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AUTO-SHAPING OR ORIENTING?

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Abstract. Four experiments were carried out to study the development of the orienting response (OR) under different experimental conditions in the cat and rat. In Experiment I and II (cat) and Experiment IV (rat) classical CS–US pairing was used (with food, shock and water reinforcers, respectively). In Experiment III (cat) an instrumental pedal press response was brought under the control of a discriminative signal. In all four experiments the auditory CS was spatially discontiguous with reinforcement in order to separate CS directed orienting responses from US related activities. Exposure to CS signalling food or water caused the animals to orient to it throughout conditioning (up to 700 trials) and this overt responding was absent if CS predicted aversive reinforcers. OR was consistently followed by goal (US) directed anticipatory activities. It is proposed that the CS directed auto-shaped response ("sign-tracking") is identical with the conditional orienting response, and that the spatio-temporal patterning of behaviors is influenced both by CS and US.

INTRODUCTION

In a now classic experiment Brown and Jenkins (6) have demonstrated that hungry pigeons began pecking a lighted response key (conditioned stimulus, CS) if illumination of the key signalled that food is forthcoming. In this paradigm (classical conditioning; 38), key pecking has no effect upon the occurrence of the reinforcer, since the presentation of food is contingent upon illumination of the key but is not contingent upon the animal's behavior. Since the first demonstration of this

phenomenon, termed "auto-shaping" (6), a number of studies have demonstrated its existence in a variety of species. These have included key pressing in monkeys and children, key pecking in chicken and quail, and lever-pressing and lever-contacting in rats (for a review, see 20).

Acquisition of auto-shaping is claimed to be governed by the Pavlovian relation between the CS and reinforcer (US). However, it also contains, implicitly, the possibility for an adventitious response-reinforcer contingency, in Skinner's (46) sense of temporal response-reinforcer contiguity. Brown and Jenkins found that both classical and instrumental procedures evoked key pecking behavior, and they did not differ from each other in terms of the number of pairings up to the first key peck. In an attempt to eliminate the response-reinforcer contingency, Williams and Williams (56) used an omission training procedure (45) in which there was a negative contingency between response and US and a positive contingency between CS and US, and found that pecking was maintained at substantial frequencies. This result seemed to give grounds for rejecting the adventitious reinforcement explanation in the pigeon. However, more recent studies, using mammals as subjects have reported that responding virtually ceased under the omission procedure (1, 4, 15, 31, but 52). Therefore the problem of the adventitious reinforcement explanation of auto-shaping has remained with us.

The almost ten years of research on auto-shaping yielded considerable data. However, it seems to us, that besides the urge to discredit Skinner's original interpretation of conditioning (46), the vast literature of auto-shaping left the student of learning without a thorough theory, and provided hardly more than a revival of Pavlov's and Thorndike's (38, 53) concepts. Or as Moore noted: "I think that at last we've made it back to where we should have been in 1930" (24).

A different approach was used by Grastyán and Vereczkei (17). Using a discriminative approach design with the CS being placed behind the starting platform, they observed a progressively increasing orienting-approaching tendency toward the acoustic CS which began to interfere with the goal response. In the course of training orienting toward the CS, although diminished in amplitude, persisted over several hundreds of trials. Grastyán and Vereczkei made the proposition that the occurrence and the persistence of the signal directed activities are an essential consequence of conditioning and it is the CS itself which becomes a new and independent goal. Or in other words "the conditioned orienting response is not only a learned response, but the only response learned" (p. 140). Since reinforcement was not contingent upon orienting toward the CS, but upon approach to the feeding device, its persisting feature

offered the possibility of being identical with auto-shaped key pecking.

There are, however, both theoretical and experimental oppositions reported which argue against this conclusion. First, and most important, the learned orienting response (OR) is a newly acquired *preparative* behavior suppressing the consummative act of eating, while CS directed auto-shaped response is interpreted as being a signal-triggered *consummatory* activity (6, 24–26, but 14, 54, 55, 57). Second, an auto-shaping paradigm calls for a Pavlovian CS–US relationship (6, 56), which was not strict in the Grastyán and Vereczkei study. One can argue, however, that the fact that both the procedure and the outcome are Pavlovian does not guarantee that auto-shaped key pecking or other CS related activities are in fact due to the Pavlovian process.

The present series of experiments demonstrates the orientational character of the auto-shaped response, using spatially discontiguous CS–US arrangement in order to make differentiation between signal and goal directed activities possible. Both cats and rats were used as subjects for comparative purposes.

In addition, our findings indicated that a host of corollary events is occurring in our experimental settings and not only the one or two CS elicited responses that have been measured traditionally. This suggested a need for a more comprehensive methodology, capable of describing intersignal behavioral flow. These results will be dealt with in the following paper (10).

The second major purpose of this study was to obtain electrophysiological correlates of well-defined behaviors (9, 11, 18). At present, however, only behavioral findings will be dealt with.

EXPERIMENT I: CLASSICAL CONDITIONING IN THE CAT (REWARDING US)

The auto-shaping procedure is operationally identical to Pavlovian conditioning, therefore it was of utmost importance to test the persistence of the OR in this paradigm.

Methods

Subjects. Nine naive, house-reared cats of both sexes were used. Six of them were implanted with cortical and subcortical, neck muscle and eye-movement recording electrodes (11).

