The Influence of Trial Sequence in Discrimination Learning

THE INFLUENCE OF TRIAL SEQUENCE
IN DISCRIMINATION LEARNING

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SCOPE AND CONTENTS: This thesis presents a study of the effectiveness of a blocked series of stimulus presentations in training pigeons to perform a discrimination. It was found that this sequence of trial presentations was at least as effective as training with a random sequence of trial presentations.

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CONTENTS

INTRODUCTION

Studies of successive discrimination have used a variety of sequences for presentation of reinforced and nonreinforced stimuli. As we will show below, knowing how the rate of formation of a discrimination is affected by the trial sequence should help to identify the critical features of discrimination training. This problem has received surprisingly little attention. The purpose of the present experiment, therefore, is to compare the effectiveness of discrimination training when reinforced and nonreinforced trials are presented in blocks with the effectiveness of training when a random sequence of reinforced and nonreinforced trials is given.

Before turning to the experiment, however, it is necessary to discuss the background of the problem. We will first consider some of the techniques used in discrimination training; second, we will consider the major theoretical interpretations and their supporting evidence.

Techniques

A variety of arrangements for successive exposures of reinforced and nonreinforced stimuli has, of course, been employed in training animals to make discriminations. Most of these involve frequent transitions between the stimuli to be discriminated rather than extensive blocks of trials or prolonged exposures to one stimulus. The common method in the case of discriminative classical conditioning is illustrated by the work of Pavlov (1927) who called it the method of contrasts. The conditioned response is first established to one stimulus, the positive stimulus, by pairing it with the unconditioned stimulus, or reinforcement. Subsequently, nonreinforced presentations of a second stimulus, the negative stimulus, are intermixed with the positive trials. Responses occur to the negative stimulus as a result of generalization from the positive stimulus, but with continued training the generalized responses are eventually eliminated. In Pavlov's terminology, the reflex is said to be differentiated or specialized. A discrimination of this kind is sometimes called a "go-no go" discrimination since the animal learns to respond to one stimulus and not respond to another.

Similarly, Skinner (1938) has used a method of successive presentations in the training of go-no go discriminations in operant conditioning. In a typical experiment, the operant response of bar-pressing was reinforced when the light in the training box was on, and not reinforced when the rat was in the dark. The light was turned on until a single response occurred, the response was reinforced and the light was then turned off for five minutes. This regular alternation of five minutes in the dark followed by a response-terminated presentation of the light was repeated, and it was found that the rate of responding during dark periods gradually decreased while the response rate when the light was on was maintained. It may be noted that only two stimulus conditions are involved in Skinner's method. Hence, positive and negative stimulus conditions must alternate. One cannot vary the sequence of trials, only the duration of exposures to the stimuli. In the Pavlovian method of contrasts, on the other hand, there are three conditions, since in addition to positive and negative trials, there is a between-trial stimulus condition.

In some recent investigations of discriminative operant conditioning, Skinner's procedure has been modified. In these studies opportunities to respond to the positive or negative stimuli are separated by periods in which responses are physically prevented, by removal of the manipulandum, for example, or are made unlikely through a drastic change in stimulus conditions. For example, in an experiment by Honig, Thomas, and Guttman (1959) which was concerned with the effects of trial sequence, successive exposures to positive or negative stimuli were separated by periods in which responses, the pigeon's key-peck, were stopped by the introduction of a blackout, ie., by turning out all illumination of the test compartment. The introduction of this third state makes it possible to vary the sequence of trials, and makes the method more similar in this respect to the Pavlovian method. The methods still differ, however, since during classical conditioning, the response, for example salivation, is not prevented from occurring between trials. Instead, a discrimination between the presence and the absence of the trial stimuli keeps the incidence of between-trial responses low.

In discrimination experiments employing a runway or a Lashley jumping stand, removal from the apparatus separates successive trials. Here the use of a random or modified random sequence of positive and negative trials, the Gellerman series for example, appears to be standard practice; for example, Sarason, Sarason, Miller, and Mahmoud (1956), Amsel (1952), and Grice (1948).

Theoretical Considerations

There are two major types of theories which would predict that irregular sequences of trial presentation would be more effective than blocks of trials. There are those which emphasize the perceptual aspects and those which are exemplified by the theories of conditioning.

Perceptual theories. First we will consider theories which imply that discrimination is based on perceptual comparison. If discrimination learning is based on comparison of the stimuli, we might expect that animals would learn more quickly when trained with a random or irregular sequence than they would when blocks of the same stimuli were used. This prediction is based on the following three properties of an irregular sequence, each of which would be expected to facilitate the comparison between stimuli: more frequent transitions between positive and negative stimuli, a shorter time-gap between stimulus presentations, and the absence of any extra cue arising from the predictability of the trial sequence itself.

Lashley has emphasized the importance of comparison to discrimination. He has argued (Lashley and Wade, 1946) that a sloping gradient of generalization, which is one measure of discrimination, does not arise unless there has been an opportunity to compare values along the dimension of the gradient. A plausible extension of his position would be that more frequent transitions, since they provide more opportunities to compare positive and negative stimuli, will lead to more rapid development of a discrimination. There is no study testing this suggestion.

Bringing stimuli nearer to each other in time should facilitate comparison. If the discrimination is to be formed between stimulus present and stimulus not present, the interval between presentations is zero. In other procedures the stimuli may be separated by a blackout period, an interval of only background stimulation from the experimental apparatus, or removal of the animal from the apparatus. Presumably, shorter intervals should lead to a faster formation of the discrimination.

Several studies have tested the effect of varying intertrial intervals. Sarason, Sarason, Miller, and Mahmoud (1956) found that rats learning a black-white discrimination in a Y-maze reached criterion more quickly under spaced conditions (12 minute intervals) than under massed conditions (20 second intervals). The spaced group also was able to reverse the discrimination more easily. The authors compare their results to North (1950a, 1950b) who did not find a significant difference between 1 and 12 minute intertrial intervals in discrimination reversal. They suggest the possibility of an optimal intertrial interval which in this situation is nearer 1 minute than 20 seconds. Evidence for an optimal interval has been found by Thompson and Pennington (1957) and Pennington and Thompson (1958) in studies of discrimination with aversive stimulation.

Simultaneous presentation of the discriminative stimuli may be viewed as the limiting case of short intertrial intervals. Several of the studies comparing simultaneous with successive presentations have shown that the successive problem is relatively more difficult than the simultaneous problem (Spence, 1952; North and Jeeves, 1956; Loess and Duncan, 1952; McCaslin, 1954). But an analysis of what is involved in these procedures suggests that they do not provide a clear test of the importance of comparison since other differences exist between them. In some successive procedures the animal may only choose to respond or not respond, in which case the response is reinforced on some trials and not on others. In other successive procedures one response is reinforced in the presence of one stimulus and a different response to a second stimulus. The simultaneous procedure provides for the reinforcement of only one response (eg., approach to the correct stimulus) and provides the opportunity for this response to be made on every trial. Because of these differences in procedure, the effectiveness of simultaneously comparing two stimuli cannot be judged from these studies.

A study which allows a more legitimate comparison between simultaneous and successive presentations is one by Riley, Ring, and Thomas (1960). They studied rats using a Lashley jumping stand and stimulus patterns consisting of rectangles of two different light intensities. One group of animals, the comparison group, could see both rectangles simultaneously, while the noncomparison group could see only one. But both stimuli were present on each trial and could be seen by the noncomparison group if they retraced through the start box. The subjects in both groups were shown the same stimuli on each trial, reinforced for the same response, and given the opportunity for a reinforcement on every trial. The authors conclude that fewer trials are required to learn a discrimination with the comparison condition. The advantage of this method increased with more difficult discriminations.

We must now consider the problem of extra cues since the blocked sequence can be though of as introducing an extra cue to reinforcement. Many authors have argued that perceptual comparison of the experimentally relevant stimuli might be affected by the presence of such cues. Lashley (1946), for example, argues that an animal responds to few, often only one, cue in the experimental environment. Whether or not other aspects of the situation are noted is largely due to chance. The difficulty of learning a discrimination in the presence of extra cues has been discussed by Spence (1936) in his conditioning and extinction model of discrimination learning and by Harlow (1959) in his extinction model. Their discussions are only tangentially relevant since both discuss this problem only for simultaneous two choice discriminations in which the stimuli are spatially separated. In this case, they argue, animals often respond to the position of the reinforced choice rather than to its other, experimentally relevant, stimulus properties.

