered simultaneously to both compartments.

Experimental Design

Independent Variables:

The design consisted of six groups with 9 rats each. Each group was administered one of the following stimulus presentations: Buzzer High (BH), Buzzer Medium (BM), Light High (LH), Light Medium (LM), Tone High (TH), and Tone Medium (TM). Intensity levels were identical to those used in Experiment I. Since a larger number of Ss per group was desired, the low intensity groups were arbitrarily excluded due to the unavailability of rats. All rats were randomly divided among the experimental groups with the stipulation that the same stimulus presentation as experienced in Experiment I could not be assigned again. All groups were administered non-contingent shocks of 0.5 ma intensity during the experimental test.

Dependent Variables:

As in Experiment I, gross motor activity and shuttling responses were measured continuously throughout the experiment.

Procedure

Each group was randomly assigned to a testing day order with one group tested per day. On the test day, each rat was allowed a 10 minute pre-test acclimation period in the avoidance chamber, immediately after which the experimental test was initiated.

The experimental test consisted of 40 trials. Each trial consisted of a 13 second stimulus presentation which co-terminated with a 3 second shock. A 60 second intertrial interval followed. Concluding the test, the rat was returned to the home cage.

RESULTS

Initial data presentation involved the computation of mean motor activity scores for each stimulus condition within the warning stimulus period and six successive ITI periods across eight blocks of five trials each. Table 1 presents these mean motor activity scores.

For formal analyses, total motor activity in blocks of five trials was computed for each S within the warning stimulus period and each successive ITI period. A 3 x 2 x 7 x 8 analysis of variance of these scores evaluated the between effects of three stimulus types and two intensity levels on motor activity within seven 10 second periods across eight blocks of trials. The results are shown in Table 2.

The significant Period x Stimulus interaction ($F = 7.09$, $df = 12/288$, $p < .001$) was further analyzed using the Newman-Keuls test for multiple comparisons (Winer, 1971). As Figure 1 indicates, motor activity was greatly increased during the first ITI period following shock administration. This activity decreased rapidly within the following ITI periods. However, with the stimulus presentation, motor activity was significantly increased for the Buzzer and Tone stimuli as compared to the last ITI period ($p < .05$). The Light stimulus showed no significant increase in motor activity over the preceding ITI period.

During the warning stimulus period both the Buzzer and Tone stimuli generated significantly greater motor activity than the Light stimulus ($p < .05$). No significant difference existed between the Buzzer and Tone stimuli. During Period 2 following shock presentation, motor activity was greatly increased for all stimuli ($p < .05$) and especially for the Light group which showed significantly greater activity than either the Buzzer or Tone group ($p < .05$).

As in Experiment I, a relative stimulus activity measure was computed by subtracting a mean ITI period activity score from the warning stimulus period activity score. This eliminated the between animal to animal variability in activity across time periods. Table 1 presents the mean relative motor activity scores within each stimulus group for either the individual blocks or the mean of the combined blocks. Figure 2 graphically presents the mean relative motor activity scores for each stimulus group for the combined blocks of trials at each intensity level.

A 6 x 8 analysis of variance was computed on the relative motor activity scores for each S within six stimulus groups for eight blocks of 5 trials each. The results are shown in Table 3.

Subsequent Newman-Keuls analyses on the Stimulus main effect showed that all stimulus groups generated significantly greater motor activity than the LH group ($p<.05$). Also the BH, BM and TH groups elicited significantly greater motor activity than the LM group ($p<.05$).

A Pearson product-moment correlation of shuttle responses and total activity during the warning stimulus period was also computed to see if shuttle responses increased with motor activity. The correlation revealed a very high linear relationship between the measures ($r = +99$, $p<.01$).

