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FOUR-PAIR SAME-DIFFERENT DIFFERENTIATION AND TRANSIENT MEMORY IN DOGS[1]

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In our previous study (Brown and Sołtysik 1971) we investigated the same-different differentiation between auditory compounds in a three-pair design with dogs (Chorążyna 1967). In this procedure, reward was presented for responses (CRs) to the second member of a positive pair, consisting of two different tones, while no reward was given for two negative pairs, consisting of like tones. It was found that when the values of tone stimuli were held constant during training, the differentiation could be solved in part on the basis of information, concerning the occurrence of reward, present in the first member of a tone pair. This was demonstrated by an analysis of the paradigm itself, and was supported by the appearance of non-CR behaviors correlated with the first tones. It was concluded, therefore, that for the study of recent memory with the same-different task (Konorski 1959), a necessary condition is the complete ambiguity of first tones with respect to probability of reward.

The present study was conducted to explore delayed responding in the same-different differentiation with a four-pair design. Two tone frequencies, low (L) and high (H), were presented in the following pairs: L-H, H-L, L-L, and H-H. In a go–no-go differentiation procedure, res-

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ponses to the second member of a pair were rewarded only when the first and second members differed. The design was balanced in that L and H tones in the first position were equally associated with positive and negative trials.

The present design bears a formal similarity to "matching-to-sample" tasks in which short-term memory may be evaluated by delayed matching behavior (e.g., Etkin and D'Amato 1969). Matching-to-sample is an instance of a conditional discrimination (*see* Cumming and Berryman 1965) in which, descriptively, different cues from one set of stimuli define as positive or negative different cues from a second set. The present design also follows this logic. In both procedures, when delay is used, the first signal (or sample) determines on each trial which of the subsequent stimuli are to be positive or negative. However, in the matching task more than one cue from the matching set are presented on each trial, and reward is always available for a correct response. The present design, on the other hand, is a go–no-go differentiation in which "correct" performance on negative trials is counted as the non-occurrence of the response. Thus, positive and negative response tendencies may be evaluated separately on different trials.

MATERIAL AND METHOD

The subjects were six mongrel dogs fed once a day in their home cages after each training session. Sessions were run six days a week. One dog was discarded because of a procedural error.

Preliminary training and the CR chamber have been described previously (Brown and Sołtysik 1971). Briefly, dogs were trained to perform a wheel-turn response (CR) to the sound of a metronome. Reward was a portion of meat and broth-soaked bread. When latencies stabilized below 5 sec, tone training was initiated.

Tones were produced by a Hewlett–Packard oscillator (Model 201C) and presented through a speaker located in front of the subject. Stimulus frequencies employed were 200 and 300 Hz for low (L) and high (H) tones. A 1200 Hz tone was also used as H, and was introduced at various training phases for different dogs. Output intensity was held constant.

Four tone pairs were presented during differentiation training: L-H, H-L, L-L, and H-H. The duration of first and second signals were 3 and 5 sec, respectively, separated by a 1 sec interstimulus interval (ISI). A CR was defined as a response with a latency less than 5 sec to the second member of a pair only when the tones differed (i.e., paris L-H and H-L). Reward was never presented on negative trials (i.e., pairs L-L and H-H). Only positive trials were presented during initial

training sessions. During approximately the first 14 sessions, the inter-trial interval (ITI) was lengthened from 30 sec to 1 min, and the number of negative trials was gradually increased until the four pairs occurred three times each in a 12 trial session.

The ISI was increased when criterion performance was reached with a given interval. The ITI and number of positive and negative trials were varied with changes in ISI as shown in Table I. Criterion was defined as at least 90% correct trials on all four compounds concomitantly, during the minimum number of sessions required to meet this criterion on ten consecutive negative trials. Thus, for ISIs 1, 2.5, and 5 sec, at least four sessions were required, while for 10 and 20 sec ISIs, the minimum was five sessions.

