

Habituation of the orienting response to auditory and visual stimuli in rats trained to press a bar

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Abstract. Habituation of the effects elicited by presentation of novel auditory (wide band noise) and visual (darkness) stimuli on on-going bar pressing for food was studied in 48 male hooded rats. Novel stimuli elicited a decrease of the bar press rate. This attenuating effect was the strongest on the first onset of the stimulus of a given modality and then slowly decayed during the stimulus action. The effect from the noise stimulus habituated more rapidly than that elicited by darkness. Then, noise onset enhanced bar pressing, and termination of the noise decreased the response rate. In contrast, termination of the darkness increased the response rate. The difference between auditory and visual stimuli in rapidity of change from attenuating to facilitating effects was more evident for shorter than for longer stimuli durations. Summation of data from repetitive presentations revealed an overall attenuating effect of the visual stimulus and a facilitating effect of the auditory stimulus on bar press rate.

Key words: orienting response, habituation, stimulus modality, stimulus duration, bar presses, rat

INTRODUCTION

The orienting response is a complex inborn reaction of an organism to a novel stimulus or to a change in level of stimulation. Many effectors are involved in execution of this response. One component of the orienting response consists of the movement directing the head towards the source of stimulation, aimed for optimal reception of the stimulus (Sokolov 1963, Konorski 1967, Buzsáki 1982, Żernicki 1987). Thus, a novel stimulus presented to an organism involved in any kind of innate or acquired repetitive behaviour (searching, walking, licking, bar pressing for food, or shuttling back and forth, as in the Sidman avoidance procedure) elicits a short arrest of the on-going behaviour.

In early studies of rats employing the Estes-Skinner (1941) conditioned emotional response (CER) method, it was noted that the presentation of a novel stimulus decreased the frequency of bar presses reinforced intermittently by food. This attenuating effect was stronger and persisted longer for more intense stimuli (Kamin and Brimer 1963). However, even in the case of salient stimuli, consisting of an interrupted tone and pulsated light compound, the unlearned attenuating effect underwent rapid habituation (Domjan and Siegel 1971).

Prior to the introduction of Pavlovian contingencies in typical CER experiments, the inborn effects of the to-be conditioned stimuli were tested by presenting them repeatedly alone during a pretest session (Annau and Kamin 1961). Since data were reported for blocks of stimulus presentations, and stimuli of long duration were employed, their initial interactions with the on-going bar press behaviour were neglected. Effects of stimuli on response rate observed later were assigned only to conditioning. However, studies employing other procedures provided convincing arguments indicating the predictive value of orienting response parameters for the course of further conditioning (LoLordo 1976, Holland 1977, Swan and Pearce 1988).

The aim of the present study is to retrace in rats those changes of on-going bar press rate elicited by

repeated presentation of stimuli. Wide-band noise and darkness provided by termination of the house light were selected for comparison. Auditory stimuli of moderate intensity and changes of the experimental space illumination have often been employed in studies of blocking (e.g., Kamin 1969), in overshadowing (e.g., Mackintosh 1976), and discrimination learning (e.g., Baker et al. 1981) in rats using the CER method. Experiment I examines stimuli of 1 min duration, whereas in Experiment II stimuli of 3 min duration were investigated.

EXPERIMENT I

Material and methods

SUBJECTS

The subjects were 24 adult experimentally naive male hooded rats bred in the Institute and weighing 200-260 g at the beginning of the experiment. They were kept in individual cages with controlled food supply and free access to water, and during the 10 days period gradually reduced to 80 % of their initial weight. They were then maintained on 22 h schedule of food deprivation. Rats were divided by chance into three squads 8 subjects each and trained at the same time each day during morning and early afternoon.

APPARATUS AND BEHAVIOURAL TRAINING

Experimental sessions were conducted in eight identical sound- and light-insulated operant chambers, each with a grid floor, a single bar on one of the walls and a food receptacle under it.