TABLE 1

MEAN MOTOR ACTIVITY AND MEAN RELATIVE MOTOR ACTIVITY SCORES FOR STIMULUS GROUPS

MEAN MOTOR ACTIVITY									MEAN RELATIVE MOTOR ACTIVITY	
STIMULUS GROUP	TRIAL BLOCK	TIME PERIOD CS	1	2	3	4	5	6	CS-ITI INDIV. BLOCKS	COMB. BLOCKS
BH	1	18.0	17.2	6.6	7.0	5.6	4.0	4.1	10.5	
	2	12.0	18.4	11.6	6.6	7.7	4.8	3.1	3.2	
	3	7.1	14.0	5.2	3.6	2.1	1.3	2.0	2.3	
	4	11.0	14.3	7.5	5.1	3.5	2.4	1.6	5.2	4.2
	5	9.0	14.5	5.4	2.6	1.0	2.1	2.8	4.2	
	6	7.6	13.4	6.1	3.3	3.3	2.5	3.2	2.3	
	7	7.7	14.8	6.6	4.7	2.7	2.6	2.3	2.0	
	8	9.0	14.3	6.3	2.6	3.4	1.8	1.5	3.9	
BM	1	18.5	15.8	8.7	6.2	6.0	5.5	7.4	9.2	
	2	8.8	14.1	7.7	6.7	3.6	4.2	3.1	2.3	
	3	6.6	17.2	7.5	6.0	2.4	3.1	1.6	0.3	
	4	10.2	12.2	5.3	3.5	1.4	2.2	1.4	5.6	2.9
	5	8.2	12.5	5.3	5.5	3.2	2.3	3.1	3.0	
	6	5.3	14.0	3.7	3.3	2.4	1.5	1.1	1.5	
	7	5.4	12.7	6.7	4.5	3.4	1.4	2.4	0.2	
	8	4.0	8.1	3.4	1.5	1.0	0.6	0.4	1.4	
LH	1	4.7	30.0	12.2	10.0	7.1	5.5	4.8	-6.8	
	2	2.5	28.2	10.5	3.8	2.1	1.7	1.7	-5.4	
	3	4.2	28.0	10.7	5.6	3.6	3.2	2.3	-4.7	
	4	2.7	25.0	10.8	5.4	2.6	3.3	2.7	-5.9	-5.6
	5	2.5	26.5	10.0	6.8	3.3	2.3	2.0	-5.9	
	6	2.1	23.6	8.5	4.7	4.8	3.0	2.2	-5.6	
	7	1.5	21.7	7.1	4.1	4.7	4.0	3.3	-5.9	
	8	2.6	22.4	9.1	5.6	2.4	2.2	3.1	-4.8	

TABLE 1 CONTINUATION

		CS	1	2	3	4	5	6		
LM	1	9.3	32.0	22.1	11.1	9.7	5.3	5.2	-4.8	
	2	5.0	24.8	12.8	7.5	3.8	4.3	3.6	-4.5	
	3	7.6	24.4	13.6	8.2	5.3	4.4	3.1	-2.2	
	4	7.1	26.0	8.1	6.0	3.1	3.8	5.2	-0.8	-1.9
	5	7.6	23.4	10.7	7.1	3.8	3.2	5.1	-1.2	
	6	8.7	24.1	12.0	3.7	3.5	4.0	2.3	0.4	
	7	7.7	24.7	10.3	3.5	4.5	3.2	2.2	-0.3	
	8	6.7	29.8	7.5	3.8	4.6	2.8	2.7	-1.8	
TH	1	19.6	20.6	16.3	11.2	8.7	9.8	10.2	6.8	
	2	8.2	12.7	8.5	6.5	6.3	5.5	5.2	0.7	
	3	10.2	11.2	8.0	6.8	6.0	3.8	5.3	3.4	
	4	11.8	13.1	8.4	9.3	4.7	4.7	6.0	4.1	2.3
	5	7.2	11.7	7.2	4.7	3.0	3.5	2.7	1.7	
	6	10.0	15.8	10.4	8.6	6.1	7.3	6.3	0.8	
	7	7.1	14.1	8.5	4.6	4.6	3.5	3.2	0.7	
	8	5.7	12.6	6.2	5.0	3.7	3.7	2.5	0.1	
TL	1	12.1	28.2	12.8	6.6	7.3	8.7	5.4	1.6	
	2	5.8	19.2	12.6	5.4	6.8	4.5	4.5	-2.9	
	3	8.2	18.8	10.1	6.2	4.4	4.3	3.4	0.3	
	4	7.5	16.4	5.3	5.1	3.0	3.4	3.2	1.4	1.0
	5	8.8	15.2	5.5	4.0	1.6	3.1	3.2	3.4	
	6	9.6	22.7	7.2	5.7	6.2	3.7	3.4	1.4	
	7	7.7	19.0	9.8	4.7	2.4	3.6	3.2	0.6	
	8	10.7	20.5	8.3	7.0	5.5	4.6	4.2	2.3	