TABLE I

Interstimulus intervals (ISI) and corresponding inter-trial intervals (ITI), number of positive trials (no.+), and total number of negative trials (no.—) per session

ISI (in seconds)	ITI (in minutes)	no.+	no.—
1	1	6	6
2.5	1	6	6
5	1.5	6	6
10	2	5	4
20	2	5	4

The two positive and two negative trials were presented equally often during each session, except of course for those cases in which an odd number of positive trials were presented. During these sessions, pairs L-H and H-L were alternated daily as the first trial. Throughout training, the first trial of a session was always positive. The order of the remaining trials was unsystematic with the restriction of no more than two negative trials in succession.

Within the general outline of the procedure presented above, treatments varied among dogs, and will be specified in the next section. Subjects were phased into the study over a period of approximately one year, with individual training periods ranging 5–13 months.

RESULTS

Performance curves beginning with the 15th training session are presented separately for each subject in Fig. 1–5. Points on the curves show, for each of the four compounds, the per cent of CRs occurring in

a block of 12 negative trials. That is, with 1, 2.5, and 5 sec ISIs, each point represents performance during 4 training sessions, and for 10 and 20 sec ISIs 6 sessions are grouped in each point. The first daily trial was omitted from the computation of positive trial results. Figures 1, 2, and 3 show performance throughout training, for subjects Epsilon, Lambda, and Sigma, respectively. All three dogs were trained initially with 200 and 300 Hz tone frequencies. Subsequently, an attempt was made to improve performance by increasing the difference between L and H tones. This was accomplished by replacing the 300 Hz tone with 1200 Hz. The change was made in two steps in which 10 sessions were given with 200 and 600 Hz, followed by the switch to 200 and 1200 Hz. Since initiation into the experiment and acquisition rates differed among these dogs, the tone frequency change, which was made simultaneously in the three animals, occurred at different phases in learning.

Epsilon's performance with a 1 sec ISI shows several features common to those of other dogs. As seen in Fig. 1, a small difference between