The first day of bar press training consisted of initial presentations of 40 "free" 45 mg food pellets on a 1 min variable interval (VI) schedule followed immediately by a period with a continuous reinforcement schedule until 120 food pellets were delivered in a single session. All consecutive sessions lasted 2 h and the bar presses were reinforced with food according to 2.5 min VI schedule during the entire session.

Starting on the 5th session, labelled as dummy day (D-day), the numbers of bar presses emitted in consecutive 30 s periods were collected and served as the main measure of behaviour. During the next two sessions (P-1 and P-2) the auditory and visual stimuli were presented alone, each of 1 min duration, in alternating sequence with onset of the stimuli at 14, 24, 38, 49, 56, 72, 79, and 101 min after beginning of the session (Walasek and Zieliński 1987). The presentations started with the auditory stimulus (N) during the 6th session and with the visual stimulus (D) during the 7th session. The auditory stimulus was wide band (white) noise of 70 dB (re: 20 μ N/m) intensity presented from a permanent magnet speaker located below the grid floor on the same wall as the bar and food receptacle. The visual stimulus was darkness resulting from the offset of the house light from a pilot incandescent bulb centered on the top of the back chamber wall. This light source provided illumination in the vicinity of the bar equal to 205 ± 5 lx.

Data were collected for each stimulus presentation separately and also for each session by summing responses during the corresponding time intervals. Various measures were used to evaluate effects of stimuli on bar presses rate. Comparison of the number of bar presses emitted during consecutive 30 s periods permitted the evaluation the immediate effects of a stimulus onset and termination, regardless of within-session and between-subject variability in absolute response rate. The other within-subject comparison, also relatively immune to between-subject differences in response rate, contrasted the number of responses executed in corresponding 30 s periods of the two neighboring presentations of different stimuli. Nonparametric two-tailed tests and ANOVA for repeated measures were used for statistical evaluation of the results.

Results

The response rates (number of bar presses per min) in consecutive 30 s periods prior to, during, and following each consecutive presentation of the stimuli are presented in Figs. 1 and 2. The rate of bar

presses fluctuated around the level of six responses per min with some tendency for lower rates toward the end of the sessions. The first presentation of the noise briefly decreased the bar presses rate. However, the comparison of the number of responses emitted in the two adjacent 30 s period just prior to and at the beginning of the first presentation of the noise failed to show a significant difference (Wilcoxon, two-tailed test). The effect of noise changed from an initial decrease to the enhancement of response rate ($P < 0.01$) in the course of the first presentation. The first termination of the noise resulted in decrease of responses ($P < 0.05$). During the next presentations, the noise tended to increase bar pressing rate, and on two occasions the onset of the noise stimulus resulted in significant enhancement of responding (Figs. 1 and 2).

The effects of the darkness stimulus on the response rate were more stable. The first house light