TABLE 2

ANALYSIS OF VARIANCE OF MOTOR ACTIVITY

SOURCE	df	SS	MS	F	p	ERROR TERM*
Blocks (8)	7	7099.51	1014.22	14.74	.001	2
Periods (7)	6	78177.35	13029.56	92.99	.001	3
Intensity (2)	1	58.33	58.33	0.10	NS	1
Stimulus (3)	2	3030.54	1515.27	2.54	NS	1
BxP	42	1151.94	27.43	1.43	.05	4
BxI	7	215.15	30.74	0.45	NS	2
PxI	6	279.81	46.64	0.33	NS	3
BxS	14	1263.37	90.24	1.31	NS	2
PxS	12	11927.43	993.95	7.09	.001	3
IxS	2	645.87	332.94	0.54	NS	1
BxPxI	42	717.81	17.09	0.89	NS	4
BxPxS	84	2107.18	25.08	1.31	NS	4
BxIxS	14	991.63	70.83	1.30	NS	2
PxIxS	12	1881.59	156.80	1.12	NS	3
BxPxIxS	84	1444.91	17.20	0.90	NS	4

*ERROR TERM	df	SS	MS
1	48	28655.63	597.00
2	336	23115.95	68.80
3	288	40354.67	140.12
4	2016	38723.30	19.21

TABLE 3

ANALYSIS OF VARIANCE OF RELATIVE MOTOR ACTIVITY

SOURCE	df	SS	MS	F	p	ERROR TERM*
Groups (6)	5	4879.95	975.99	12.19	.001	1
Blocks (8)	7	571.12	81.67	2.98	.01	2
GxB	35	1316.78	37.62	1.37	NS	2

*ERROR TERM	df	SS	MS
1	48	3840.12	80.00
2	336	9193.51	27.36

Figure 1. Mean motor activity levels for stimuli across warning stimulus (1) and successive ITI periods (2-7).