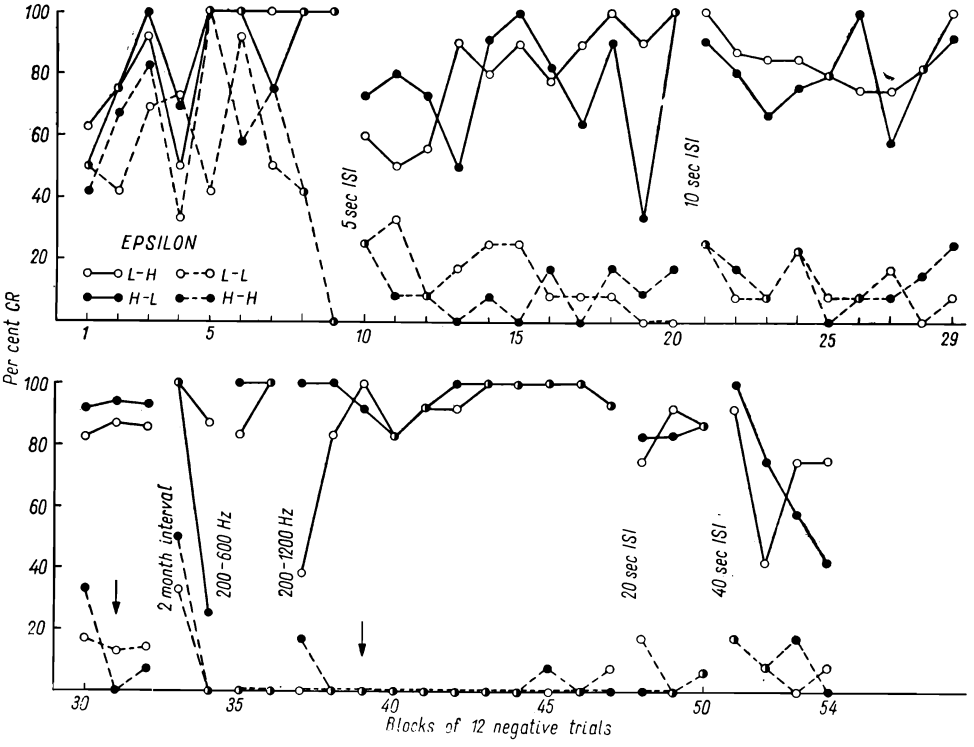

Fig. 1. Differentiation pefromance in Epsilon: per cent CRs to the four compounds L-H, H-L, L-L and H-H in blocks of 12 negative trials. Arrows on the abscissa denote criterion performance under ISI-10 sec. Points with 600 and 900 Hz are plotted in blocks of 10 negative trials.

positive and negative trials appeared early in training, and was maintained over a considerable period prior to criterion performance. Note that within positive and negative trials, the curves for the two compounds are matched. Thus, both positive compounds show similar acquisition rates, and a common trend appears in both negative pairs as well. This dog reached criterion after 49 sessions, the most rapid acquisition seen in this study. Following criterion, the ISI was lengthened to 5 sec, in which differentiation performance was maintained. A considerable period of well differentiated responding preceded criterion performance attained after approximately the same number of sessions (44) as with ISI-1 sec. Performance under 10 sec ISI resembled the 5 sec condition with a long period of above chance perfomance prior to criterion. While the immediate post-switch behavior on ISI-10 sec showed slightly better transfer than on ISI-5 sec, CRs on positive trials began to decline gradually. In order to maintain responding, the proportion of positive to negative trials was increased during 23rd–25th blocks. Therefore these points in the figure represent an inflated number or positive trials. Criterion was met in block 31, as indicated in the figure. After a two month interval with no training, the differentiation was maintained, but with some deterioration.

It is interesting to note that with changes in ISI, immediate post-switch behavior showed good transfer, which improved slightly from 5 to 10 sec ISIs. However, in neither case was this transfer reflected in subsequent behavior. That is, in terms of number of trials to criterion, there was little or no evidence of "savings".

Increasing the difference between L and H frequencies from a half an octave (200 and 300 Hz) to one and a half and then two and a half octaves (200 and 1200 Hz) produced a noticeable improvement in differentiation. Except for temporary disruption with the introduction of the 1200 Hz tone, presumably due to disruption of responding to this novel frequency, perfect performance was seen on both positive and negative trials, rarely seen in prior training. This is especially noticeable during an extended period of post-criterion training on the 10 sec ISI (blocks 40 to 47)[3]. Because of the confounding of larger stimulus differences with additional training, it is not possible to specify precisely the cause of this improvement. However, its rapidity would suggest that the larger tone differences were responsible.

When ISI was lengthened for Epsilon to 20 sec with 200 and 1200 Hz, criterion was met relatively rapidly. A further increase to a 40 sec ISI

[3] Post-criterion training with ISI-10 sec was given in connection with heart rate measurements cited in a prior study (Brown et al. 1971).

was attempted. During this period five trials a day were presented, 3 positive and 2 negative, with a 3 min ITI. As seen in the figure, differentiation under this ISI was maintained.

The pattern of acquisition for Lambda, shown in Fig. 2, is similar to Epsilon's with ISI-1 sec, with the exception that Lambda required