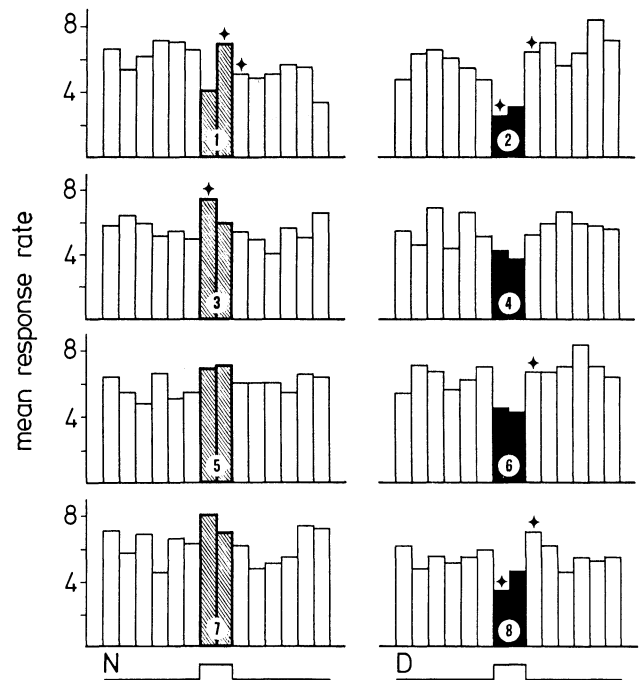


Fig. 1. Bar presses rate in consecutive 30 s periods prior to, during and following each stimulus presentation on the P-1 day. On the left are data for the noise and on the right data for the darkness stimulus. Numbers within each panel denote the order of stimulus presentations. Stars designate a significant ($P < 0.05$) change in response rate in the second of the adjacent value within a pair (Wilcoxon matched pair tests, two tailed).

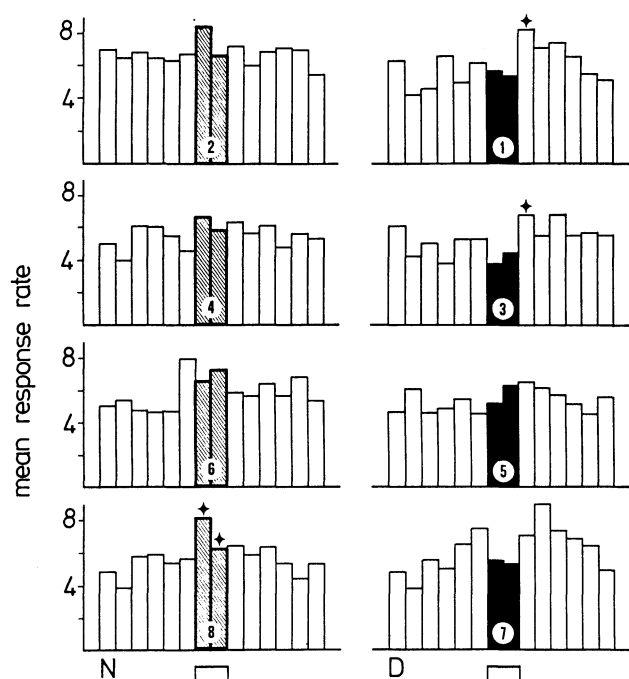


Fig. 2. Bar presses rate in consecutive 30 s periods prior to, during and following each stimulus presentation on the P-2 day. Denotations as in Fig. 1.

termination resulted in a marked decrease of bar presses ($P < 0.05$), which persisted during the entire period of darkness. When the house light resumed, the response rate increased ($P < 0.01$). A decreased response rate during the entire darkness period and

enhancement of bar presses after darkness termination were the predominant effects elicited by changes of the experimental space illumination.

Presentation of stimuli of two modalities in alternative sequence enabled within-pair comparisons of bar presses emitted in corresponding periods of stimulus action. Data presented in Table I revealed an overall enhancing effect of noise and a decreasing effect of darkness. During the P-1 day all comparisons, regardless of the first or the second 30 s period of stimuli action, showed higher bar presses rates during the noise than during the darkness. During the P-2 day, the direction of the difference was the same, but mostly not significant. Decay of the attenuating effect of darkness on response rate was the main reason for the disappearance of the difference between the effects elicited by stimuli of different modalities.

Since the noise and the darkness elicited opposite effects on the on-going bar press behaviour, it was decided to summate data within a session for all presentations of a stimulus of a given modality. The daily data for consecutive 30 s periods prior to, during, and following stimuli are given in Fig. 3. Also presented as a reference in this figure are data for corresponding periods within the D-day, the last day of training before introduction of stimuli. Comparisons of the number of bar presses emitted in

TABLE I

Comparison of response rate during the noise (N) and darkness (D) stimuli within each pair of presentations (Wilcoxon matched pairs two-tailed test)