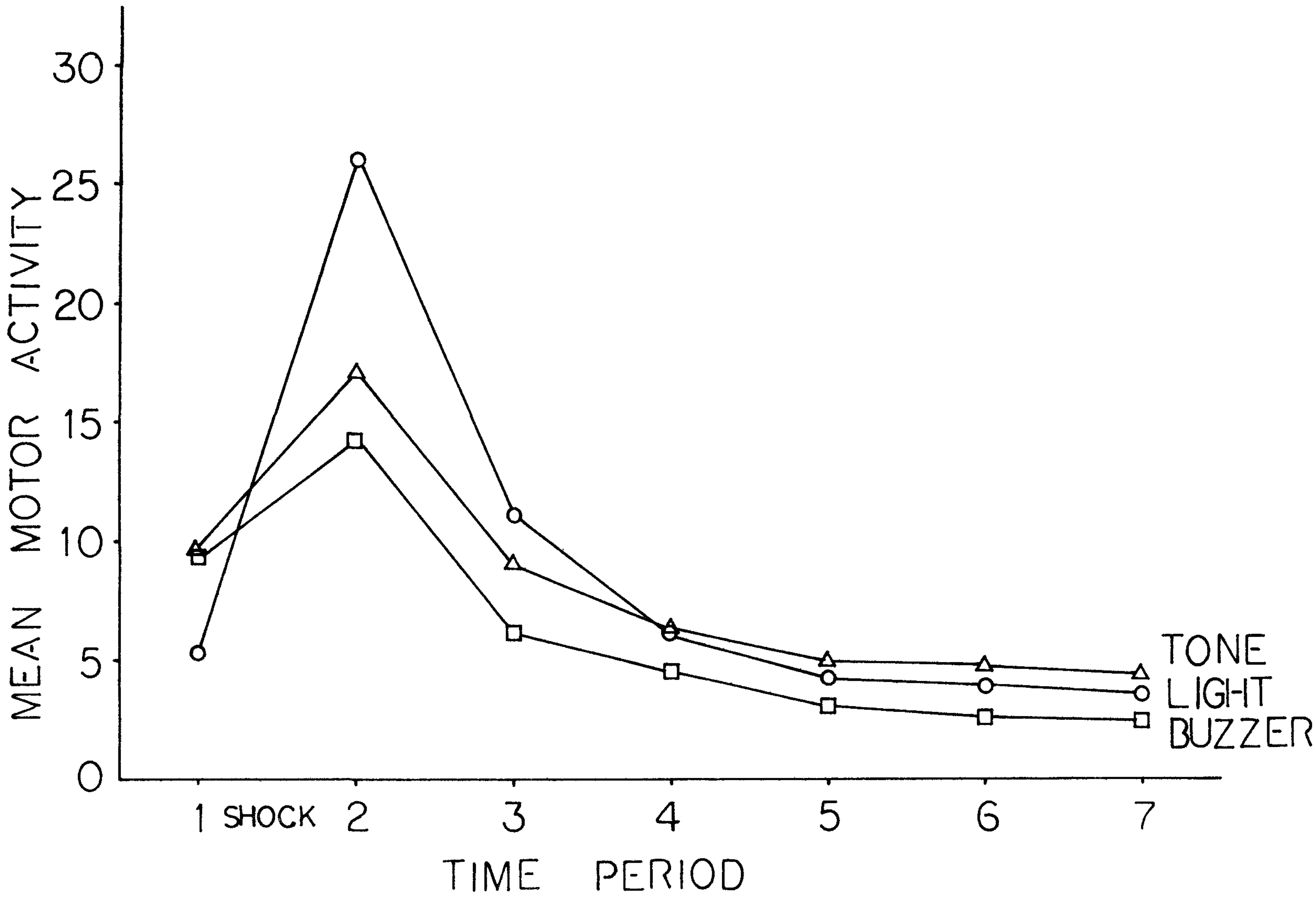
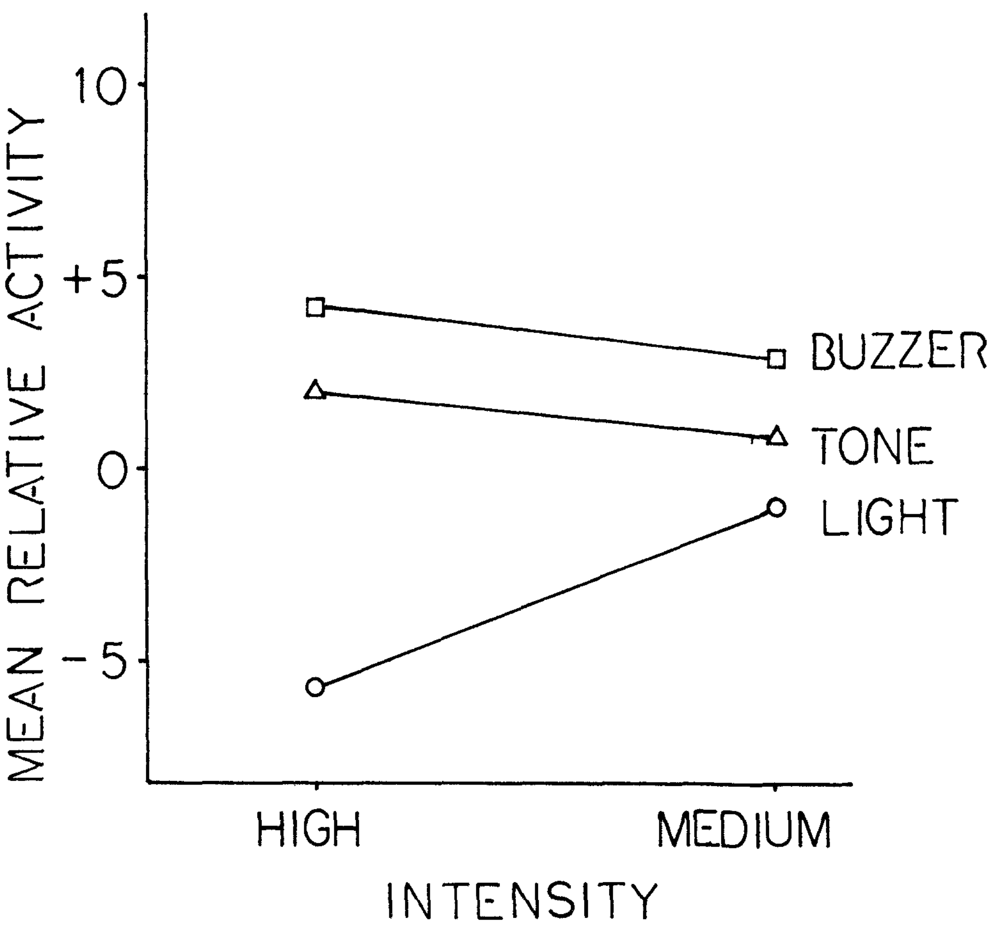

MEAN MOTOR ACTIVITY
0
5
10
15
20
25
30
1 SHOCK 2
3
4
5
6
7
TIME PERIOD
TONE
LIGHT
BUZZER

Figure 2. Mean relative motor activity levels for stimulus groups across intensities.