Apparatus. The experimental chamber (2 m long, 50 cm wide, and 80 cm high), with white plywood inner walls and aluminum outer walls and plexiglass top, was illuminated from above by two 200 W bulbs.

An automatic rotary feeder protruded from one end-wall. A loudspeaker, in a 27 × 18 × 7 cm box, was mounted on the wall opposite to the food magazine 40 cm above floor level. The observation window, 25 × 35 cm, was cut above the feeder. The behavior of the animal was monitored by means of a closed-circuit TV system and critical phases of the experiments were video-taped (AKAI, VT 100).

Procedure. All cats were first trained to eat reliably from the feeder dish (about 5 g pellets of raw meat). At the beginning, pellets were delivered whenever the cat looked into the feeder dish. Once consistent eating was observed, pellets were delivered on a variable-time (VT) 1-min schedule. This was accomplished in 2 or 3 days. Behavioral responsiveness to the future CS was assessed in additional sessions. The conditional stimulus (2 s long, 500 Hz tone, about 75 dB) was switched on by one of the experimenters. The tone (CS) and food pellets (US) were scheduled independently (pseudoconditioning, PSEU). In each interval between tone presentations (ranging from 20 to 80 s), between zero and two presentations of food might have occurred. PSEU sessions were repeated until responding to the future CS decreased to an arbitrary low level (see scoring). Next, stimulus sequences were arranged so that termination of CS was consequently followed by US delivery (classical conditioning, COND). The CS–US sequence (trial) was presented independently of a subject's behavior. A daily session consisted of 20 trials. In two cats training was followed by extinction (5 sessions) and discriminative reconditioning (14 sessions). On extinction days (EXT) the animals were put into the experimental chamber, the CS was presented 20 times, but was not followed by food magazine noise. After each session the cats received 20 meat pellets in the home cage. In reconditioning (DISCR) a new CS+ (2,000 Hz) was introduced which was always followed by US. The previously used 500 Hz tone (now CS−) was presented 20 times, interspersed between CSs+, but never followed by food magazine noise (and consequently no food). Milk was available in the home-cage for 1 h after each daily session throughout the experiments.

Scoring. The CS related behavior of the cat was rated on a 4-point scale in the following manner. A count of one was given for pricking of the ears or turning of the head less than 30° toward the source of the CS, a count of two for turning 30°–90°, a count of three for turning the head more than 90°. A count of zero was given for any response occurring not toward the CS, regardless of its magnitude (e.g., scratching, running, jumping to feeder). OR scores were summed for each day resulting in a maximum daily score of 60 for an individual animal.

Results

The OR score of each subject across sessions is shown in Fig. 1. In evaluating these data, the reader should bear in mind that no response, except to catch the presented meat pellet, was required to get food.

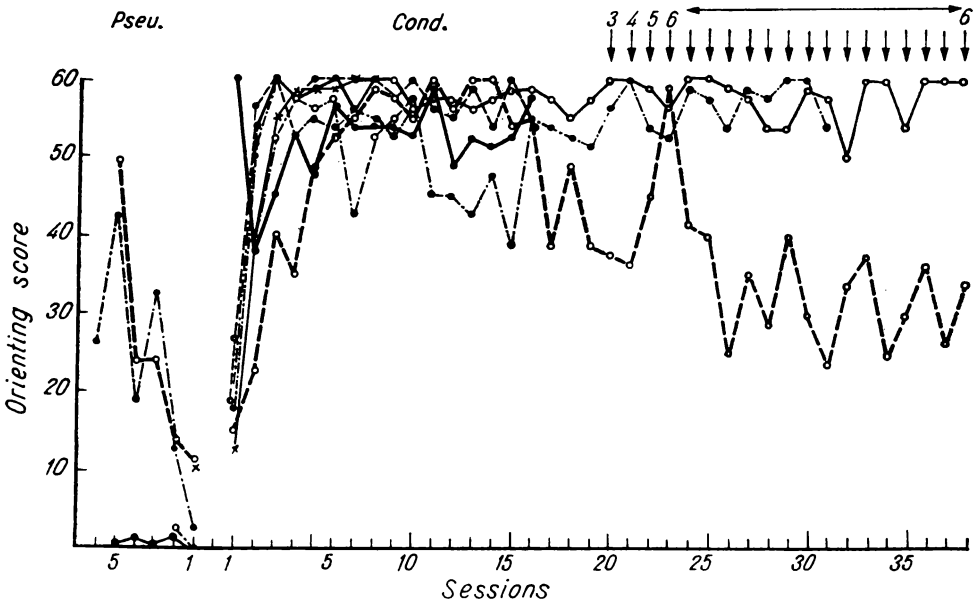

Fig. 1. Individual orienting response curves during successive sessions (20 trials each) of pseudoconditioning (PSEU), and conditioning (COND). Ordinate: total orienting score per session. Arrows indicate that the CS–US interval was increased according to the numerals above them (S).

Responding to the tone during PSEU varied over a wide range. Some animals reached high OR scores in the first PSEU session, but responding declined progressively during subsequent sessions. Responding to CS increased rapidly during conditioning and usually reached maximum in session 2 or 3. The frequency of occurrence of responding remained high over many sessions, the amplitude of OR, however, somewhat decreased. In the above method of representation (combined frequency of occurrence and amplitude measure) no account is taken of the time course of activities during a given trial. The within-trial behavior fell reliably into two classes: (INI) initial behavior corresponding to OR toward the source of the CS; (TER) terminal response was the behavior that consistently occurred just before food delivery. TER included activities like turning of the head back to the food magazine, sniffing,

pawing and occasionally jumping onto the feeder. The time-course of INI and TER behaviors within a single trial varied with training, showing a general decrease of the INI/TER ratio. This "two-phase" responding was already evident in session 1. The duration of OR shortened with further training and was unaffected by the lengthening of CS duration up to 6 s (see arrows above curves in Fig. 1). It was a consistent observation that if the head of the animal was already directed toward the loudspeaker, presentation of CS evoked a quick head jerk toward the food magazine.