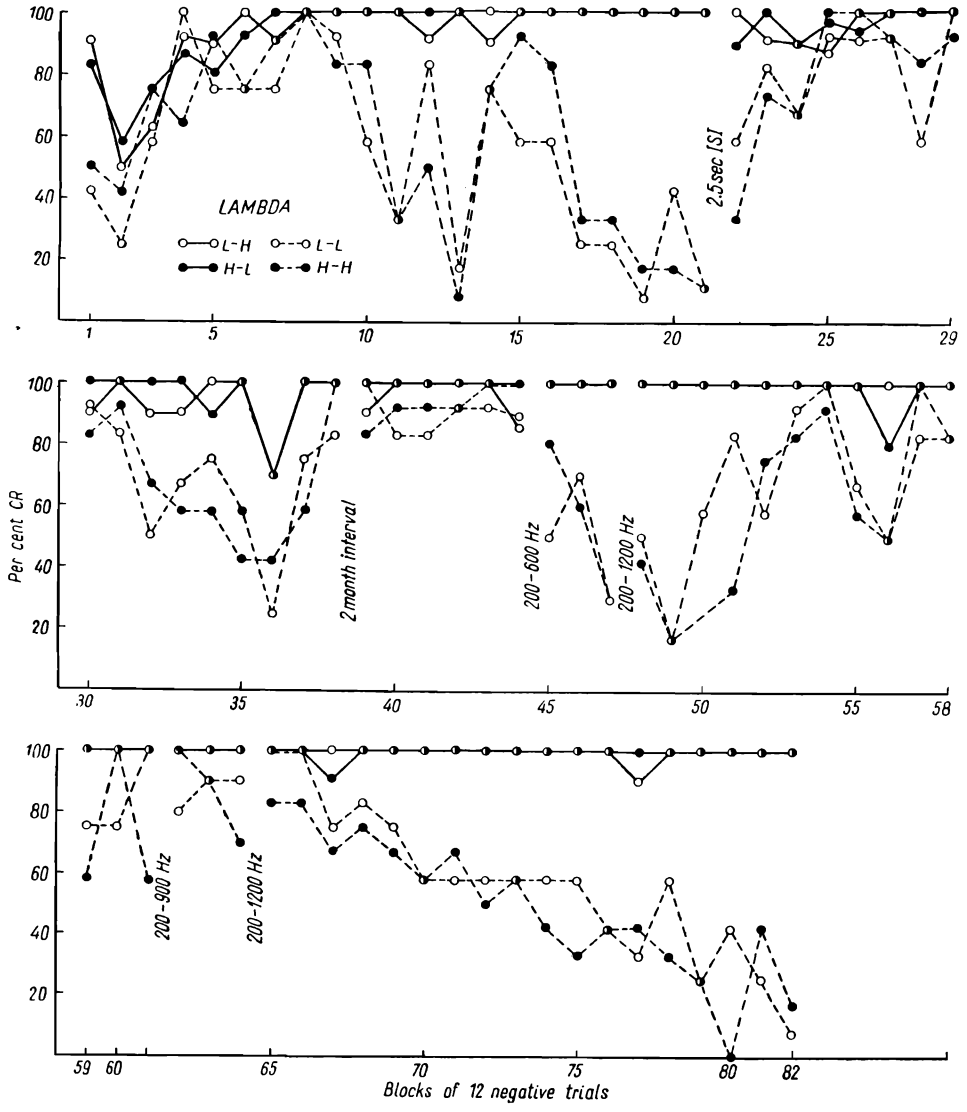

Fig. 2. Differentiation performance in Lambda: per cent CRs in blocks of 12 negative trials, except for performance with 600 and 900 Hz plotted in 10 negative trial blocks.

more than twice as many sessions to criterion. In this animal, the ISI was then increased to 2.5 instead of 5 sec. In spite of this more gradual increase in ISI, Lambda's post-switch performance was poorer than Epsilon's. While transfer of the differentiation was apparent on initial sessions with ISI-2.5 sec, performance on negative trials steadily deteriorated with no sign of systematic improvement in the course of 100 sessions. With the introduction of larger tone differences, an immediate effect was observed. As seen in Fig. 2, inhibition in negative trials appeared at once, and increased further with the change from 600 to 1200 Hz tones. This sudden improvement appeared to wane, however, with further training.