MEAN RELATIVE ACTIVITY
10
+5
0
-5
BUZZER
TONE
LIGHT
HIGH
MEDIUM
INTENSITY

DISCUSSION

The results of Experiment II suggest that the introduction of shock greatly reduces the amount of unconditioned motor activity generated by warning stimuli. However, the activity generated during the warning stimulus period was significantly greater than the motor activity present during the preceding intertrial interval period. Specifically, significantly greater motor activity was generated by the Buzzer and Tone stimulus conditions than either of the Light conditions. These findings are analogous with those of Experiment I in that a buzzer stimulus particularily produces more motor activity during its presentation than a light stimulus.

It is possible that the reduction of motor activity levels for all stimuli was due to the previous experience with a different warning stimulus presented in Experiment I. Although it is possible that the depression of motor activity levels may be due to the previous presentation to a novel stimulus, it is not plausible that such a presentation would affect another stimulus in the present situation.

An interesting finding noted during Experiment I and again demonstrated in Experiment II was that the stimulus which generated the lowest motor activity during the stimulus presentation period generated the highest activity during the first ITI period. If light is a suppressor of motor activity as suggested by Experiment I, perhaps the control over activity which is exerted during its presentation is released during the first safe period. The operation of such a mechanism is further suggested by the fact that the buzzer, which generated the most activity during its presentation, produced the least activity during the first ITI period.

In avoidance conditioning shock is related to avoidance or escape response contingencies. Experiment II allowed neither of these response contingencies, and a decrease in motor activity levels was noted relative to Experiment I. Yet, the motorigenic properties of the warning stimuli were not completely masked. Perhaps if shock were response-contingent, the motor activity levels would not be so adversely affected and the motorigenic property of a stimulus might prove to be an influential variable in the emergence of avoidance responding.

EXPERIMENT III

If avoidance performance is a function of motor activity present during the stimulus presentation, then the level of avoidance performance should be predictable knowing the amount of unconditioned motor activity generated by the warning stimulus. In other words, if a buzzer and a tone generate comparable amounts of motor activity during their presentations, then the levels of avoidance performance by use of these stimuli should be similiar.

The purpose of Experiment III was to investigate the effect of motorigenic stimuli on two-way active shuttle avoidance performance. Three stimulus presentation groups were chosen based upon unconditioned motor activity levels obtained during their previous presentations in Experiments I and II. It was hypothesized that the Buzzer Medium group would demonstrate comparable avoidance performance to the Tone Medium group since both stimuli generate comparable amounts of motor activity. Furthermore it was hypothesized that the Buzzer Medium and Tone Medium groups would demonstrate better avoidance performance than the Light High group, since the Light High stimulus produced the least motor activity of the three groups.

METHOD

Subjects

Thirty naive male Hooded rats, weighing 225-250 gm, were procured from Canadian Breeding Farm and Laboratories and housed individually in standard wire cages at the rat colony of Wilfrid Laurier University. The Ss were maintained ad libitum on food and water throughout the experiment.

Apparatus

The two-way active avoidance chamber described in Experiments I and II was used. Stimulus presentations were programmed so that they could be presented to either side of the avoidance chamber depending on the location of the rat. Similiarly, shock could be presented independently to either grid floor following the stimulus presentation. Both the stimulus presentation and shock were terminated by a 1-count shuttle output.

A digital millisecond stopclock (Venner Electronics, Type TSA-3314) was programmed to record latency times. All pre-experimental activity counts and shuttle responses were recorded on counters.

Experimental Design

Independent Variables:

The design consisted of three groups with 10 rats each. Only three groups were tested because of a limitation on the number of rats available for experimentation. The following groups were tested: Buzzer Medium (BM), Tone Medium (TM), Light High (LH). These groups were selected on the basis of the previous experiments which showed the BM and TM groups to be comparable in the amount of motor activity present during stimulus presentation, and LH group to consistently lower in motor activity than either the BM or TM group.

Stimulus intensity levels were identical to those used in Experiment I. Shock, if administered, was of 0.5 ma intensity.

Dependent Variables:

Latency time from stimulus onset to stimulus offset were recorded for each trial. Gross motor activity and shuttling counts were recorded only during the acclimation and pre-test periods.

Procedure

All rats were randomly assigned to an experimental group. Two rats from each group were tested per day with the testing order for groups randomly assigned.

On the day preceding testing, each rat was removed from the home cage and allowed 10 minutes to explore the avoidance chamber. On the following test day, each rat was again allowed a 10 minute pre-test acclimation period in the avoidance chamber, immediately after which the experimental test was initiated.