Intersignal activities also showed characteristic changes both in the number of behavioral sequence variations and in the topography of activities. Circling around the chamber, rearing, regular jumping onto the feeder decreased to a low level already in the shaping and PSEU phase of the experiment. Sitting on all four legs or hindlegs before the food magazine and grooming were the most frequent intersignal behaviors in the COND phase.

OR score diminished during extinction, although diminution was not quick (Fig. 2). It is important to remember that the animals were

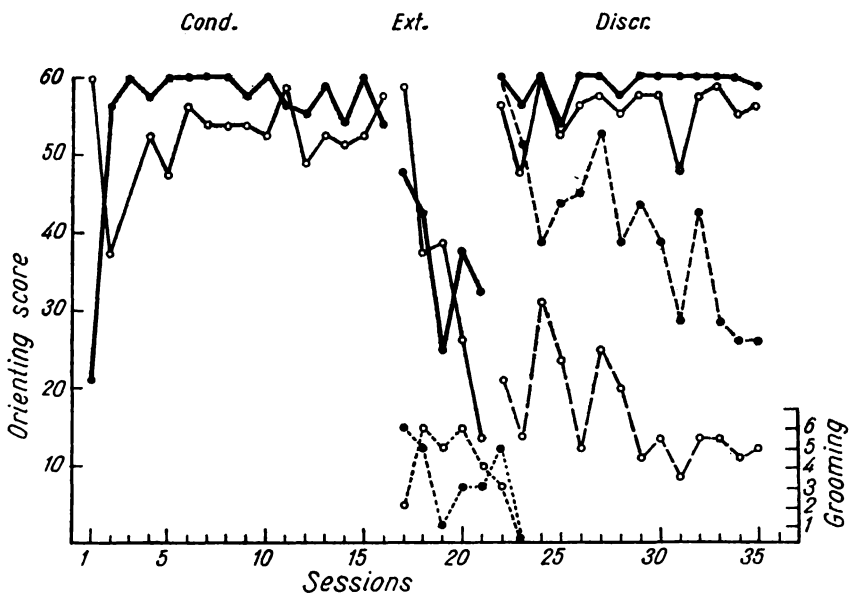

Fig. 2. Orienting response curves for cat S1 (open circles) and S2 (filled circles) during successive sessions of conditioning (COND), extinction (EXT) and two-tone discrimination (DISCR). Right ordinate: total number of occurence of grooming induced by CS presentations. Solid lines, responses to CS+; dashed lines, responses to CS−; dotted lines, evoked grooming.

hungry during the extinction sessions. Evoked grooming was defined as a behavioral change occuring during and induced by the CS. In the discrimination phase differential responding to CS^+ and CS^- was already evident on the first day of discrimination in cat S1. More sessions were necessary to respond differentially for cat S2. Nevertheless, differential responding was obvious in both cats by the end of the DISCR phase (Fig. 2). Two animals (one operated, one intact; not shown in the figures) showed no overt responding toward the source of CS in neither stage of the experiment. Both animals quickly learned to react and jump onto the feeder only in the presence of the CS, but neither cat displayed any observable sign of orienting activity.

The data from this experiment indicate that in a Pavlovian situation OR toward the CS persists throughout conditioning, even though it is always the TER response and not INI which is reinforced by food. Auto-shaping, by definition, is a persisting CS directed activity as a result of CS–US pairings (6). The present findings show that the conditioned OR meets this criterion.

EXPERIMENT II: CLASSICAL CONDITIONING IN CATS (AVERSIVE US)

The persisting nature of the OR was demonstrated in Experiment I, in which the reinforcement was food. We became interested how the animal will deal with the CS when it predicts an aversive US.

Methods

Subjects and surgery. Three cats which completed Experiment I (S1, M16 and M20) and two naive animals were used in this study. In the two latter subjects, under Nembutal anaesthesia (40 mg/kg), the frontal sinus was opened and a chronic canulla was positioned into the mouth through the hard palate. The canulla was fixed with screws and dental acrylic.

Procedure. The apparatus, quality and position of CS, monitoring and scoring were the same as described in Experiment I. One week was allowed for recovery for the operated subjects. PSEU phase was omitted. Four percent acetic acid infusion into the mouth delivered through a flexible tube for 4 s (about 2 ml) or electric shock (four 50 ms pulses 200 ms apart) through wound clips attached to the posterior part of the back served as unavoidable USs. Twenty to eighty trials completed a daily session. CS–US pairings were carried out in the two naive subjects and in one subject which completed Experiment I (cat S1).