The transient nature of the increased inhibitory tendency led us to consider whether the rapid improvement in performance was related to the increase in the tone differences per se, or simply to the novel change in tone values. To answer this question, the H tone was reduced to 900 Hz for ten sessions (Fig. 2, blocks 62–64), followed once more by 1200 Hz. No effect of this manipulation was observed. Thus, the improvement following the original introduction of 1200 Hz tones seemed to

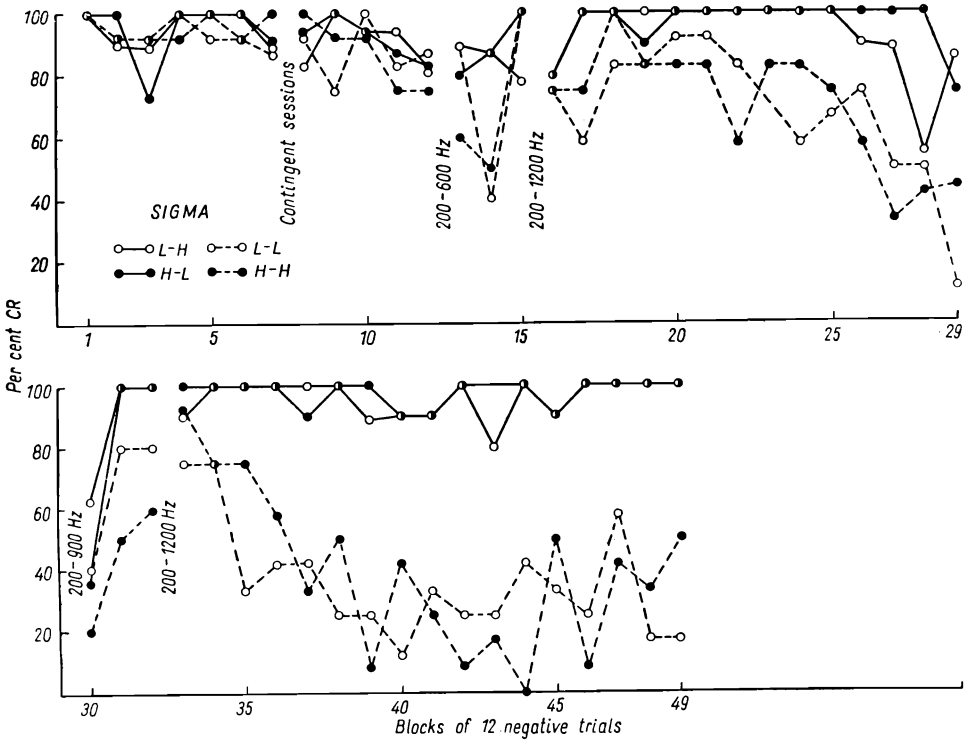

Fig. 3. Differentiation performance in Sigma: details as in Fig. 2.

be related to the increase in tone differences, although the subsequent reversal of the inhibitory tendency remains puzzling.

An ISI of 2.5 sec was used from the outset of training for Sigma, whose performance is depicted in Fig. 3. This dog differed chiefly from the preceding animals in a high initial level of responding to all four compounds. Responding also occurred to the first member of the tone pairs, and persisted for over 50 sessions, while in other animals, such first-tone responding typically extinguished in about 15–30 training sessions. An attempt was made to extinguish first-tone responding in Sigma, by withholding the second tone on some trials if a CR occurred to the first tone, and by presenting a positive trial if no first-tone response occurred. The effect of this contingency procedure, employed in blocks 8–12 was to decrease slightly responding to the first tones, but at the expense of second-tone responding as well. It might appear from the performance seen in Fig. 3 during this period, that this general effect on responding was associated with a failure of differentiation learning. However, when standard sessions were resumed with the introduction of 600 and 1200 Hz frequencies as H tones, an immediate difference appeared in the direction of correct differentiation. As in the case of Lambda, a subsequent ten session period with 900 Hz as tone H failed to produce a similar improvement in performance.

To summarize the results of these three dogs it is clear that the four-pair same-different differentiation may be solved with delays exceeding 20 sec. The task is a difficult one, requiring hundreds of trials for solution with a small interval between stimuli. Transfer to longer intervals was not consistently maintained, with zero or even negative savings. Abrupt, though temporary, improvement in differentiation performance was observed following an increase in the difference between L and H tone frequecies.