The experimental test consisted of 100 trials. A delayed conditioning procedure was used for avoidance training. Each trial consisted of the stimulus presentation for 10 seconds followed by 20 seconds of shock. An escape response terminated both the warning stimulus and the shock, while an avoidance response terminated the warning stimulus and prevented shock onset. An avoidance or escape response was determined by a shuttle response when the rat moved to the opposite compartment. The intertrial interval was 60 seconds. Following the test, the rat was returned to the home cage.

RESULTS

The mean latency response times for blocks of 10 trials were computed for each S. Initial data presentation involved the computation of the mean latency response times for each stimulus group across ten blocks of trials. Table 1 presents these mean latency response times.

A 3 x 10 analysis of variance evaluated the mean latency response time scores between the three stimulus groups across ten blocks of 10 trials each. The results are shown in Table 2. The significant Block main effect ($F = 13.45$, $df = 9/243$, $p<.001$) was further analyzed with the Newman-Keuls test for multiple comparisons. As Figure 1 displays, the first three blocks of trials were significantly different from the remaining seven blocks of trials ($p<.05$). By trial 40, latency times for avoidance responding had reached a plateau which continued for the remaining trials.

The mean trial in which the first five consecutive avoidances began was computed for each stimulus group. The TM group averaged five consecutive avoidance responses beginning at trial 24.6. The LH group began at trial 42.3 while the BM group started at trial 46.3.

Table 3 presents the avoidance responses made by each stimulus group S across four blocks of 25 trials. The percent avoidance for 100 trials is also shown for each rat. The mean percent avoidance computed for each group showed the TM group with 73.6% avoidance while the LH and BM groups had 56.8% and 51.8% avoidance responding respectively.

In summary, the results of Experiment III show no differences exist between the BM, TM, and LH warning stimulus groups and their latency response times over 100 trials of active two-way shuttle avoidance.

TABLE 1

MEAN LATENCY RESPONSE TIMES (secs.)

FOR STIMULUS GROUPS ACROSS TRIAL BLOCKS

STIMULUS GROUP	TRIAL BLOCK 1	2	3	4	5	6	7	8	9	10
BUZZER MEDIUM	11.9	8.8	7.7	6.8	7.7	7.1	7.3	8.3	6.6	7.3
LIGHT HIGH	11.9	10.2	8.8	7.8	7.2	7.1	7.4	7.2	8.4	9.1
TONE MEDIUM	10.7	7.1	5.3	4.1	4.4	4.2	4.1	3.8	3.7	4.1

TABLE 2

ANALYSIS OF VARIANCE OF LATENCY RESPONSE TIMES

SOURCE	df	SS	MS	F	p	ERROR TERM*
Groups (3)	2	644.08	322.04	1.62	NS	1
Blocks (10)	9	781.01	86.77	13.45	.001	2
GxB	18	83.87	4.65	0.72	NS	2