Results

CS-aversive US pairings generated a very low level of OR score (Fig. 3). Vigorous running around the chamber, evoked by the CS, occurred within 5 to 10 trials. These activities were termed escape

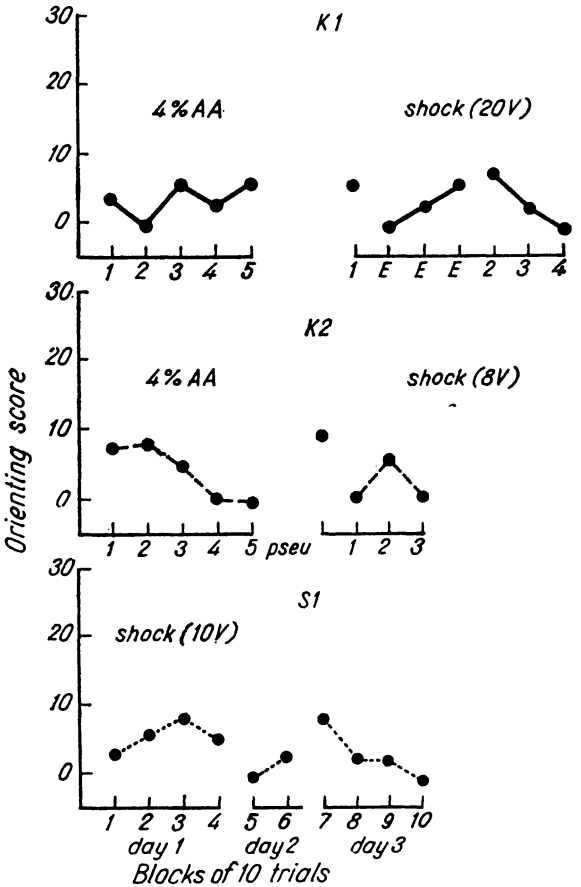

Fig. 3. Orienting response curves for cats, K1, K2 and S1 during unavoidable punishment sessions. 4% AA, 4% acetic acid delivered to the mouth as US. Note the low level of OR score. Note also that cat S1 had considerably high level of OR scores for 35 days (see Fig. 2) prior to punishment.

attempts. With further training, however, these violent reactions progressively declined and the animal remained frozen for the rest of the session and the only response observed was a small head jerk of the dorsum of the back preceeding or during shock-US. In the "acid"-US sessions the animals sat immobile with eyes closed and mouth open. Salivation was profuse and continuous. In cats M16 and M20 food-

US trials were interspersed among the shock-US trials. Figure 4 shows such a representative session. It is quite evident that aversive US reduced OR score built up during appetitive trials. Thus, this expe-

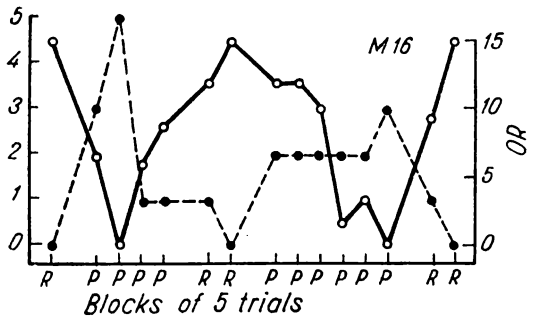

Fig. 4. Orienting scores (right ordinate) and escape attempts (left ordinate) during successive food reinforced (R) and shock reinforced (P) blocks of five trials within a single session. Note the dynamic changes and inverse ($r = -0.76$; $P < 0.01$) relationship between OR (heavy line) scores and escape attemps (dashed line).

riment demonstrates that overt OR does not emerge if the CS signals aversive US. This, of course, does not necessarily imply that the CS leaves the animal unaffected (33).

EXPERIMENT III: INSTRUMENTAL FOOD-REWARD CONDITIONING IN THE CAT

In the classical conditioning arrangement the CS and US are presented independently of the subject's behavior. US follows CS by a predetermined time lag. In this situation the occurrence of US might not only reinforce CS related behavior, but by the same token it can interfere with the orienting response in progress. If, however, the occurrence of reinforcement is paced by the subject, this latter problem can be eliminated. The discriminative instrumental procedure fits this requirement. In this arrangement the presence of CS is a necessary but not sufficient condition for reinforcement to occur, and needs the subject's active participation. In the following experiment we examined the conditioned OR under such a procedure.

Methods

Subjects. Three intact and nine implanted cats of both sexes were used.

Procedure. The apparatus, quality and position of CS, monitoring

and scoring were the same as described in Experiment I. The upper part of the protruding food magazine was converted into a pedal by putting a switch below the panel. About 80 g pressure was necessary to activate the microswitch.

The cats were put into the experimental chamber for half an hour daily for 5 to 7 consecutive days (adaptation). In the first part of the experiment the cats were shaped to press the top of the food magazine (i.e., the pedal) in order to obtain food reward (continuous reinforcement, CRF). Next, only those responses were rewarded which were initiated after withdrawal from the pedal for longer than 5 s in order to avoid continuous pedal-pressing. These procedures took 4 to 6 days with 20 meat pellets in a daily session. In the discriminative phase of the experiment only those presses were efficient which occurred in the presence of the discriminative tone stimulus (S_D). S_D was switched on by one of the experimenters and terminated by the cat's pedal press. Those presses which occurred in the absence of S_D were termed intertrial pedal presses (ITP). The number of bar presses and the response latency (i.e., the duration of S_D) were recorded on a paper chart and on digital counters. Stimulus events were programmed by a Neurolog System (DIGITIMER). In addition to switch closures, contacts with the pedal were registered, as a linear function of force, by means of a pressure transducer. A daily session consisted of 20 trials with one min intertrial interval on the average. The cats were trained either to reach 20 or less ITPs in a session or twenty days, whichever came first. Six subjects, under satiated condition, received 20 tone presentations (habituation) on the last adaptation day, the remaining six received none.