The last two dogs, Tau and Omega, were trained from the outset with 200 and 1200 Hz tones and a 1 sec ISI. The performance of Tau is shown in Fig. 4, in which differentiation appears from the beginning of training, and continues to increase, if somewhat irregularly in subsequent blocks. Criterion was met for this dog in approximately the same number of trials as required for Lambda. However, in contrast to the latter dog, Tau's performance on lengthened ISI conditions proceeded more rapidly to criterion. Criterion on ISI-5 sec was met in block 31, not shown in the Figure.

Figure 5 depicts Omega's performance from the beginning of four-pair training with 200 and 1200 Hz tones. Prior to training on the four-pair problem, this dog had been given approximately 90 sessions of differentiation training between L-H and L-L compounds, comprised

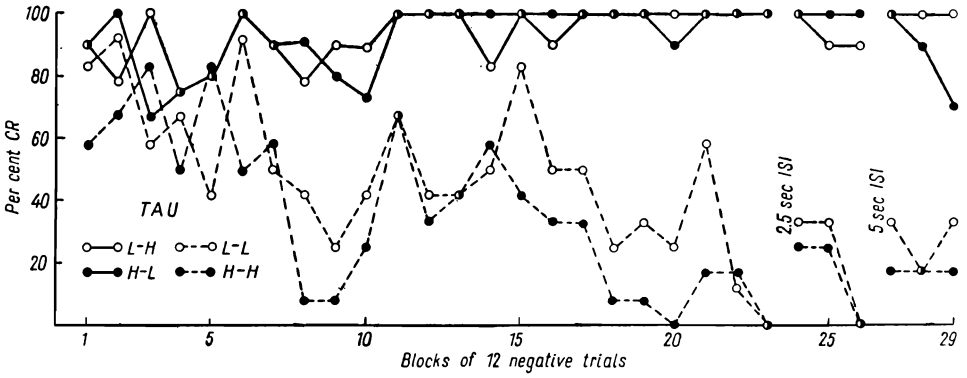

Fig. 4. Differentiation performance in Tau: per cent CRs in blocks of 12 negative trials.

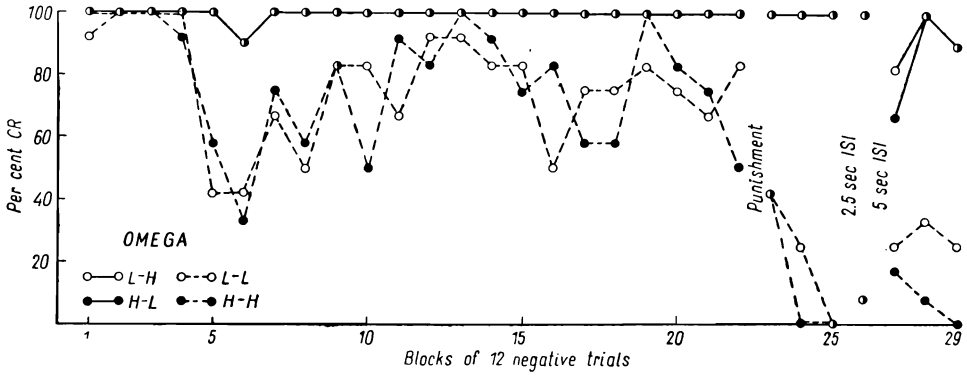

Fig. 5. Differentiation performance in Omega: per cent CRs in blocks of 12 negative trials. Explanation in text.

of 200 and 300 Hz tones. Virtually perfect differentiation was exhibited throughout the final 60 sessions of this period. Since this differentiation may be solved on the basis of second tones only, it is interesting that no specific transfer was exhibited in the four-pair problem: the onset of differentiation in this task was characterized by equivalent decreases in CR frequency for the L-L and H-H compounds.