There has been a tendency to ignore another possibly important cue which can occur in successive discriminations. This is the cue of pattern of trial presentation. A predictable trial sequence might interfere with the development of the relevant discrimination. When long runs of one type of trial occur, the animal may learn that one reinforcement is almost always followed by another, and similarly, that one nonreinforcement is followed by another nonreinforcement. A plausible implication of Lashley's discussion is that if a hungry animal is responding to the pattern of reinforcement, it may not compare the other stimuli which are correlated with reinforcement. The animal would not learn to perform the discrimination as easily if trials were presented in blocks as if they were presented in a random sequence. In a random sequence of trial presentations the only consistently reinforced cue is the one which the experimenter considers relevant.

Conditioning theories. The other major view of discrimination learning, the one which is perhaps dominant, is that discrimination is a combination of the effects of conditioning and extinction, and no special consideration need be given to a process of perceptual comparison. Although this view probably gives less weight to the trial sequence than does a view which stresses perceptual comparison, it also leads to the expectation that an irregular sequence is more effective. An obvious consideration of this view is that an irregular sequence would maintain responding. If long runs of negative trials were presented, the response might become extinguished to the positive as well as to the negative stimulus.

The conditioning and extinction view of discrimination learning also suggests the importance of transitions. Curves of the change in response rate during the course of acquisition or extinction of a response typically show relatively large increments or decrements in the earlier stages, or at the beginning of a series of trials. As the trial presentations continue, the rate of change decreases. The effectiveness of an average trial in longer runs would therefore be less since the later trials in the runs provide smaller increments or decrements in response strength. Therefore, runs of shorter length should be more effective in producing the required difference in the strength of response to positive and negative stimuli.

In the model of discrimination learning proposed by Bush and Mosteller (1951), transitions are also assigned a critical role. It is assumed that the stimuli to be discriminated have some characteristics in common and some which make them distinctive. During training, the reinforced and nonreinforced stimuli become less and less similar. The model defines an index of similarity between the stimuli. The value of the index is diminished by an operator D which is applied to the index each time the environmental event following the response changes from one type of event to another, e.g., from reward to nonreward.

Another operator Q is applied on each trial to change the probability of response to that stimulus on its next occurrence. To predict whether or not a response will be made on the next trial, both operators Q and D must be applied. But it is operator D which makes this model distinctive in assuming that the stimuli only become less similar through transitions from one to another.

In summary, it would appear that whether one views the process of discrimination as involving an act of comparison or as the result of the combined effects of conditioning and extinction, one would expect irregular trial sequences with frequent transitions to be more efficient than a sequence of extensive blocks of trials of one type.

A study by Honig, Thomas, and Guttman (1959) is one which provides relevant data. In it, the effect of a random sequence of exposures to the positive and negative stimuli is compared with that of a series of exposures to each. Pigeons were trained to peck a key illuminated by a light of 550mu. They were given one session of continuous reinforcement on a variable interval schedule. The following day they were extinguished at 570mu, one group for twenty minutes and one group for forty minutes. All training and extinction sessions were divided into one minute intervals by ten second blackouts. On the next day the birds were tested in extinction by presenting 11 stimuli, ranging from 490 to 610mu, in a random sequence. Generalization curves were compared with those of a control group which also received the reinforced training and the generalization test, but not the extinction at 570mu. Responding after extinction lowered the response rate, but lowered it uniformly so that all points were a constant proportion of the points of the control group. The extinction procedure produced no effects specific to the nonreinforced stimulus. Following this first extinction test the birds were given discrimination training with a random mixture of exposures to positive and negative stimuli. The extinction test following discrimination training showed a sharpening of the generalization gradient and a shift in location of the peak, changes which were not found after one session of a series of exposures to the negative stimulus. The authors conclude that the change in an extinction generalization test which is found after discrimination training is not the result of separate processes of conditioning and extinction. Guttman (1963) in a later interpretation of these results suggests that a discrimination is formed from a temporal integration of the stimuli, not independent conditioning and extinction.

The absence of any contribution to a discrimination by an extended series of exposures to the nonreinforced stimulus is a strong result. It implies that the variables of transitions between stimuli or time intervals between them are critical to the formation of a discrimination. In the present study the question of trial sequence is reexamined with certain modifications of procedure.

First of all, in the experiment by Honig, Thomas, and Guttman, successive exposures of the stimuli were separated by blackout intervals which presumably prevented responses from occurring. As noted previously, this arrangement is to be distinguished from one in which the trials are discriminated from the between trial stimulus condition as in the Pavlovian method of contrasts. The present experiment uses a discriminated trial procedure which is an analogue in operant conditioning to the method of contrasts in classical conditioning.

Secondly, in the discriminated trial procedure, there is no doubt that the animal is responding to some aspect of each separate stimulus presentation, since the onset of the stimulus occasions a response with short latency. It is of interest to learn how much of a contribution to the development of a discrimination will result from blocks of trials under these circumstances.

The plan of the present experiment also differs from that of Honig, Thomas, and Guttman in the way in which the effects of a period of training under a random trial sequence or under a blocked sequence are tested. In the present case, the effects are tested in terms of the subsequent course of discrimination learning in which all subjects are given random sequences, rather than in terms of a test of generalization in extinction.

METHOD

Subjects:

Twenty-four male White Carneau pigeons served as subjects. Three additional birds were discarded when they did not easily learn to key-peck. The birds were housed individually with water continuously available. They were starved to eighty per cent of their ad lib body weight and fed only enough grain to maintain their weight within ten grams of this value.

Apparatus:

The experimental box was 11 x 11 x 15½ inches, housed within a larger wooden box. This box was put in a small room to isolate it from the noise of the controlling equipment. Water was available from a cup on the floor of the box and a fan provided ventilation. The compartment was continuously illuminated by a diffuse light source mounted above the working panel. A metal strip served as a visor to shade the area in which the stimuli were presented. White noise from a Grason-Stadler noise generator was used to mask sounds from the control equipment.

The key, a round plastic disk mounted at the center of the working panel, was lighted from behind by a microscope illuminator. A shutter between the light source and the key was opened to begin a trial and closed to end it. The discriminative stimuli were parallel black lines on a white ground shown in a vertical or horizontal orientation. They were presented from behind the key. The patterns were on disks which could be swung into position from either the right or left side. Three disks were used, and each was changed so that the lines were alternated between the horizontal and the vertical positions.

The disk, its orientation, and whether it was placed in the right or left side varied daily according to a predetermined schedule.

To present a stimulus, the disk was swung into place behind the key and five seconds later the shutter opened. The trial lasted until four responses were made or until 4.7 seconds had elapsed, whichever occurred first. The shutter closed to end the trial. Between trials the key was dark, but the compartment remained illuminated. Pecks to the darkened key (intertrial responses) were possible, but rarely occurred. An intertrial response delayed the presentation of the following trial for one minute.

Key pecks to the positive stimulus were reinforced by raising a tray of grain within reach of the bird for 4.2 seconds. The tray was raised into an opening located near the floor of the box under the key. This opening was illuminated as long as grain was available to the bird.

The order of trials and the intervals between them were controlled by paper tapes fed into a teletype. Intervals between the onsets of trials were 15, 30, or 45 seconds, randomly mixed with the restriction that there be equal numbers of each interval. In tapes of twenty trials, seven presentations of one interval and six of the other two intervals were used. Six tapes were used for each pattern of trial presentation, each tape being made so as to give different mixture of intertrial intervals. The tapes were varied among birds within a single daily session and within birds over sessions, according to a predetermined schedule.

Responses were recorded on counters and an Esterline-Angus recorder. Counts were made of the number of reinforced and nonreinforced stimulus presentations, the number of responses made to each type of trial, the number of responses made between trials, the number of tray operations, the number of trials in which the response requirement was completed, and a cumulative latency for the completion of the response requirement to each type of trial. Latency was measured in tenths of a second.

Procedure:

Each bird was shaped to a key showing the positive or reinforced stimulus which is designated S^+. This was the disk with lines in the horizontal position. The response requirement was slowly raised from one to four responses. Most birds were given this training in two sessions. A few birds did not perform well and were given a third session, while one bird learned quickly and was given only one.