Results

A detailed analysis of behavior along with the electrophysiological responses will be described in a separate paper. Therefore, only those topics will be mentioned here which are relevant in the present context.

The number of ITPs and the OR score for each animal are presented in Fig. 5. The most striking finding was the low level of responding to the tone signal in the habituation and in the first discriminative sessions. As learning proceeded (inferred from the ITPs) OR score progressively increased. The highest rates of ITP were generally observed in session 2 or 3. The latency of responding also reached its peak in session 2 or 3 and then progressively decreased during subsequent sessions, and it was found significantly shorter in the last session than in session 1 ($t(12) = 4.11$, $P < 0.01$). As in Experiment I, responding was "two-phasic". Upon presentation of S_D the animal turned its head (and body) toward the source of S_D. The direction of head turnings

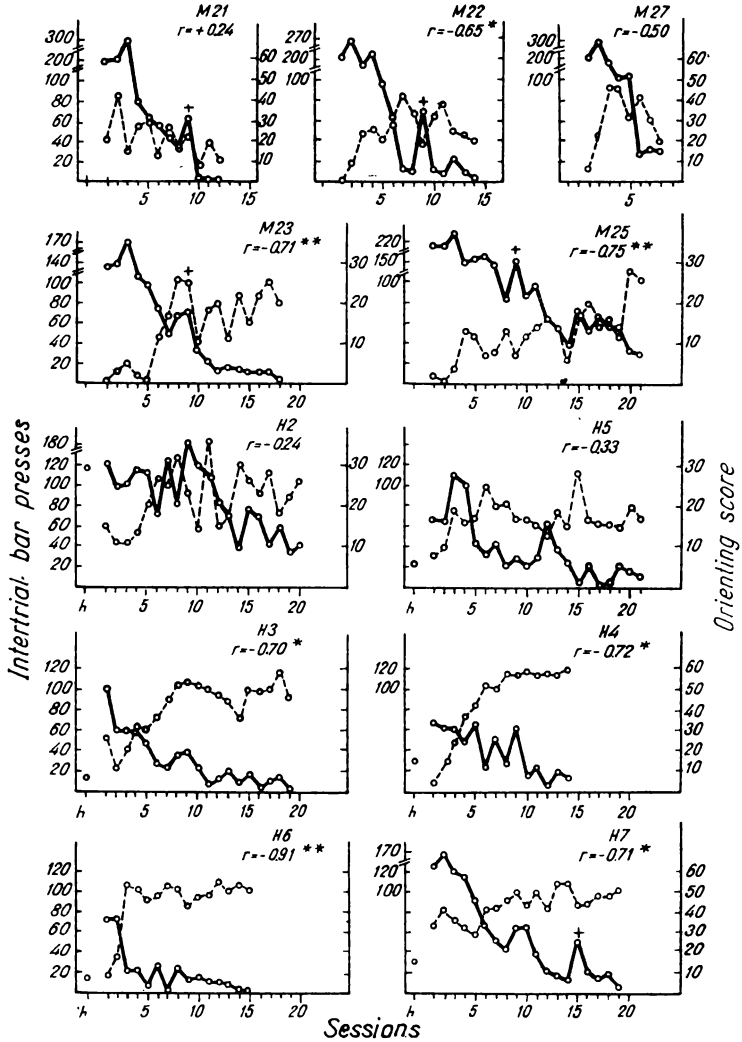

Fig. 5. Relationship between the total number of intertrial bar presses (heavy line) and OR scores (dashed line) for individual animals. h, habituation session. Asterisks indicate the level of significance. * $P < 0.05$; ** $P < 0.01$. Sessions were conducted always in the afternoon except on days marked by +.

varied from animal to animal, but was more or less consistent within subjects. This OR was followed by a head turning back to the food magazine. Pedal pressing, however, did not occur immediately. The majority of cats placed their preferred paw onto the pedal gently, withdrew it and this "ritual" was occasionally repeated five to eigtht times before actual press (switch-closure) occurred. This peculiar terminal

behavior was gradually replaced by definite presses by the end of conditioning. ITPs occurred quickly and vigorously. Thus the shortening of response latency by the end of training could be traced back mainly to the shortening of "first magazine touch-pedal press" periods, and to a lesser extent to the shortening of the duration of OR. Parallel with the decreasing number of ITPs, the OR score progressively increased. In fact, in all but one subject the correlation between ITP and OR was inverse and in seven cats this was found statistically reliable. Thus OR built up gradually. In early sessions OR responses occurring during the S_D periods were not source specific. Upon presentation of S_D the ongoing pedal presses came to a halt and the animal began to sniff the pedal and floor, raised its head and occasionally turned its head toward the source of S_D. This turning of the head became progressively greater in amplitude during subsequent sessions. One cat (not shown in Fig. 5) did not display any observable S_D directed OR in any phase of the experiment. Discrimination, inferred from its ITPs, went on normally.

The inverse correlation between the number of ITPs and ORs found in this experiment left little doubt that the first ORs occurred not by accident, but as a result of conditioning.