Presentations	1-30 s			31-60 s		
	N	D	P	N	D	P
P-1						
1 and 2	4.2	2.5	<0.01	7.0	3.1	<0.01
3 and 4	7.5	4.3	<0.01	6.0	3.8	<0.02
5 and 6	7.5	4.5	<0.05	7.2	4.3	<0.01
7 and 8	8.1	3.5	<0.01	7.0	4.6	<0.01
P-2						
1 and 2	8.4	5.8	NS	6.8	5.4	NS
3 and 4	6.8	3.8	<0.01	5.9	4.5	NS
5 and 6	6.7	5.1	NS	7.3	6.2	NS
7 and 8	8.2	5.5	<0.01	6.2	5.3	NS

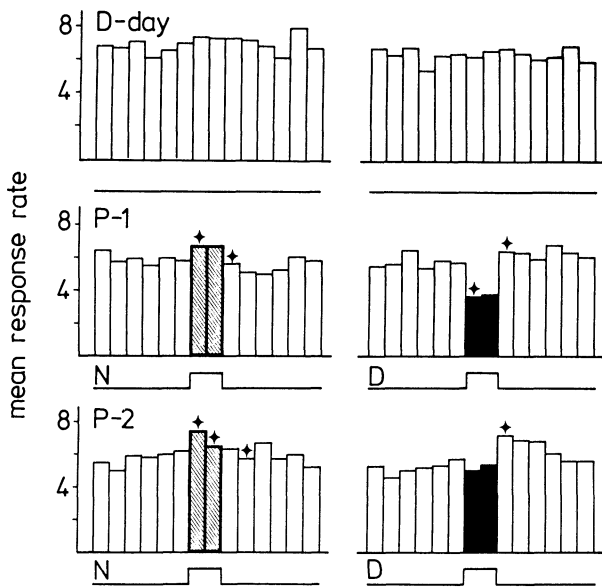


Fig. 3. The effect of the stimuli on the mean daily response rate in 30 s periods on P-1 and P-2 days in comparison to corresponding time periods on D-day. All denotations as in Fig. 1.

consecutive 30 s periods of the D-day did not yield one significant case of change in response rate. On the other hand, the summary effect of the noise onset was an enhancement of bar presses ($P < 0.01$). During the P-1 day this enhancement persisted during the entire auditory stimulus action. Termination of the noise resulted in decrease of response rate ($P < 0.01$). During the P-2 day the enhancing effect of noise was seen only during the first 30 s period ($P < 0.01$) and response rate decreased already by the second half of noise action ($P < 0.01$). The summary attenuating effect of darkness on response rate was significant only during the P-1 day whereas enhancing effect of the resumed house light was evident both during the P-1 and the P-2 days (P 's < 0.01).

Discussion

The data indicated that the alimentary bar press behaviour, maintained by a 2.5 min variable interval schedule, when measured for consecutive 30 s periods and averaged across 24 subjects, was not stable. The fluctuations of bar press rate were unsystematic until the introduction of stimuli. The first

presentation of either the auditory or the visual stimulus decreased the bar press rate. The two stimuli differed substantially in generality of this effect for group of rats and in its persistence over time. Subsequent presentations of the noise tended to increase response rates whereas the darkness stimulus decreased bar presses in a number of following presentations. Termination of the stimuli of different modalities also elicited opposite changes of bar presses rate.

The change from attenuating to enhancing effect on response rate was clearly seen as soon as the first presentation of the auditory stimulus. In contrast, weakening of the attenuating effect of the darkness was noticed only when data for consecutive sessions were compared. It may be expected that prolongation of the darkness stimulus action would help to disclose the change from attenuating to enhancing effects within a single presentation. Thus, the next experiment was aimed at answering whether the discrepancy of the effects between auditory and visual stimuli was related to the overall difference of their action or only to the time factors.