Pretraining was given in six daily sessions of forty reinforced trials each. Each bird was given a minute for adaptation to the box before trial presentations began. If a bird stopped responding during a session, the tray was operated independently and the bird usually began responding. If responding did not begin, the bird was returned to his cage. An additional pretraining session was given if fewer than twenty trials had been completed.

After pretraining the birds were randomly assigned to four groups. Each group was given twenty S^+ trials and twenty S^- trials in each daily session. The order of presentation varied among the groups. The birds assigned to Group I were trained on a random mixture of trials, that is, the S^+ and S^- trials were interspersed in a random sequence. Those in Group II were given one day of training with the trials arranged so that one block of twenty S^+ trials was followed by one block of twenty S^- trials. During the remaining sessions they were trained on a random mixture of trials. Birds in Group III were given three days of this blocked training (twenty reinforced followed by twenty nonreinforced trials) then trained on a random trial mixture. Group IV received just twenty reinforced trials a day for three days before being placed on the random trial sequence. The design is summarized below.

Group	N	Pretraining	Trial sequence Training phase 1	Trial sequence Training phase 2
I	4	6 days	None	Random
II	8	" "	1 day blocked	"
III	8	" "	3 days blocked	"
IV	4	" "	3 days S^+ trials	"

In each group, a total of 12 sessions of phase two discrimination training were given.

An evaluation of the contribution of blocks of S^- trials (phase 1) to the formation of the discrimination is made in terms of the performance during the first session of phase 2. Group IV provides a check on the possible effects of the S^+ trials alone. The design also permits an evaluation of the relative effectiveness of random and blocked sequences. The effects of one session of a blocked sequence may be compared with the effect of one session of a random sequence by comparing the performance of Group I in the second session of phase 2 with that of Group II in the first session of phase 2. A similar comparison for three sessions in obtained by comparing the fourth session of phase 2 for Group I with the first session of phase 2 for Group III.

RESULTS

Pretraining. All birds were responding reliably to the reinforced stimulus, S^{+}, by the sixth day of pretraining and maintained a high probability of response throughout the study. The probability of response to S^{+} for individual birds is given in Table 12 of the appendix.

Effect of blocked sequence of trial presentation. The effect of training with blocked sequences of trial presentation (phase 1) was studied by comparing the performance of the several groups on the first session of phase 2. The primary measure is the probability of completion of the response requirement to S^{-}. Groups I and IV which received no S^{-} trials in phase 1 but differed in the number of S^{+} trials received in phase 1, were statistically indistingishable in their performance in the first session of phase 2 by the Mann-Whitney U test ($p = 1.00$).[1] Additional training on S^{+} did not alter performance of the discrimination. These groups will be considered as a single group which is designated as the Random Group since the discrimination training for these animals was entirely in phase 2 under the random sequence.

The median probability of a completed response to S^{-} is given by sessions for Groups II, III, and the Random Group in Figure 1. These data are also given in Table 4 of the appendix. It appears from these curves that training under the blocked sequence did contribute to the development of the discrimination since the probability of a completed response to S^{-} was lower on session 1 of phase 2 for Groups II and III than for the Random Group. The effect was clearly significant

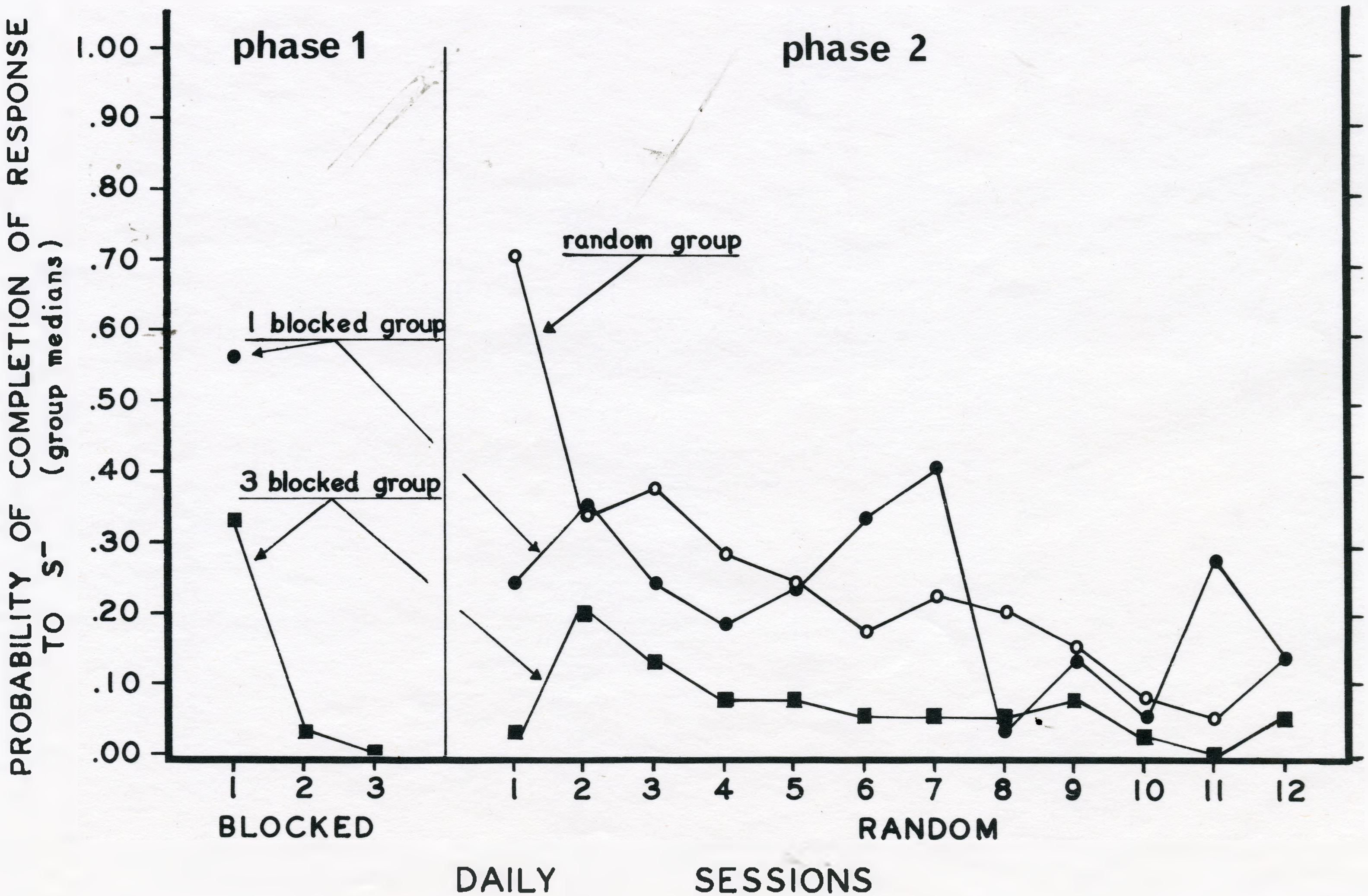

Fig. 1- Probability of completion of response to S^-

for Group III which received three sessions of blocked training ($\underline{p} = .03$), and was also significant for Group II which received one session ($\underline{p} = .05$).

The total number of responses to S^- (this includes responses on trials in which fewer than the four responses required to terminate the trial were made), and the number of trials on which no response was made are also measures of discriminative performance. They are tabled in the appendix. The results of U tests made on the total number of responses to S^- are included in Table I of the appendix. The results are consistent with those for the median probability of completed response which are also given in Table I.

Relative effectiveness of blocked vs. random sequence. To compare the effectiveness of blocked with random training, curves of Figure 1 are replotted in Figure 2 and shifted so that points representing performance after an equal number of training sessions (either phase 1 or 2) have the same abscissa.

The effectiveness of three blocked sessions may be compared with that of an equal number of random sessions by comparing the Random Group with Group III on the fourth session (the fourth session is the first session in phase 2 for Group III). As is apparent from Figure 2, three sessions of blocked training are at least as effective as three sessions of random training. The difference is, however, not significant ($p = .19$).