It was observed during the early sessions on the four-pair problem, that Omega developed the habit of licking the exposed, empty food cup following unrewarded responses on negative trials. In order to discourage this behavior, a small sliding door on the food tray was advanced to cover the food cup whenever the licking occurred on negative trials. It was observed that closure of the door, touching the dog's snout, often elicited abrupt withdrawal from the food tray. This procedure was intro-

duced in the 16th session (block 4) and terminated after the 23rd session (block 6). Door closure was used a total of six times during this period. Licking ceased almost immediately, and was soon afterwards followed by the marked decrease in CRs on negative trials seen in the 5th block. Although licking behavior remained permantly suppressed, responding on negative trials subsequently increased gradually, eliminating most of the earlier improvement.

The sudden improvement seen in the 5th block demonstrated that subsequent performance was not reflecting the actual degree of learning. We were encouraged, therefore, to introduce systematic punishment in an attempt to suppress responding on negative trials. Conductive paste was applied to two shaved areas of a hindleg to which stainess steel electrodes were fastened. Prior to the session a graded series of biphasic shocks (100 Hz) of 0.3 sec duration was given, and a shock level was chosen which reliably elicited leg flexion, but no vocalization or startle. Punishment was introduced in the 23rd block. As seen in Fig. 5, the suppression effect on negative trials was immediate, while responding on positive trials was left intact. Within 11 sessions, criterion on ISI-1 sec was reached, and with the switch to 2.5 sec, criterion was met in the minimum 4 sessions. On the second session following the introduction of the 5 sec ISI, no responses were made on positive trials, presumably owing to the increased number of shocks taken in the previous session. Since positive CRs were absent also in the beginning of the third session, smaller ISIs were introduced without shock in the remainder of this sessions and the following one (data not shown in the Figure). With the resumption of the 5 sec ISI and shock in the fifth session, positive CRs returned and good differentiation performance was observed. Criterion on the 5 sec ISI was met in block 34, not shown in the figure.

Behavior during the interstimulus interval was carefully observed in all five dogs throughout training. Marked differences in ITI behavior were observed. Epsilon remained virtually motionless during the interval, while the other dogs showed varying degrees of activity. Differences between orientation in ISI and ITI were sometimes seen. However, no systematic differential behavior was detected in any dog following L and H tones in the first position.

DISCUSSION

It is evident from the present findings that the four-pair same-different problem is a difficult one requiring hundreds of acquisition trials to criterion. One dog (Epsilon) reached criterion with ISI-1 sec after approximately 600 trials, while the remaining dogs required a minimum

of about twice as many trials to reach the same criterion. Extension of the ISI, even in gradual steps, produced relatively weak transfer.

An intrinsic property of the present design is the requirement of the animals to make comparisons between tone values. The difficulty attending this feature of the task has been noted previously with auditory discrimination in dogs (Chorążyna and Konorski 1962). In our prior study with a three-pair same-different differentiation in which solution by comparison was possible, it was found that dogs readily reverted to another solution strategy (Brown and Sołtysik 1971). A question of initial importance is why these animals experience so great difficulty in tasks involving stimulus comparison, a process often invoked in theoretical considerations of discrimination learning. While an answer to this question is not afforded by existing data, several hypotheses may be advanced.

Transient memory. One possibility is that recent memory traces decay too rapidly to support discrimination. Although the poor differentiation at longer intervals support this hypothesis, it is probably not sufficient to explain the problem difficulty found initially with a 1 sec interstimulus interval.

Sensory integration. A more interesting possibility is that the same-different variety of discrimination is based on perceptual patterns of stimulus sequences, and that the sensory integration of auditory sequences in dogs requires strict stimulus contiguity. One might ask how differentiation would proceed with a null ISI, or with tone differences produced by continuous frequency change.

Abstractness. A third alternative is that the dog's cognitive capabilities do not extend to such discrimination as "same" versus "different". Although data suggest that this mode of discrimination is possible in dogs, it is likely that it is not a primary one. In this case, other "preferred" solution strategies may be found. The problem of alternative strategies is discussed further below.