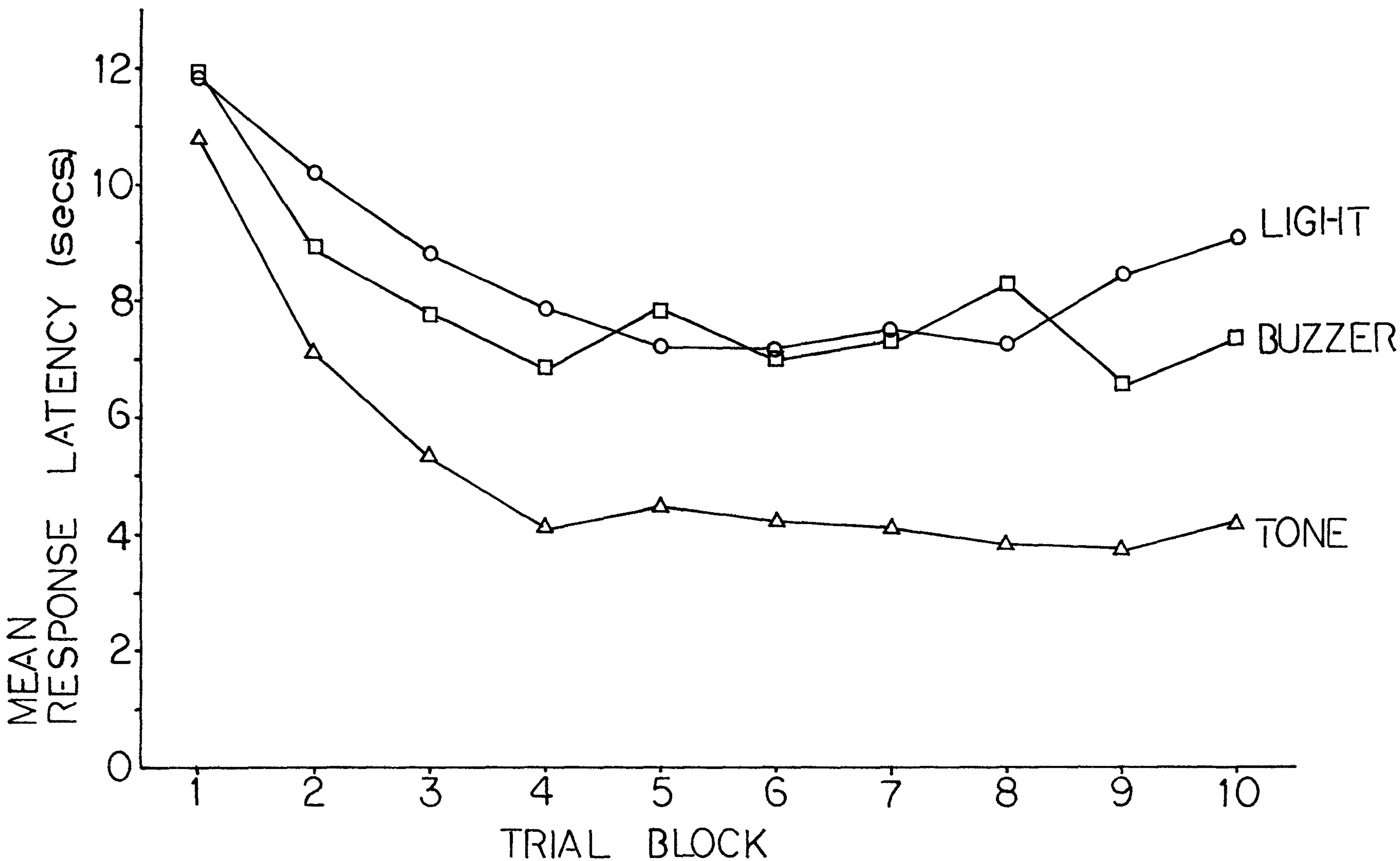
*ERROR TERM	df	SS	MS
1	27	5365.39	198.71
2	243	1567.53	6.45

TABLE 3

AVOIDANCE RESPONSES AND PERCENT AVOIDANCE
FOR STIMULUS GROUP SUBJECTS ACROSS BLOCKS OF 25 TRIALS

Stimulus Group Subjects		Trial Block				% Avoidance	
		1	2	3	4	S	Group
BM	1	13	20	12	11	56	
	2	11	22	25	24	82	
	3	3	4	2	3	12	
	4	14	20	23	23	80	
	5	1	6	23	25	55	51.8
	6	10	25	18	17	69	
	7	4	16	25	24	69	
	8	10	19	2	8	39	
	9	5	1	11	9	26	
	10	9	14	5	2	30	
LH	1	0	0	0	0	0	
	2	19	24	24	24	91	
	3	10	25	24	24	83	
	4	17	25	25	25	92	
	5	4	19	23	25	71	56.8
	6	9	23	21	13	67	
	7	3	1	2	1	7	
	8	0	18	16	7	41	
	9	0	10	24	24	58	
	10	5	19	22	13	59	
TM	1	7	10	9	18	44	
	2	13	19	23	24	79	
	3	16	24	24	23	87	
	4	9	22	18	22	71	
	5	16	24	22	21	83	73.6
	6	11	19	24	25	79	
	7	7	14	24	23	68	
	8	5	6	20	22	53	
	9	12	24	25	24	85	
	10	14	25	24	24	87	

Figure 1. Mean response latency times (secs.) for stimulus groups across trial blocks.


MEAN RESPONSE LATENCY (secs)
0
2
4
6
8
10
12
1
2
3
4
5
6
7
8
9
10
TRIAL BLOCK
LIGHT
BUZZER
TONE

OVERALL DISCUSSION

Taken together, the results of the present investigations indicate that the amount of unconditioned motor activity generated by a warning stimulus in an avoidance paradigm bears no direct relationship to subsequent avoidance performance. Contrary to results in previous studies (Myers, 1959, 1964; Biederman, 1967; Frontali and Bignami, 1973; Rosic, Frontali and Bignami, 1969), the buzzer, tone and light warning stimuli demonstrated similar avoidance performance, even though their unconditioned motor activity levels were different.