The effect of one session of blocked training appears to be equivalent to that of one session of random training. This is shown by comparing Group II on session 2 (the first session of phase 2) with the Random Group on session 2. While the difference is in the same direction

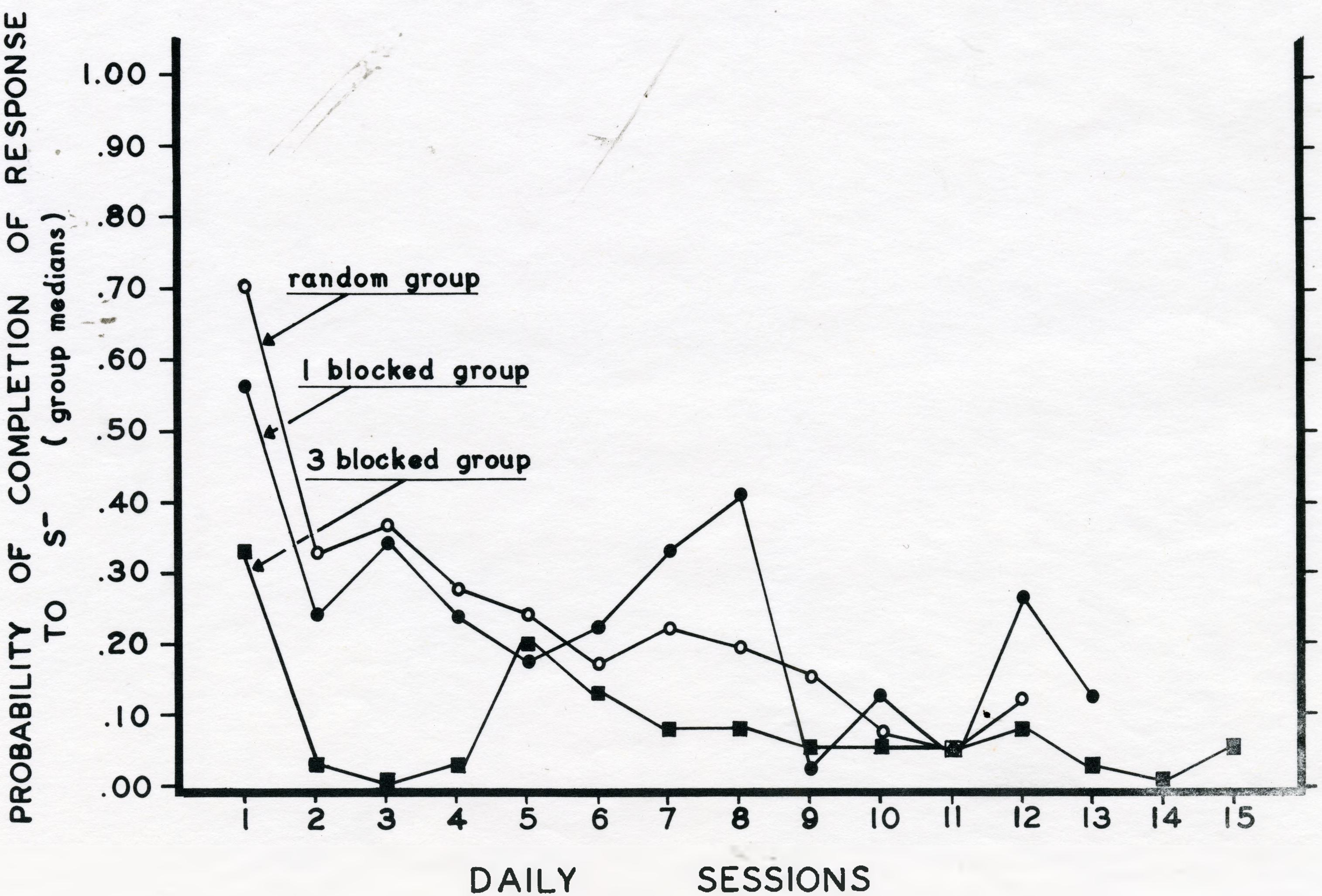

Fig. 2- Probability of completion of response to S^-

as the previous comparison after three sessions, the U test yields $\underline{P} = .72$ which means that the groups are statistically indistinguishable. The assumption that one day of random training has some effect was supported by a sign test (two-tailed) based on the change in probability of completed response to S^- from session 1 to session 2 in the Random Group ($\underline{p} = .07$).

Fewer responses are made to S^- during training with the blocked sequence than are made to S^- in the corresponding sessions of training in the random trial sequence. In the first session of blocked training, Groups II and III, the average total of S^- response was 43 while the comparable figure under the random sequence was 61 ($\underline{p} < .10$). For three sessions of blocked training (Group III only) the average total was 69, while the random sequence yielded 153 ($\underline{p} = .01$). Thus, for equal numbers of training trials, discriminative performance after training under the blocked sequence is at least as good as it is after training under the random sequence, even though far fewer S^- responses have occurred during the blocked sequence.

<u>Development of discrimination in phase 2</u>. Figure 1 shows that in the random group there is a sharp decrease in the probability of response to S^- from the first to the second session, while this is not the case in Groups II and III. The number of subjects in each group showing a decrease in S^- responding was as follows: 7 in the Random Group, 3 in Group II, and 0 in Group III. To test the significance of the difference between the frequencies for the Random Group and the others, the remaining subjects in each group were classified as non-decreasing, and Fisher's Exact Probability Test was applied to the resulting counts. While the difference between the Random Group and

Group II did not approach significance, a probability of .05 was obtained when the Random Group was compared with Group III. The discrimination achieved after three days of blocked training did not show the expected improvement from the first to the second session of training under the random sequence, but rather a slight deterioration in performance. This deterioration may also be seen within the first session of phase two training. S^- trials were analyzed in blocks of five trials and a mean probability of response computed for each block. Means of the four blocks in the first session were .10, .18, .20, and .28.

The performance of the three groups during the random sequence of trial presentations, phase two, was also compared in terms of the length of time it took to complete four responses on a reinforced trial. An analysis of variance of these data gives a nonsignificant between groups term ($F < 1.00$), but a significant between sessions term ($F = 7.59$; 11/231 df; $p < .01$) and interaction term ($F = 1.98$; 22/231 df; $p < .01$). The latencies do become shorter over the sessions but the extent of this change varies with the group. A plot of group medians against daily session shows the Random Group and Group II with gradually decreasing latencies while Group III does not show this decrease. This graph is in the appendix.

DISCUSSION

The results show that the discrimination between a positive and negative stimulus may develop as rapidly with a blocked as with a random sequence of trials, after many fewer errors. One day of training on a blocked trial sequence was as effective as one day of training on a random trial sequence, while performance after three days of training on a blocked sequence was slightly better than performance after three days of training on a random trial sequence. This result was not predicted and is very surprising. The several factors which were considered in the introduction, number of transitions between stimuli, average time interval between them, and number of available cues, all led to the expectation of more rapid learning under the random sequence. In the random case, approximately 20 transitions between positive and negative trials occurred per session while in the blocked sequence, only a single transition occurred per session. Transitions apparently do not play as critical a role in the development of a go-no go discrimination as the role assigned to them in the model proposed by Bush and Mosteller (1951). The average time between the onset of a negative trial and the onset of the most recent positive trial was approximately 315 seconds in the blocked trial sequence as compared with 60 seconds in the random sequence. It was expected that perceptual comparison would be easier if the stimuli were presented nearer in time. However, the present results indicate that, at least for this range of time intervals, the time between transitions is not a critical variable. Finally it may be noted that the irrelevant cue arising from the high degree of predictability with which one nonreinforcement follows another in the blocked trial sequence, apparently did not seriously interfere with the learning of the required visual discrimination. This result would be predicted by a theory which views discrimination as the outcome of separate processes of conditioning and extinction.

The present results differ from those reported by Honig, Thomas and Guttman (1959). They found that a single series of exposures to the nonreinforced stimulus did not contribute to the discrimination of the stimuli (ie., did not sharpen the gradient of generalization), whereas a random sequence of exposures to the positive and negative stimuli did. Of the several ways in which the procedure used by Honig, Thomas, and Guttman differed from the present procedure, there are two of particular interest and importance. First, as previously noted, the between-trial stimulus condition used by Honig, Thomas, and Guttman was a blackout. As a consequence, a change in the entire visual environment accompanied the presentation of the experimentally relevant stimulus. In the present procedure, on the other hand, only the illumination of the key marked the trial from the intertrial period. This arrangement ensures that responses are made to at least some aspect of the relevant stimulus. Perhaps this condition is necessary if blocks of negative trials are to contribute to the formation of a discrimination.