EXPERIMENT II

Material and methods

Another group of 24 adult experimentally naive male hooded rats weighing 200-260 g at the beginning of the experiment and obtained from the same source as in Experiment I was used. Subjects were maintained and trained similarly as described for Experiment I. However, stimuli of 3 min instead of 1 min duration were used, and the order of stimuli presentation was somewhat changed to depart from the alternating sequence. Thus, for the 6th and the 7th sessions the respective sequences N, D, D, N, D, N, N, D and D, N, D, N, D, N, N, D were used.

Results

In the experiment, attention was focused on changes of response rate during extended presentation of the darkness stimulus. The response rates for

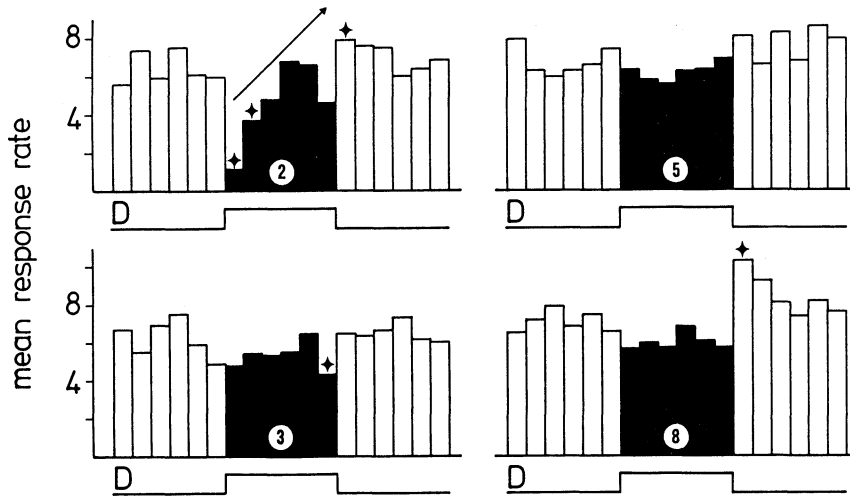


Fig. 4. Bar presses rate in consecutive 30 s periods prior to, during and following each darkness stimulus presentation on the P-1 day. An arrow denotes significant ($P < 0.001$) monotonic increasing trend of response rate within the 3 min action of the stimulus (Ferguson trend analysis). All denotations as in Fig. 1.

consecutive 30 s periods prior to, during, and following each consecutive presentation of darkness during the P-1 day are presented in Fig. 4. The first presentation of the darkness resulted in a marked decrease of response rate ($P < 0.01$). As may be seen, the response rate was lowered for 1.5 min, but comparison of the first and the second 30 s periods of stimulus action showed a partial recovery ($P < 0.02$). When numbers of responses emitted in six consecutive 30 s periods were compared within the prolonged darkness presentation, a monotonic increasing trend of response rate was revealed ($P < 0.001$, non-parametric trend analysis by Ferguson 1965). The response rate increased with resumed house light illumination ($P < 0.02$).

During subsequent presentations of the 3 min darkness periods, the changes in response rate were less systematic. Comparison of numbers of responses emitted in consecutive 30 s periods yielded only two significant changes during the P-1 day: a decrease of responses in the last 30 s of darkness during the second presentation of this stimulus ($P < 0.01$) and marked enhancement of responses after the last presentation of darkness ($P < 0.01$). Those changes suggested the general suppressive effect of darkness and recovery of normal response rate after resumed house illumination.

The effects of the darkness changed toward the end of the next session. During the P-2 day, the third presentation of darkness elicited an enhancement of response rate ($P < 0.05$). Similar, but not significant,

the effect of darkness was seen also during the last presentation. It should be mentioned that the enhancing effect of darkness was observed on the background of an overall lowered rate of bar presses in the second half of the P-2 day.

The noise elicited similar effects as those observed in Experiment I. The first presentation of the noise decreased the rate of bar presses initially. This decrease of response rate was not significant but the following enhancement of responses in the second 30 s periods attained significance ($P < 0.02$). The subsequent noise presentations during the P-1 day resulted in some increase of response rate. The observed enhancement was weak and not stable. In effect, comparisons during the second presentation showed decrease of response rate after two min of noise action ($P < 0.05$).