EXPERIMENT IV: CLASSICAL CONDITIONING IN THE RAT (REWARDING US)

In addition to the use of another species, this experiment differed in two important ways from Experiment I. First, prior to CS–US pairings instead of pseudoconditioning, the rats were exposed only to CS presentation (habituation). Second, water reward was used as the unconditioned stimulus.

Methods

Subjects. The subjects were eleven naive male hooded rats, weighing 200–350 g upon initiation of the experiment. They were supplied with bipolar electrodes implanted into the hippocampus (7, 8, 9).

Apparatus. The behavioral apparatus was a 30 × 17 × 30 cm wooden box. The front side was of glass to allow behavioral observation. A lever, 5 × 10 cm, protruded from one end at 5 cm above the grid floor. A solenoid operated small guillotine window, 2 × 1 cm, which allowed access to a drinking tube, was placed at the opposite end of the box. A miniature loudspeaker, placed 5 cm above the lever, served to deliver the 500 Hz tone (about 75 dB) CS. The duration of the CS was 2 s long and it was switched on by one of the experimenters. In order to reduce

subject-experimenter bias, the CS came on 1 sec after switch closure (prestimulus epoch, PRE). Upon termination of the CS the drinking magazine was automatically activated for 25 s. The stimulus events were controlled by a Neurolog System (DIGITIMER). Coded behaviors and verbal notes were recorded on tape-recorder (AKAI, 1730SS).

Procedure. Prior to the experiment each rat was handled for 5 to 10 min a day. On habituation sessions they were placed in the experimental box. After 5 min of adaptation the tone was presented 32 times. The interval between tone presentations was irregular and averaged 1 min. The same stimulus was used as CS during the conditioning trials. After 2 days of habituation the animals were deprived for 24 h and for three days they were trained to lick water (US) from the drinking tube upon activation of the solenoid. The rats were then subjected to the classical conditioning paradigm for 10 (4 rats) or 13 (7 rats) consecutive days. A daily session consisted of 32 trials. Food was available ad lib. in the home cage throughout the experiments. On day 14 the paradigm was arranged so that by pressing the lever the CS–US sequence could be initiated. (Up to day 14 the lever could be pressed at will but had no scheduled consequence). After 3 days of self-initiated response dependent conditioning the lever was withdrawn and reconditioning continued for two more days. Four rats were also tested when satiated.

Response description and scoring. Behavior of the rats was recorded by a single observer seated about 2 m in front of the experimental box. Prestimulus behaviors (PRE, during the second preceding CS), like lying, grooming, scratching, rearing, freezing, etc. were noted on a prepared scoring sheet. Scoring OR behavior was identical with that used in the cat experiments. In addition, a count of four was given for running to the loud-speaker upon presentation of the CS. Since OR usually did not last throughout the CS–US interval, terminal behavior (TER), following OR, was also noted. In general behavior categories were mutually exclusive.

Results

Since the rats had been handled regularly prior to the experiment, freezing was rarely observed upon placing the animal into the experimental box. Figure 6 shows the OR scores across sessions for all animals. The mean OR scores, averaged across animals at critical stages of the experiment, are shown in the lower-right panel of the figure. The Friedman test revealed a significant effect of training ($P < 0.02$). Responding to the future CS during habitation sessions showed little

variability across animals and was essentially low both in its frequency of occurrence and amplitude. It is important to note that the rats were satiated during habituation sessions. During conditioning sessions, how-

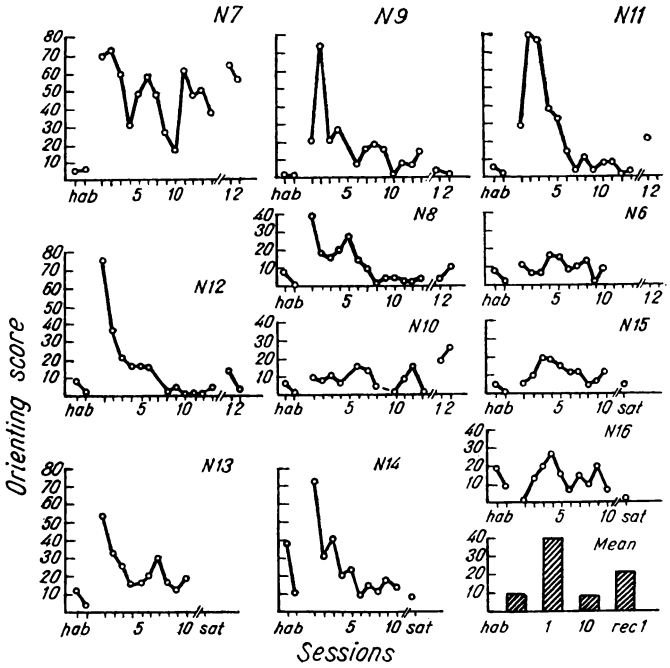

Fig. 6. Individual orienting response curves during successive sessions (32 trials each) of habituation (hab), conditioning, satiation (sat) and reconditioning (rec.). Average scores are shown in the lower-right panel.

ever, there was a considerable between-subject variability. In most subjects OR score reached the highest level in the first session and decreased progressively during further training. By the end of training OR scores declined to the habituation level and differed significantly from the first session ($P < 0.02$, Wilcoxon test). This decline could be traced back to the decrease in the probability of responding on the one hand, and to the change in topography of the OR on the other hand (Fig. 7). Running to the loudspeaker and turning the head and body toward the CS was gradually replaced by quick and little head movements or no observable response at all upon presentation of the CS by the end of training.