A second difference is the separation of negative and positive exposures. Exposures to the negative stimulus under the massed extinction condition in the Honig, Thomas, and Guttman experiment were separated from positive exposures by 24 hours. The animals were, of course, removed from the apparatus for this interval. In the blocked sequence condition of the present experiment, on the other hand, negative trials followed positive trials within the same session, separated only by an intertrial interval. Perhaps the use of a 24 hour separation would produce results similar to those of Honig, Thomas, and Guttman.

A procedural difference which would seem to be less critical is the test of performance of the discrimination. Honig, Thomas, and Guttman used a generalization test in extinction to evaluate the effects of training whereas the present study, performance of a discrimination under continued reinforced training on a random trial sequence was used for this purpose.

It might be argued that the blocked training in the present case did not actually establish the discrimination, but only increased the rate at which it was subsequently acquired. However, an examination of performance within the first session of phase two shows that some animals which had previously received the blocked training performed without a single error. Moreover, there was an increase, on the average, in S^- responding over the course of the first session. It is quite evident that the discrimination was established by the blocked training prior to the first session of phase two.

There is an interesting suggestion in the present results of a factor in the random trial sequence which may be working against the elimination of responses to S^-. Specifically, in Group III, which had received three sessions of blocked training, an increase in the number of responses to S^- appeared from the first to the second session of random training. An increase was apparent in some animals within the first session. In Group III there was only one session in phase two for which the median probability of response to S^- was lower than it was in the very first session of phase two.

The frequent occasions on which an unreinforced response to S^- is followed after an intertrial interval by a reinforced response to S^+ are a feature of the random sequence which might be responsible for the increase. The response to S^- is thus secondarily reinforced. Since this factor is absent from the blocked sequence, it could explain the observed increase. Secondary reinforcement, which might lead to an "accidental" chaining of responses to S^+ and S^-, could also be responsible for the continuation of responses to both reinforced and nonreinforced stimuli by two birds in the present experiment. The operation of secondary reinforcement in the random sequence might help to explain why the blocked groups required fewer nonreinforced responses to S^- to achieve the same reduction in the probability of response to S^-.

The results of the present experiment obviously do not bear critically on the issues which separate the conditioning-extinction view from the perceptual comparison view of discrimination. But these views provide a grossly oversimplified view of discrimination. They will need many revisions before their analysis is precise enough to provide a framework for further experiments. The results of the present study, however, do provide evidence against the importance of transitions from the negative to the positive stimulus to the formation of a discrimination, and even suggest that these transitions may serve to maintain or to increase responses to the negative stimulus.

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Appendix

TABLE 1

Summary of statistical analyses

Mann-Whitney U test comparisons*

Performance measured by probability of response to S^-

1.	Group II phase 2, session 1 compared with Random Group phase 2, session 1	$U = 13$ $n_1 = 8$	$p = .05$ $n_2 = 8$
2.	Group II phase 2, session 1 compared with Random Group phase 2, session 2	$U = 27.5$ $n_1 = 8$	$p = .69$ $n_2 = 8$
3.	Group III phase 2, session 1 compared with Random Group phase 2, session 1	$U = 11$ $n_1 = 8$	$p = .03$ $n_2 = 8$
4.	Group III phase 2, session 1 compared with Random Group phase 2, session 4	$U = 19$ $n_1 = 8$	$p = .19$ $n_2 = 8$

Performance measured by total response to S^-

1.	Group II phase 2, session 1 compared with Random Group phase 2, session 1	$U = 17$ $n_1 = 8$	$p = .13$ $n_2 = 8$
2.	Group II phase 2, session 1 compared with Random Group phase 2, session 2	$U = 28$ $n_1 = 8$	$p = .72$ $n_2 = 8$
3.	Group III phase 2, session 1 compared with Random Group phase 2, session 1	$U = 10$ $n_1 = 8$	$p = .02$ $n_2 = 8$
4.	Group III phase 2, session 1 compared with Random Group phase 2, session 4	$U = 18.5$ $n_1 = 8$	$p = .18$ $n_2 = 8$

Number of responses to S^- in blocked sequence compared with number of responses to S^- in random sequence

1.	Groups II and III phase 1, session 1 compared with Random Group phase 2, session 1	$U = 34$ $n_1 = 8$	$p < .10$ $n_2 = 16$
2.	Group III phase 1 sessions 1, 2, 3 compared with Random Group phase 2, sessions 1, 2, 3	$U = 9$ $n_1 = 8$	$p = .01$ $n_2 = 8$

* All two-tailed probability

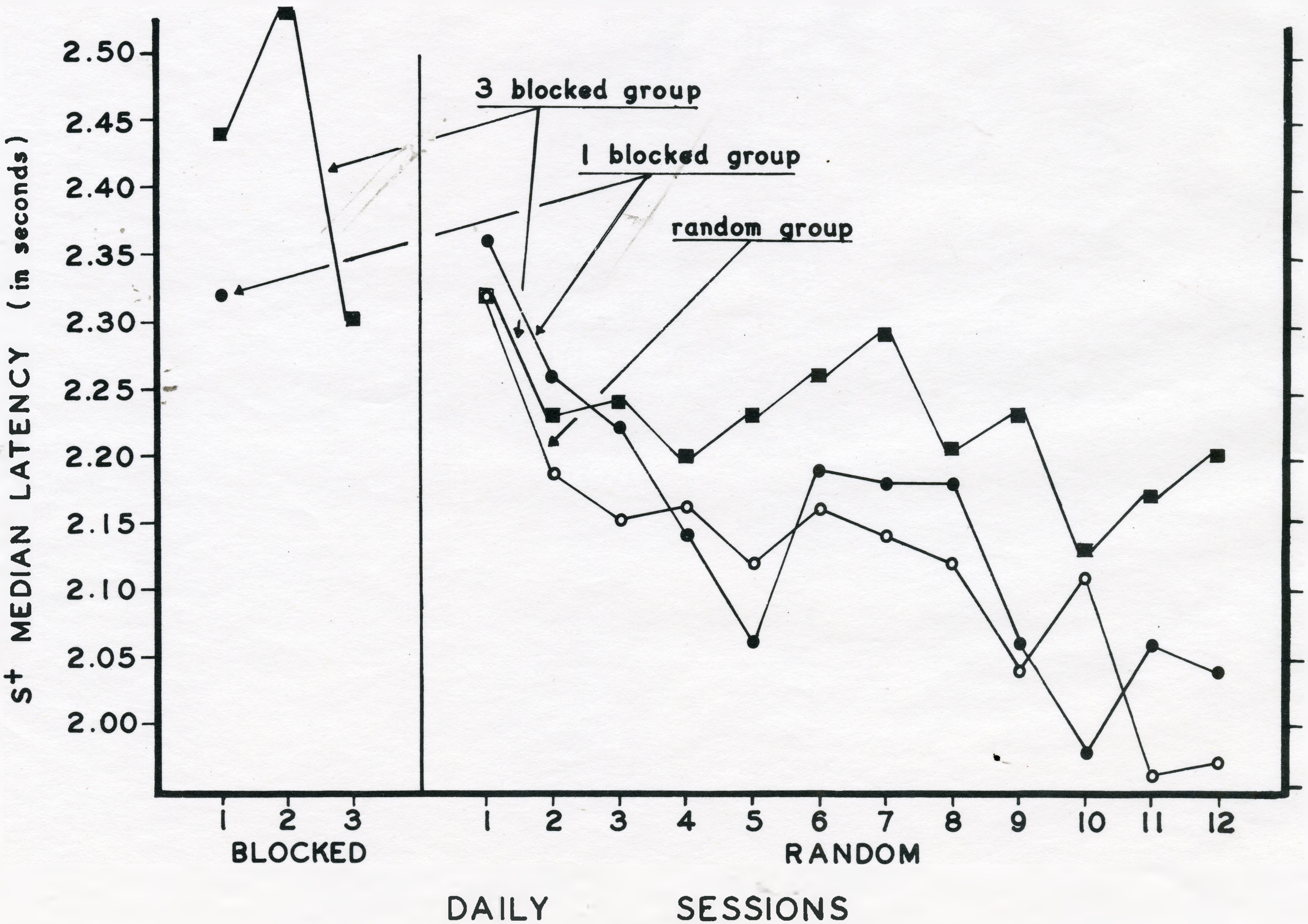

Fig. 3- Mean latency of response completion to S^+

TABLE 2

Analysis of variance of mean latency of completion of response requirement to S^{+}