During the P-2 day the first noise presentation resulted in an initial decrease (not significant) of response rate followed by a marked enhancement at the beginning of the second min of the stimulus action ($P < 0.01$). This increase of responses was followed by two instances of decrease: at the beginning of the third min of the stimulus ($P < 0.02$) and just after termination of the noise ($P < 0.05$). The noise onset resulted in a marked enhancement of responses during the second ($P < 0.01$) and the fourth ($P < 0.05$) presentations.

The daily data for consecutive 30 s periods prior to, during, and following stimuli of a given modality are presented in Fig. 5. During the P-1 day the

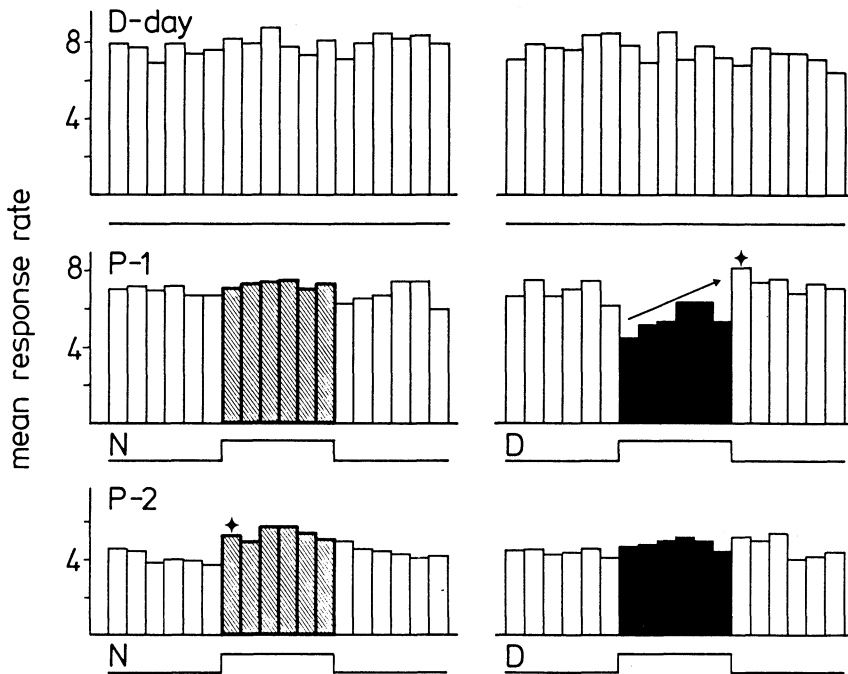


Fig. 5. The effect of the stimuli on the mean daily response rate in 30 s periods on the P-1 and P-2 days in comparison to corresponding time periods on D-day. All denotations as in Fig. 4.

attenuating effect of the darkness, the partial recovery of bar presses in the course of this stimulus action, and the enhancing effect of the resumed house light all were evident. The daily data for darkness were fully determined by the effects elicited by the first presentation of this stimulus. The attenuating effect of the first noise onset and subsequent enhancement of responding in next presentations canceled each other and no summary effect of noise was found. During the P-2 day, on the contrary, the noise onset exerted an enhancing effect, whereas the summary effect of darkness on response rate was negligible.

As seen in Fig. 5, the response rate in absence of stimuli was lower in each consecutive session of testing. A similar change of responding was also noticed in Experiment I (Fig. 3). Mean response rates in three min periods prior to each presentation of

stimuli and in corresponding periods during the D-day are presented in Table II. The ANOVA for repeated measures based on these data showed an effect of days ($F_{2/92}=11.78$, $P<0.001$) and an interaction of days with groups ($F_{2/92}=3.11$, $P<0.05$). Thus, a decrease of response rate was observed in all rats but the effect was stronger in Experiment II, in which stimuli of 3 min duration were employed.