Whatever the source of difficulty may be, in general, the sudden improvement in performance which followed different experimental manipulations in the present study, as well as long periods of weak, though non-perfect differentiation suggest that problem difficulty is the result of a deficiency in performance rather than learning factors. The use of larger differences between L and H tones from the outset of training seemed to facilitate transfer to longer ISIs. The introduction of shock punishment led almost immediately to criterion performance at shorter as well as longer ISIs, indicating the usefulness of this procedure for dogs as well as monkeys (Stępień and Cordeau 1960). These results suggest that the use of larger stimulus differences, combined with mild

punishment would substantially reduce the amount of training required for criterion performance.

The limiting effective delay in the same-different task has not yet been established in the five dogs of the present study. However, the results of one animal indicate that performance can be maintained with a delay exceeding 20 sec. This result extends previous estimates of the short term memory trace in studies with dogs (Chorążyna 1967, Ellison 1964).

One factor probably responsible for limiting the estimate of the transient memory trace to about 20 sec is the relationship between ISI and ITI. These intervals were increased together in the present study. It is unlikely that longer ITIs per se have a detrimental effect upon performance in this differentiation task; incidental observation and intuition suggest that the opposite is true. It is more likely, instead, that ISI and ITI interact in such a manner that identification of tones as first or second is impaired with longer ITIs, but only when ISI is also long. In this connection it should be noted that the ratio of ITI to ISI in the present study decreased by a factor of 10 from ISI-1 sec to ISI-40 sec, a relation imposed by practical time considerations. Thus, discrimination between first and second tone positions became more difficult as ISI was lengthened. A desirable objective is to ensure the proper identification of trial onset independent of the relation between ITI and ISI. This problem could be solved by employing a ready signal prior to the first tone of a pair, or by requiring the animal to control trial onset by an observing response (Dewson and Cowey 1969). Which of these alternatives is preferable with dogs has yet to be determined.

No differential behavior was observed following L and H tones in the first position. This result is in accordance with our expectations of the unbiased role of first tones in the balanced four-pair design. It also argues against the possibility that responding on positive and negative trials was controlled by simultaneous compounds consisting of the second tone and response produced cues of mediating behavior generated by the first tone, rather than by short term memory traces (Blough 1959). The failure to detect overt mediating behaviors may lead to a false negative conclusion. On the other hand, it would be difficult to decide between alternative interpretation based on covert mediating behavior as distinguished from central neural events. A decision can only be made on the basis of operations which eliminate or selectively reduce one of these processes. In a recent study by Etkin and D'Amato (1969), the effect of possible mediating behavior was controlled by varying the size of the stimulus set in a delayed matching-to-sample procedure with monkeys. These authors found that for each delay interval, performance was as good with

large as with small stimulus sets. Chorążyna (1959, 1967) found that the same-different differentiation could be maintained with dogs at small delay intervals in a three-pair design with variations in the values of L and H signals.

The argument that performance in the same-different differentiation task reflects the operation of a short-term memory process in the present study would be strengthened if the differentiation could be maintained in spite of an increase in the number of tone values employed (a multiple pair design).

SUMMARY

Dogs were trained to differentiate between four pairs of auditory stimuli: high tone followed by a low tone, or vice versa, were positive CSs and the wheel-turn CR during the second tone was reinforced with food; two successive low tones or two high tones were negative CSs and no reward was available (go–no-go differentiation). Learning the task with a 1 sec intertone interval was difficult and required 600 trials in the best subject, while in average well over 1000 trials (of each kind) were necessary. Transfer to longer interstimulus intervals was poor and even negative savings were observed. The maximum interstimulus interval obtained under criterial performance was 20 sec, but the limit has not yet been determined. Using larger tone pitch differences and a mild punishment of responding to negative pairs of tones rapidly improved the performance, thus indicating that the difficulty of task is not exclusively related to the processes of short-term memory but also reflects the motivational complexity of the design. In conclusion, the four-pair same-different differentiation is a promising test for transient memory, but could be further improved by procedures which would facilitate acquisition, and preclude or reduce the subject's use of solution strategies involving non-transient memory factors.

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