Source	DF	SS	MS	F	
Between *S*s	23				
groups	2	.90	.45	0.5	n.s.
error	21	17.02	.81		
Within *S*s	264				
sessions	11	1.92	.17	7.59	$p<.01$
sessions & groups	22	1.00	.05	1.98	$p<.01$
error	231	5.31	.02		
Total	287	26.15			

TABLE 3

Pretraining: Mean latency response completion
(group medians)

Sessions:	1	2	3	4	5	6
Groups I&IV:	3.18	2.40	2.42	2.36	2.39	2.43
Group II:	2.52	2.79	2.75	2.62	2.47	2.36
Group III:	2.61	2.64	2.66	2.64	2.46	2.43

TABLE 4

Training: Probability of completion of the response requirement to S^-
(group medians)

	phase 1			phase 2											
Sessions:	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Groups I&IV:				.700	.325	.365	.275	.240	.170	.220	.195	.150	.075	.050	.125
Group II:	.560			.240	.340	.240	.175	.225	.330	.405	.025	.125	.050	.265	.125
Group III:	.325	.025	.000	.025	.195	.125	.075	.075	.050	.050	.050	.075	.025	.000	.050

TABLE 5

Training: Probability of completion of the response requirement to S^-
(group means)

	phase 1			phase 2											
Sessions:	1	2	3												
Groups I&IV:				.656	.370	.404	.342	.304	.261	.274	.222	.142	.135	.146	.119
Group II:	.465			.361	.466	.382	.366	.401	.404	.414	.280	.311	.348	.379	.359
Group III:	.418	.180	.050	.242	.370	.301	.215	.160	.100	.094	.088	.088	.062	.038	.038

TABLE 6

Training: Total responses made to S^- - corrected to 20 trials
(group medians)

	phase 1			phase 2											
Sessions:	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Groups I&IV:				69	49	45.5	41	35	27	23	20	17.5	16.5	13	19.5
Group II:	51			40.5	43.5	36	30.5	34.5	43	44	10	21.5	10.5	27	15
Group III:	36.5	12.5	7	16.5	33	20	20.5	11	5.5	8	13	7	3	2.5	4

TABLE 7

Training: Total responses made to S^- - corrected to 20 trials
(group means)

	phase 1			phase 2											
Sessions:	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Groups I&IV:				61	45.1	46.8	42.1	37	32.9	30	23.8	19.9	21.1	18.4	17.6
Group II:	45.6			42.9	47.1	44	35.9	38.1	41.1	39.2	25.8	31.8	32.5	36.2	33
Group III:	40.5	18.8	9.9	27.4	38.9	31.5	26.5	17.5	11.1	11.6	13.1	9.9	7.8	6.8	6.9

TABLE 8

Training: Number of S⁻ trials in which no response was made (group medians)

	phase 1			phase 2											
Sessions:	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Groups I&IV:				2	3.5	5	6	9.5	9.5	10	14	14.5	12.5	15	13
Group II:	6.5			4.5	6	8.5	10	9	7	7.5	15.5	11.5	15.5	11	14
Group III:	7	16	17	11	5	9.5	12.5	15	17.5	17.5	16	18	19	18	18

TABLE 9

Training: Number of S⁻ trials in which no response was made (group means)

	phase 1			phase 2											
Sessions:	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Groups I&IV:				3	5	5.6	5.8	8	8.6	10	12.5	13	12	13.8	13.4
Group II:	6.2			4.5	6	8.5	10	9	7	7.5	15.5	11.5	15.5	11	14
Group III:	7.5	14.4	15.6	11	5	9.5	12.5	15	17.5	17.5	16	18	19	18	18

TABLE 10

Training: Mean latency of completion of the response requirement on S^+ trial in seconds (group medians)

	phase 1			phase 2											
Sessions:	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Groups I&IV:				2.32	2.18	2.15	2.08	2.12	2.16	2.14	2.12	2.04	2.11	1.96	1.97
Group II:	2.35			2.36	2.26	2.22	2.14	2.06	2.19	2.18	2.18	2.06	1.98	2.06	2.04
Group III:	2.44	2.54	2.30	2.32	2.23	2.24	2.20	2.23	2.26	2.29	2.20	2.23	2.13	2.17	2.20

TABLE 11

Training: Mean latency of completion of the response requirement on S^+ trial in seconds (group means)

	phase 1			phase 2											
Sessions:	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Groups I&IV:				2.38	2.40	2.21	2.10	2.12	2.17	2.07	2.05	2.09	2.05	1.98	1.95
Group II:	2.32			2.40	2.28	2.19	2.13	2.09	2.10	2.15	2.18	2.04	2.05	2.05	2.05
Group III:	2.45	2.51	2.29	2.30	2.24	2.26	2.20	2.28	2.34	2.28	2.23	2.24	2.20	2.23	2.27

TABLE 12

Pretraining: Probability of response

Subjects	1	2	3	4	5	6
41	.65	.85	.98	.95	1.00	.97
42	1.00	1.00	.90	.95	1.00	1.00
43	.75	.95	.85	.98	.95	1.00
44	.90	.72	.93	.87	.95	.98
45	.95	1.00	.98	1.00	1.00	1.00
46	1.00	1.00	.82	.92	.85	1.00
47	.90	.62	.97	1.00	1.00	1.00
49	.47	.90	.82	.95	.88	.95
50	.88	.77	1.00	1.00	1.00	1.00
51	1.00	1.00	1.00	1.00	1.00	1.00
52	.95	.98	.92	.98	1.00	1.00
53	1.00	1.00	1.00	1.00	1.00	1.00
54	.92	.89	.80	1.00	1.00	1.00
55	.98	.98	1.00	1.00	.84	.97
56	1.00	1.00	1.00	1.00	1.00	1.00
57	.92	.87	.95	.95	1.00	.92
58	.98	1.00	.98	1.00	1.00	1.00
59	.71	.98	.98	.95	.55	.87
61	1.00	.95	.95	1.00	1.00	1.00
62	1.00	.98	.98	1.00	1.00	1.00
63	.92	.52	.77	.85	.95	.82
64	.87	.92	1.00	1.00	1.00	.92
67	1.00	.95	1.00	.95	.98	1.00
69	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 13

Pretraining: Mean latency of response

Subjects	1	2	3	4	5	6
41	-	3.52	2.57	2.38	2.39	2.32
42	2.79	2.43	2.64	2.69	2.29	2.30
43	-	3.12	3.42	2.87	3.22	2.59
44	-	-	-	3.06	2.73	2.77
45	3.46	3.12	2.87	2.67	2.47	2.33
46	2.47	2.64	-	2.79	2.83	2.51
47	3.92	-	2.68	2.58	2.82	2.60
49	2.16	-	-	2.94	3.62	2.58
50	3.32	-	2.60	2.64	2.54	2.57
51	1.99	2.16	2.02	2.28	2.06	1.88
52	2.81	2.79	2.75	2.33	2.42	2.38
53	2.03	2.16	2.23	2.28	2.02	2.02
54	2.56	3.74	-	2.31	2.15	2.35
55	2.96	3.01	2.67	2.79	-	2.64
56	2.16	2.16	2.66	2.56	2.53	2.32
57	2.66	2.89	2.92	2.97	2.63	2.66
58	2.19	1.98	1.77	1.80	1.75	1.78
59	3.17	2.40	2.31	2.33	2.39	2.42
61	2.18	2.10	-	1.93	2.11	1.88
62	2.12	2.39	2.29	2.15	2.00	2.03
63	3.62	-	-	3.47	3.02	3.99
64	3.18	3.35	2.42	2.27	2.20	2.44
67	3.12	3.36	2.80	3.31	3.21	2.82
69	2.52	2.50	2.00	2.14	1.89	1.70