TER behaviors included activities like running or turning to the water magazine, biting screws or the grid floor, nosing, pawing and scratching the magazine wall. This behavior usually continued until

water delivery, and was less variable from rat to rat than was the OR. The time course of the initial CS related behavior (INI = orienting) and TER behaviors within a single trial also varied with training, showing a general decrease of the INI/TER ratios.

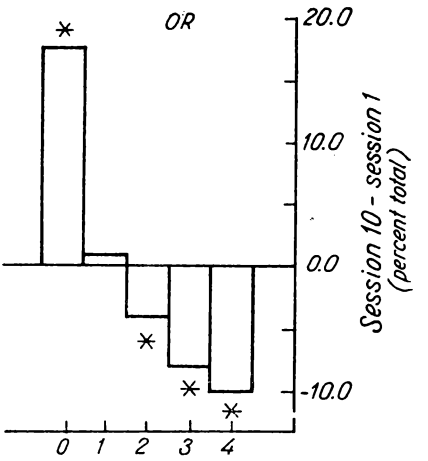

Fig. 7. Difference of proportional distributions of orienting score categories between session 10 and session 1. Asterisks mark significant changes ($P < 0.05$).

Besides changes in responding to CS, intersignal (CS–US off period) activities also showed marked changes across sessiong. The most consequent post-water behavior was grooming. Quantitative comparisons were possible, however, only on behavior occurring during the last second of the intersignal interval (PRE). Figure 8 illustrates the change

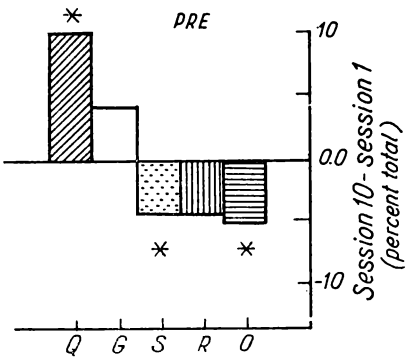

Fig. 8. Difference of proportional distributions of behaviors preceding CS (PRE) between session 10 and session 1. Asterisks mark significant changes ($P < 0.05$); Q, quiet sitting; G, grooming; S, sniffing; R, rearing; O, other behaviors.

in the frequency of occurrence of different behaviors as a result of training. PRE activies with less than 10% frequency of occurrence were grouped as "other" behaviors. Exploratory sniffing and "other" behaviors significantly decreased ($P < 0.01$), quiet sitting significantly

increased ($P < 0.05$), rearing and grooming did not show reliable changes.

In order to investigate PRE behavior-OR response interactions we examined the amplitude of OR as a function of PRE activities in the first session. The highest OR scores were reached when sniffing was in progress at the moment of CS presentation and the lowest when the animal was engaged in grooming. These differences were statistically reliable ($P < 0.05$, Friedman test). The implication is such that responding to CS depended not only on the number of previous pairings, but also on behavior-in-progress (PRE) when the CS was presented. Similar observations on behavioral flow were made also by Ray and Brown (41) and the above results are supported by the electrophysiological findings that hippocampal evoked potentials significantly differed as a function of PRE activities (9).

On day 14 the paradigm was arranged so that the CS–US sequence was initiated by pressing the lever (response dependent arrangement). The most striking observation of this measure were the findings that all seven animals learned this task in *one* trial (pressed the lever and ran to the water magazine before US occurrence) and perseveration of lever pressing was not observed (although it is often seen in the acquisition phase of a lever press operant task). That is response independent-response dependent paradigm shift did not result in any observable behavioral change (apart from the fact that the rat was required to press the lever), and the behavioral sequence was completed *before* water reinforcement occurred. The implication is such that the animal is able to utilize its previous response independent experience and thus a new behavioral sequence is integrated in one trial.

On day 17 the lever was withdrawn and experimenter initiated Pavlovian conditioning (reconditioning) continued for two more days. Although OR scores were generally higher than on day 13, this difference was not reliable ($P > 0.05$, Wilcoxon test).

DISCUSSION

The principal conclusion of the present series of experiments is that exposure to stimuli signalling food or water (either under Pavlovian or discriminative operant procedures) causes the animal to orient towards it over long series of trials, but this overt responding is absent if the stimulus predicts aversive reinforcers.

The procedure in the auto-shaping experiment (6) is the same as that in the classical conditioning. In each case, an initially neutral

stimulus is followed regularly, and independently of the subject's behavior, by a reinforcing stimulus (US). Although the occurrence of reinforcement is not contingent upon the animal's behavior, the animal nevertheless behaves. We claim that this signal directed behavior (which is usually referred to as the auto-shaped response) is a persisting orienting response. Our claim, although in agreement with several experimental facts, is at variance with theoretical accounts of auto-shaping (6, 25, 34), as well as with the widely-accepted interpretation of the classical conditioning (38). In the ensuing discussion we attempt to defend our viewpoint.