The results of Experiments I and II show support for the hypothesis of Rosic et al. (1969) that warning stimuli vary in the amount of unconditioned motor activity generated during stimulus presentations. Specifically, the Light High group exhibited significantly less motor activity during its stimulus presentations than the Tone Medium, Buzzer Medium and Buzzer High groups. These stimuli group differences were present in Experiment II, even though with the introduction of shock the amount of motor activity decreased during the stimulus presentations. Furthermore, the results of these experiments showed that stimuli differ in the amount of motor activity generated during the warning stimulus period as compared to the activity generated during the preceding ITI period. Whereas most Buzzer and Tone stimuli generated significantly greater activity during the warning stimulus periods, the Light stimuli, especially the LH group, showed significantly less activity. These results corroborate the findings of Cicala et al. (1973) that motor activity during the warning stimulus period is lower among shocked than nonshocked animals, and that activity during the warning stimulus period is greater than during the period immediately preceding the presentation of the warning stimulus.

Cicala et al. (1971) have suggested on the basis of their results that warning stimuli may function as excitors of activity. Rosic et al. (1969) and Frontali and Bignami (1973) have suggested that certain warning stimuli may function as excitors of motor activity while others may function as inhibitors. Experiments I and II corroborate these assumptions with data suggesting that a buzzer and tone act as excitors of activity and a light as an inhibitor of activity during the stimulus presentation period.

One might speculate that the decreased motor activity elicited by the light stimulus was due to a salience effect where the buzzer and tone stimuli were more noticeable than light. The present study attempted to control for salience by presenting all stimuli from the same position below the grid floor. Furthermore, good separation of compartments was achieved by a partition separating compartments below the grid floor.

A peculiar effect noted during Experiments I and II suggest that the Light High stimulus functions as an inhibitor or suppressor of activity. During the warning stimulus period, the Light High group generated a very low level of motor activity. However, with stimulus offset a great amount of activity was displayed in the first ITI period. This suggests that the inhibitory effect exerted by the light stimulus over motor activity during its presentation is released during the first safe period. The operation of such a mechanism which is also seen in the Buzzer High group but in an opposite direction suggests that the salience hypothesis is doubtful.

An interesting finding in the present study was the fairly high level of shuttle avoidance demonstrated by all three warning stimuli in Experiment III. These results suggest that even though the light stimulus has a lower probability of a shuttle response being emitted than other stimuli since less motor activity is generated during the warning stimulus period, avoidance performance does not seem to be affected. Indeed, the amount of unconditioned motor activity generated to a stimulus presentation does not appear to be a critical factor in determining shuttle avoidance performance.

Previous descriptions by Rosic et al.(1969) had suggested that a tone was a very poor warning stimulus. Myers (1964) had suggested that a buzzer was a better warning stimulus than a light. Unfortunately, the data offer no certain explanation for the present result; however, one might speculate that some unusual effect augmented the avoidance performances such as the following.

Typically, avoidance training occurs in an apparatus much smaller then the one presently used. In such a case, the rat has little choice but to "step" onto the other compartment if the shock is to be escaped or avoided. Perhaps, in a small compartment such as that, the level of fear is greatly increased because the rat is confined in an area which offers little opportunity for escape. Weiss, Krieckhaus and Conte (1968) have shown in avoidance training that fear not only facilitates adaptive responding but that it can also interfere with it by eliciting unconditioned competing responses, such as freezing. Therefore, whereas a small avoidance chamber might cause increased fear and thus increased freezing leading to very poor avoidance performance, a larger chamber such as the present apparatus might decrease fear to a level for optimum response facilitation. Furthermore, just as the rats reacted differently to warning stimuli in the amounts of unconditioned motor activity generated, so might they react differently in the amount of freezing elicited by warning stimuli. Therefore, in a small avoidance chamber where initial fear of the situation is greater, the tone or light might produce more freezing behavior than a buzzer.

Avoidance conditioning is a complex phenomenon involving numerous interactions between many variables. Although the present investigation did not show a significant relationship between motorigenic stimuli and shuttle avoidance, the importance of stimulus modality effects must still be considered in relation to response requirements and other stimulus factors. The impressive data showing that warning stimuli vary in the amounts of unconditioned motor activity generated during their presentations warrant the further examination of this variable as a major source of variance in avoidance experiments.

FOOTNOTES

[1] Rosic et al. (1969) defined noise as "a loud noise from a buzzer". They reported that in a preliminary study no differences were found between buzzer noise and speech noise on the difficulty factor of learning discriminations. Therefore they switched in later experiments to speech noise for better control of the intensity level. This noise was produced by a Grason-Stadler generator (Model 901B). In the present experiment, Rosic's terminology of "noise" has been retained; however, it should be noted that the effects of light and buzzer are really being compared.

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