TABLE 14

Probability of completion of the response requirement to S^-

Subjects	training: phase 1			training: phase 2											
	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Group I															
63				.35	.00	.10	.10	.25	.10	.05	.10	.20	.10	.05	.20
41				.95	.50	.38	.48	.25	.19	.05	.00	.00	.05	.00	.00
59				.96	.91	.95	.91	.86	.65	.77	.41	.24	.19	.32	.30
61				.35	.20	.30	.25	.15	.05	.10	.00	.10	.00	.00	.00
Group IV															
44				.85	.35	.00	.30	.23	.15	.19	.29	.10	.00	.00	.20
58				.55	.30	.75	.40	.45	.65	.45	.40	.20	.36	.40	.20
64				.24	.30	.40	.20	.05	.20	.25	.10	.05	.00	.05	.00
50				1.00	.40	.35	.10	.19	.10	.33	.48	.25	.38	.35	.05
Group II															
52	.55			.15	.10	.00	.10	.05	.00	.00	.00	.10	.05	.05	.05
43	.05			.35	.20	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00
55	.65			.33	.85	.43	.25	.35	.30	.41	.05	.24	.68	.50	.57
53	.71			.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00
49	.25			.05	.00	.10	.00	.10	.36	.40	.00	.00	.00	.10	.00
56	.59			.86	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
45	.35			.15	.48	.38	.48	.71	.57	.50	.19	.15	.05	.00	.05
69	.57			.05	.10	.10	.10	.00	.00	.00	.00	.00	.00	.43	.20
Group III															
47	.40	.00	.00	.00	.15	.00	.00	.00	.10	.05	.00	.00	.00	.00	.05
57	.45	.05	.00	.00	.00	.10	.00	.00	.00	.00	.00	.00	.00	.00	.00
54	.25	.15	.10	.05	.05	.00	.00	.05	.00	.05	.20	.10	.05	.05	.05
67	.15	.00	.00	.00	.24	.15	.15	.10	.00	.05	.10	.10	.00	.00	.05
51	1.00	.95	.25	.80	1.00	1.00	.95	.70	.35	.40	.30	.30	.30	.20	.05
46	.24	.29	.05	.38	.81	.68	.33	.33	.25	.05	.05	.15	.05	.05	.10
42	.20	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
62	.65	.00	.00	.71	.71	.48	.29	.10	.10	.15	.05	.05	.10	.00	.00

TABLE 15

Probability of response to S⁻ by blocks of 5 trials

training: phase 2

Subjects	1				2				3				4				5				6			
Group I																								
63	1.00	.00	.20	.20	.00	.00	.00	.00	.20	.00	.00	.20	.00	.40	.00	.00	.00	.20	.20	.60	.20	.20	.00	.00
41	1.00	1.00	.80	1.00	.60	.20	.60	.60	.20	.40	.60	.40	.20	.40	.40	1.00	.20	.20	.60	.00	.20	.20	.00	.20
59	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.80	1.00	1.00	1.00	.80	1.00	.80	1.00	1.00	1.00	.60	.80	.60	.40	.80
61	.80	.20	.20	.20	.00	.20	.00	.60	.00	.40	.40	.40	.80	.20	.00	.00	.20	.20	.20	.00	.00	.00	.20	.00
Group IV																								
44	1.00	.80	.80	.80	.60	.60	.20	.00	.00	.00	.00	.00												
58	1.00	.80	.40	.00	.40	.00	.40	.40	.80	1.00	.60	.60												
64	1.00	.00	.00	.00	.80	.20	.20	.00	.20	.40	.80	.20												
50	.80	.60	1.00	1.00	.80	.00	.60	.20	.40	.80	.00	.20												
Group II																								
52	.20	.00	.20	.20	.20	.00	.20	.00	.00	.00	.00	.00												
43	.40	.60	.20	.20	.40	.40	.00	.00	.20	.00	.00	.00												
55	.20	.20	.80	.20	1.00	.80	.60	1.00	.40	.40	.60	.40												
53	1.00	.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00												
49	.00	.20	.00	.00	.00	.00	.00	.00	.20	.00	.00	.20												
56	.60	.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00												
45	.20	.20	.20	.00	.20	.00	.80	.80	.00	.20	.80	.40												
69	.20	.00	.00	.00	.00	.20	.20	.00	.00	.40	.00	.00												
Group III																								
47	.00	.00	.00	.00	.20	.00	.00	.40	.00	.00	.00	.00												
57	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.20	.20												
54	.20	.00	.00	.00	.00	.20	.00	.00	.00	.00	.00	.00												
67	.00	.00	.00	.00	.00	.60	.40	.20	.40	.00	.20	.00												
51	.60	.80	.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00												
46	.00	.60	.60	.40	.60	1.00	1.00	.80	1.00	.80	.80	.40												
42	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00												
62	.40	1.00	1.00	.40	.60	.60	.80	.80	.40	1.00	.20	.40												

TABLE 16

Probability of completion of the response requirement to S^+

Subjects	training: phase 1			training: phase 2											
	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Group I															
63				.90	.80	1.00	1.00	1.00	1.00	.95	1.00	1.00	1.00	1.00	1.00
41				1.00	.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.91	1.00
59				1.00	1.00	1.00	1.00	.90	1.00	.95	.90	1.00	1.00	1.00	1.00
61				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Group IV															
44	1.00	1.00	.90	.90	.85	.95	1.00	1.00	1.00	.95	1.00	1.00	1.00	1.00	.90
58	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
64	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
50	.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00	1.00	1.00	1.00	1.00	1.00
Group II															
52	1.00			.75	1.00	.95	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00	1.00
43	.91			.81	1.00	.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.95
55	.95			.95	.95	.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
53	1.00			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
49	1.00			.95	.80	.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00
56	1.00			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
45	1.00			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
69	1.00			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Group III															
47	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
57	.95	.85	.95	.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
54	.91	.95	1.00	.95	1.00	1.00	1.00	1.00	.95	1.00	1.00	1.00	1.00	1.00	1.00
67	1.00	1.00	1.00	1.00	.95	1.00	1.00	1.00	.95	.95	1.00	.95	1.00	1.00	1.00
51	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00	.95	1.00	1.00	1.00	1.00
46	1.00	1.00	1.00	.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00	1.00
42	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.95	1.00	.95	1.00
62	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 17

Total responses to S^-

Subjects	training: phase 1			training: phase 2											
	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Group I															
63				33	9	19	30	41	29	10	14	19	29	19	33
41				79	53	53	54	50	40	17	0	5	4	0	2
59				77	80	79	76	75	68	69	51	39	33	42	45
61				49	26	36	45	22	7	9	0	12	2	0	1
Group IV															
44				76	52	18	37	29	12	18	26	16	4	6	21
58				62	53	77	45	42	65	49	46	26	45	37	21
64				32	42	54	33	15	25	28	10	10	3	7	0
50				80	46	38	17	22	17	40	43	32	49	36	18
Group II															
52	50			32	18	13	10	10	15	5	2	15	7	9	9
43	19			49	28	12	8	3	2	1	0	0	1	2	4
55	64			45	77	67	47	54	48	52	16	38	68	52	55
53	61			78	80	80	80	80	80	80	80	80	80	80	80
49	27			17	20	24	3	15	38	39	0	8	4	8	2
56	58			75	83	84	78	80	83	85	84	84	86	85	84
45	34			36	59	47	46	61	59	49	20	28	14	12	13
69	52			11	12	25	15	2	4	3	4	1	0	42	17
Group III															
47	40	17	9	19	35	10	3	1	13	7	6	3	0	2	5
57	44	8	6	4	6	8	4	3	0	3	3	0	0	0	0
54	33	21	19	14	20	8	5	4	1	9	16	14	6	10	20
67	23	0	0	9	31	30	36	20	1	9	12	8	0	3	11
51	80	76	33	70	80	80	78	62	43	45	35	36	33	31	9
46	28	23	8	37	69	62	37	32	21	5	18	12	11	8	8
42	18	2	1	2	2	0	1	0	0	0	1	0	0	0	2
62	58	3	3	64	68	54	48	18	10	15	14	6	12	0	0