The first issue to be considered is the difference in the performance of cats and rats in the appetitive classical conditioning arrangement. This disparity is an uncomfortable one, but as we shall show, it is more apparent than real. Rats displayed the highest OR scores on day 1 or 2 and OR score decreased to the habituation level by the end of conditioning, while cats reached highest level in session 2 or 3 and this level was kept for several consecutive sessions. The initial difference can, at least partly, be traced back to the fact that cats were exposed to random presentations of the CS and US (PSEU) prior to conditioning, while rats underwent habituation under satiation (2, 33, 43). Furthermore, for cats COND immediately followed PSEU, while for rats four days separated conditioning from habituation. In rats OR score declined to the habituation level after 300 trials. There is, however, evidence that OR to the CS, even though not observable by our method, does not cease. First, high amplitude rhythmic hippocampal theta activity, characteristic to OR behavior (19, 28), persisted throughout conditioning in spite of the overt behavioral changes (9). Second, we have shown (10) that rats do not stop responding to CS although, for technical reasons, it is difficult to observe their responding under CS–US spatial contiguity. In that experiment rats were trained under signal-reward spatial contiguity condition for several days and in the stage of overlearning the relation between the signal and reward was made spatially discontiguous. The conspicuous behavioral changes left little doubt that the animal responded to the signal throughout conditioning. Furthermore, the decreasing tendency of OR amplitude across sessions was also characteristic in cats. In this context it is relevant to note that responding to CS in auto-shaping experiments also diminishes after a few hundreds of trials (4, 5, 25).

One important methodological difference between the procedures of the present experiments and those commonly used in auto-shaping experiments is the nature of the CS. Auto-shaping experiments apply almost exclusively visual or compound CSs. Following the first successful

demonstration of auto-shaping in the rat (39), that procedure became orthodox. Insertion of a small retractable lever, sometimes accompanied by illumination of a cue lamp in proximity of the lever, is followed by US usually after long (8–15 s) CS–US interval (1, 31, 39, 52). In this arrangement contacts with the lever (termed as auto-shaped response) are physically-spatially incompatible with US-source related activities, thus reducing the chances of temporal contiguity (23). If the signal is auditory, the problem of temporal contiguity is seemingly settled (17). At this point it is important to note that direct contacts with the loudspeaker were not observed in the present experiments, although in the discriminative food-reward procedure (Experiment III) the S-R interval was paced by the subject and the occurrence of US (as is the case in classical conditioning) did not disturb OR towards the CS. At the same time no observable OR occurred when CS predicted aversive US. The theoretical implications of this latter observation will be dealt with in a separate paper.

Interestingly, investigators have noted in the pigeon, that nonlocalizable visual and auditory stimuli paired with food failed to evoke consistent pecking (4, 20), and have been claimed to evoke other nonpecking behavior. More recently, in a careful study Holland (22) demonstrated that stimulus modality as well as localizability and vertical location of visual stimuli affect the topography of responding. In the present experiments identical CS related responses (INI) were observed, although the paradigms, reinforcers, as well as the species used were different. Therefore we can conclude that responding to CS is mainly affected by the nature of the CS rather than by that of the US.

Pavlov regarded the orienting response as an inborn, unconditioned behavioral entity elicited by external stimuli (38). According to him, it occurs consistently in the presence of CS prior to the establishment of the conditioned response. In the present experiments the identical topography of the behavioral patterns in pretesting (pseudoconditioning, habituation) and conditioning suggested that the maintenance or enhancement of the response evoked by the CS is one and the same as the orienting response. In this sense, auto-shaping is not a new phenomenon, but rather, a new way of looking at on old paradigm.

The conditioned character of the orienting response is at variance with the widely accepted view that OR disappears when performance becomes automatic, but in agreement with several recent results using classical conditioning arrangement (12, 13, 16, 35–37, 40, 58). Furthermore, our treatment of the signal directed response is at variance also with the stimulus substitution view of classical conditioning (32, 38,

48–50), which has been revived in the theoretical formulations of the autoshaping experiments (6, 25, 34, 39). As a support of this interpretation, Jenkins and Moore (26) reported that exposure to CS–US pairings caused the pigeon to peck the CS in a way that resembled the consummatory reaction evoked by the reinforcer (either food or water). Similar observations were reported in the rat (24, 39, 42). At this point it is important to remember that the INI response was consistently and reliably followed by TER (US-related) activities. These included anticipatory behaviors, like attempts to activate the magazine, occasional licking and chewing screws or the guillotine window (when US was rewarding) and crouching or escape attempts (with aversive US). Although the time course of INI and TER behaviors changed during training (showing progressively decreasing INI/ TER ratios), "two-phase" responding was maintained throughout conditioning. The separation of INI and TER was spelled out also by Boakes (termed as "sign-tracking" and "goal-tracking" 5) and Dykman (12). In a study of the contingent negative variation (CNV), Hillyard and Galambos (21) claimed that two (CS and US related) factors contributed to the development of the CNV. This "two-phase" responding is further illustrated by the findings of Ławicka (30). She observed that responding to spatially discontiguous CS decreased (thus resulting in less errors) if the animal (dog) was unleashed after CS offset.

The relevance of the foregoing discussion to learning theory is that the result of conditioning is not solely a specific UR-like response, but a complex reorganization of behavioral elements (3, 10, 27, 41, 44, 51), the spatio-temporal sequences of which depend on several factors, notably the physical properties and spatial location of the CS, contextual stimuli, precurrent behavior and the nature of the US. Furthermore, it is not only the CS evoked response which is modified during the course of conditioning, but intersignal behavior is also subject to change (10, 41).

Since the USs used in the present experiments could also serve as operant reinforcers, one can argue that the persistence of OR is an adventitiously reinforced instrumental response (perhaps enhanced by the artificial separation of the CS from US), and as such, an epiphenomenon of a particular paradigm (29, 46, 47). This problem is explored in detail in the following paper (10).

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