Discussion

The results of the Experiment II confirmed the prediction that the initial attenuating effect of darkness on response rate will dissipate in the course of prolonged action of this stimulus. Moreover, the use of stimuli of longer duration markedly reduced the number of presentations required for habituation of the initial decreasing effect of the onset of darkness on response rate. Already the second onset of darkness of 3 min duration had no effect on response rate. A similar lack of the decreasing effect of the onset of 1 min darkness stimulus was observed only during the P-2 day.

The darkness of long duration increased the response rate at the end of testing. Such an effect was observed when the on-going bar presses rate was markedly lower than prior to stimuli presentations.

TABLE II

Mean response rate prior to presentations of stimuli in consecutive days of testing

Experiment	D-day	P-1	P-2
I	6.7	5.9	5.4
II	7.9	6.8	4.3

GENERAL DISCUSSION

When changes of the on-going behaviour are used as a measure of the experimental variable effects, it is difficult to achieve two aims of sensitivity and reliability at the same time. Comparison of response rate collected in long periods reduce uncontrolled fluctuations but make impossible to discover phasic changes elicited by the intervening factor. In this study the bar press rate was analyzed in periods that were short in relation to the variable interval passing between consecutive food reinforcements. To reduce the variability of the data, large groups of rats were used and measures of the effects were based on within-subject comparisons. This strategy was successful in discovery of the two opposite phases of the effect elicited by presentation of stimuli on response rate.

The first response to a novel stimulus, either auditory or visual, consisted in the decrease of bar presses rate. This initial attenuation of bar presses was apparently a consequence of the investigatory (attentional) response. Persistence of the suppressive effect depended on stimulus modality. The close spatial proximity of the loud speaker, the food receptacle and the bar facilitated localization of the auditory stimulus source. On the contrary, darkness has to be considered as hardly localizable stimulus. Habituation of this investigatory phase of the orienting response to a noise was rapid, whereas to the darkness was protracted. Subsequent presentations of stimuli tended to increase the bar press response rate. Enhancement of bar presses indicated an energizing effect of stimulus action on the on-going behaviour. The difference between the two stimuli in the rapidity of the conversion from attenuating influence to facilitation of bar presses was a main reason for their opposite effects on the on-going behaviour: the rate of bar presses was higher during the action of the noise than during the periods of darkness.

In the case of auditory stimuli, the effects of subsequent presentations depended on the intensity relations between the sporadic stimulus and the background noise level. Noise more intense than

the background increased bar presses (Jakubowska and Zieliński 1976, Balezina et al. 1981), while less intense than the background decreased response rate (Zieliński 1966, 1981). These effects on response rate, the direction of which depended on the intensity relations between the stimulus and the background, did not habituate during more than 100 presentations of a stimulus having no signalling value (Jakubowska and Zieliński 1975). The enhancing effect of darkness on response rate has not documented to date. In the present study the darkness of long duration increased response rate at the end of testing when the overall level of bar presses was significantly lower than before.

It was shown earlier that the distraction of the on-going licking behaviour in rats caused by illumination change was greater and persisted longer than that elicited by noise (File and Russel 1972). The stimuli were of 20 s duration and were presented only once a day. In such conditions habituation to one stimulus exerted no effect on the orienting response elicited by stimulus of the other modality. In another study short stimuli (4 s duration) elicited similar arrest of licking, however the effect habituated faster to the tone than to the light (Willigen et al. 1987).

The influence of the duration of a stimulus on the rate of change of its unlearned effects may have implications for further training. Sporadic stimuli, even before any training, evoked various behaviours having a different temporal distribution within a trial. In rats tested in the alimentary experimental context, the startle response to auditory stimuli and the rearing behaviour to visual stimuli occurred mainly near stimulus onset, whereas food-directed behaviours were displayed later (Holland 1980, Buzsáki 1982).

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