TABLE 18

Number of S^- trials with no response

	training: phase 1			training: phase 2											
Subjects	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Group I															
63				10	14	12	9	6	7	15	14	15	7	13	8
41				0	3	4	1	0	3	9	20	18	19	20	19
59				1	0	0	1	0	1	0	3	5	7	6	4
61				3	11	10	5	12	16	17	20	16	19	20	19
Group IV															
44				0	2	11	8	12	17	15	14	14	18	17	14
58				3	1	0	4	7	1	6	6	10	4	7	11
64				7	5	2	7	15	12	11	16	17	19	18	20
50				0	4	6	11	12	12	7	7	9	3	9	12
Group II															
52	6			6	11	11	17	15	12	17	18	15	17	15	16
43	9			1	7	15	15	18	18	19	20	20	19	19	17
55	1			5	0	0	2	1	2	3	12	7	2	5	4
53	5			0	0	0	0	0	0	0	0	0	0	0	0
49	9			12	10	11	18	14	10	9	20	16	18	18	19
56	4			0	0	0	0	0	0	0	0	0	0	0	0
45	9			4	5	6	6	4	4	6	14	8	14	13	13
69	7			15	16	11	14	19	18	18	17	19	20	9	15
Group III															
47	7	12	14	7	2	11	17	19	15	18	17	18	20	18	18
57	7	17	17	18	18	19	19	19	20	19	19	20	20	20	20
54	6	13	12	12	8	15	16	18	19	17	16	15	18	17	12
67	9	20	20	14	9	8	6	12	19	17	16	18	20	18	16
51	0	1	8	1	0	0	0	2	4	7	9	7	9	8	16
46	13	15	17	10	2	3	9	11	14	18	12	17	15	17	18
42	14	19	19	19	18	20	19	20	20	20	19	19	20	20	19
62	4	18	18	2	1	0	3	12	16	15	13	20	15	20	20

TABLE 19

Training: Mean latency to S^+ in seconds

Subjects	phase 1: 1	2	3	phase 2: 1	2	3	4	5	6	7	8	9	10	11	12
Group I															
63				3.54	3.47	2.55	2.40	2.24	2.51	2.31	2.12	2.41	2.37	2.21	2.10
41				2.44	2.47	2.19	2.11	2.15	2.32	2.14	2.19	2.13	2.16	1.97	1.95
59				2.49	2.10	2.00	2.23	2.24	2.16	2.13	2.14	2.46	2.26	2.14	1.99
61				1.89	1.99	2.08	1.79	1.93	1.36	1.88	1.88	1.76	1.67	1.68	1.70
Group IV															
44	-	2.95	2.70	2.78	3.01	2.58	2.54	2.39	2.67	2.34	2.23	2.39	2.32	2.30	2.26
58	1.76	1.66	1.71	1.56	1.83	1.90	1.63	1.70	1.68	1.66	1.76	1.68	1.67	1.67	1.72
64	2.10	2.04	2.16	2.21	2.12	2.24	2.06	2.20	1.98	1.98	1.98	1.94	1.90	1.90	1.90
50	2.44	2.31	2.20	2.15	2.25	2.11	2.05	2.10	2.15	2.15	2.12	1.95	2.06	1.95	1.99
Group II															
52	2.47			2.83	2.54	2.26	2.32	2.34	2.26	2.23	2.31	2.08	2.04	2.18	2.17
43	2.53			2.57	2.27	2.37	2.20	2.30	2.32	2.28	2.48	2.26	2.34	2.18	2.27
55	2.84			3.06	2.84	2.68	2.66	2.58	2.50	2.67	2.78	2.48	2.43	2.56	2.63
53	1.97			2.04	2.08	2.06	1.92	2.01	1.96	2.06	2.01	2.00	1.92	1.89	1.89
49	2.38			2.17	2.40	2.28	2.34	2.04	2.33	2.49	2.24	2.36	2.36	2.26	2.23
56	2.32			2.43	2.25	2.17	2.08	1.86	1.80	1.71	1.79	1.61	1.80	1.73	1.61
45	2.28			2.29	2.10	2.02	1.94	2.07	2.12	2.12	2.13	2.05	1.93	1.93	1.92
69	1.79			1.79	1.77	1.66	1.56	1.53	1.50	1.63	1.68	1.52	1.61	1.65	1.70
Group III															
47	2.84	2.73	2.31	2.36	2.31	2.31	2.29	2.33	2.29	2.34	2.24	2.36	2.21	2.28	2.32
57	2.78	2.91	2.40	2.55	2.57	2.68	2.33	2.53	2.56	2.46	2.16	2.24	2.17	2.12	2.10
54	2.57	2.97	2.49	2.37	2.43	2.12	2.15	2.19	2.23	2.24	2.23	2.22	2.02	2.20	2.27
67	2.95	2.57	2.37	2.27	2.28	2.35	2.06	2.27	2.43	2.42	2.12	2.22	2.09	2.14	2.14
51	1.86	2.12	2.03	2.11	2.08	2.15	1.95	2.04	2.22	2.11	2.01	1.93	1.94	2.03	1.94
46	2.32	2.50	2.30	2.39	2.18	2.37	2.61	2.69	2.57	2.54	2.48	2.27	2.43	2.47	2.65
42	2.31	2.38	2.27	2.24	2.14	2.17	2.24	2.14	2.20	2.12	2.54	2.58	2.68	2.56	2.70
62	1.95	1.92	2.17	2.11	1.93	1.92	1.98	2.05	2.20	1.98	2.03	2.08	2.02	2.02	2.07

TABLE 20

Mean latency of completion of response requirement to S^-

	training: phase 1			training: phase 2											
Subjects	1	2	3	1	2	3	4	5	6	7	8	9	10	11	12
Group I															
63				3.94	-	3.40	2.60	2.52	3.15	3.70	.70	2.67	2.80	4.60	2.25
41				2.44	2.73	2.37	2.99	3.28	2.85	1.80	-	-	2.80	-	-
59				2.33	2.23	2.60	2.43	2.59	2.22	2.26	2.21	2.16	2.27	2.13	2.70
61				2.89	2.17	2.45	1.98	2.10	3.10	1.85	-	1.95	-	-	-
Group IV															
44				3.15	3.44	-	2.60	3.08	2.70	3.87	3.38	2.30	-	-	2.75
58				1.85	2.10	1.87	1.67	2.41	2.00	2.53	2.29	1.87	2.01	1.57	2.15
64				2.24	2.48	2.25	2.25	2.50	2.75	2.75	2.40	2.00	-	1.80	-
50				2.63	2.62	2.59	3.30	2.20	2.15	2.19	2.05	2.50	2.25	2.39	2.10
Group II															
52	3.27			3.97	3.30	-	3.05	-	-	-	-	3.65	3.60	4.50	2.90
43	-			3.36	3.75	3.00	-	-	-	-	-	-	-	-	-
55	3.24			3.30	3.08	3.41	2.90	2.90	2.85	2.64	2.40	2.74	2.65	2.52	2.71
53	2.52			1.93	1.99	2.06	1.97	1.98	1.94	2.11	2.08	2.51	1.99	2.06	2.31
49	2.80			3.10	-	2.80	-	2.10	1.99	2.41	-	-	-	1.95	-
56	2.39			2.51	2.12	2.08	2.02	1.90	1.88	1.97	1.82	1.75	1.78	1.66	1.76
45	2.69			3.07	2.48	2.26	2.55	2.21	2.17	2.51	2.12	2.70	1.50	-	1.40
69	2.53			1.80	2.70	2.60	1.90	-	-	-	-	-	-	1.90	1.92
Group III															
47	3.36	-	-	-	2.83	-	-	-	3.30	-	-	-	-	-	2.60
57	3.31	2.40	-	-	-	2.50	-	-	-	-	-	-	-	-	-
54	3.10	3.90	2.30	2.90	2.40	-	-	2.40	-	2.30	2.27	1.85	2.30	1.90	1.80
67	4.23	-	-	-	3.12	3.10	2.80	3.55	-	2.60	2.40	2.25	-	-	2.10
51	1.89	2.49	2.66	2.09	2.12	2.07	2.12	2.34	3.09	2.91	2.97	2.73	2.87	2.70	2.50
46	3.16	2.53	2.40	2.51	2.49	2.51	2.60	2.99	2.64	3.30	3.10	2.60	2.70	1.90	2.25
42	2.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-
62	3.01	-	-	2.66	2.86	2.86	2.55	2.50	2.75	2.53	2.30	2.40	1.95	-	-

FOOTNOTES

1. Unless otherwise indicated, probability levels are for a two-tailed Mann-Whitney U test based on the probability of a completed response to S^-. A probability of 1.0 is obtained in this case since all possible orderings of the rankings of the two groups are at least as extreme as the one obtained.