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THE EFFECTS OF FOREPERIOD DURATION UPON DISCRIMINATION AND
CHOICE REACTION TIME

by

Harvey D. Neiderbach

A dissertation submitted to the Graduate Faculty in Psychology
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New York

1997

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TABLE OF CONTENTS

Approval ii

Acknowledgements iii

Table of Contents iv

List of Illustrations vi

Introduction 1

Experiment 1 16

Introduction 16

Method 17

 Subjects 17

 Apparatus 17

 Procedure - Preliminary Training 19

 Procedure - Experimental Training 20

 Procedure - Generalization Test 22

Results 23

Discussion Experiment 1 31

Experiment II 33

Introduction 33

Method 34

 Subjects 34

 Apparatus 34

 Procedure 35

Results 37

 Training 37

 Generalization test 39

Discussion Experiment 2	51
General discussion	52
Summary	64
References	67

LIST of ILLUSTRATIONS

Experiment 1

Figure 1-1 Geometric Mean RT by Training Group 25
Figure 1-2 Individual Data - Geometric Mean RT 27
Figure 1-3 Accuracy by Training Group 28
Figure 1-4 Individual Data - Accuracy 30

Experiment 2

Figure 2-1 Response Pattern During FP - Training 40
Figure 2-2 Geometric Mean RT by Training Group by Block . 42
Figure 2-3 Individual Data Block 1 - Geometric Mean RT . 44
Figure 2-4 Log Geometric Mean RT by Training Group
by Block 46
Figure 2-5 Accuracy by Training Group by Block 48
Figure 2-6 Individual Data Block 1 - Accuracy 50
Figure 2-7 Response Pattern During FP 62

THE EFFECTS OF FOREPERIOD DURATION UPON DISCRIMINATION AND
CHOICE REACTION TIME

The overall purpose of this work was to study attention in pigeons. Attention can loosely be thought of as a process by which a limited portion of the sensory field becomes psychologically "meaningful". More specifically, some authors have assumed that attention enhances the processing of stimuli (e.g., Broadbent, 1958, Neisser, 1967; Posner, 1978). In humans this effect has been extensively studied in spatial cuing paradigms. Operationally, the presumed enhanced stimulus processing has been assessed by measuring increases in correct responding and decreases in response time to stimuli presented in expected spatial locations (Posner, 1978). It would be useful to determine if the enhanced processing view of attention can be used to study attention in animals.

It is noteworthy that similarities between humans and animals have been discussed in other cognitive domains, e.g., in explorations of timing, and associative learning (see Church, 1993; Shanks, 1994). In the study of attention there exist at least two areas and possibly a third area in which research in humans and animals suggests similar attentional processes. These areas entail investigations of the intradimensional - extradimensional shift problem, spatial attention, and alertness effects.

The intradimensional - extradimensional (ID - ED) shift problem has been useful in studying the orienting of attention to stimulus dimensions (for a review see, Wolff, 1967, and Sutherland and Mackintosh, 1971). Although most of the research in this area has been performed with animal subjects, there have been efforts to document the phenomenon in humans as well (e.g., see Dickerson, 1966). A typical example of research in this area with animals comes from a study reported by Mackintosh and Little (1969). In this study two groups of pigeons were trained with compound stimuli. The response key background was white and in the center were three lines with either a 0 degree or 90 degree orientation. On different trials these lines were colored either red or yellow. This created four color-orientation compound stimuli (red-zero degree, red-ninety degree, yellow-zero degree, and yellow ninety degree). For the first group of birds color was relevant in solving the discrimination. For example, the two stimulus compounds containing red were designated as positive: responses to these stimuli were rewarded with a 5 s access to grain, while responses to the compound stimuli containing yellow were followed by an 8 s blackout. For the second group, line orientation was the relevant dimension. This means for example, that responses to the two compound stimuli including 0 degree orientation were considered positive and rewarded with a 5 s access to grain, whereas, responses to

the two compound stimuli including the 90 degree line orientation were considered negative and resulted in an 8 s blackout.

After the birds learned to respond to the reinforced color-orientation compound stimuli and not to respond to the nonreinforced color-orientation stimuli, these groups were each split into two further groups. A new set of compound stimuli was given to these subgroups during the test phase. The new stimulus compounds consisted of different colors (blue and green) combined with two new line orientations, (45 degrees and 135 degrees). During the test phase, one subgroup from the original color-relevant group received a color-relevant transfer problem, while the second subgroup was transferred to an orientation-relevant problem. The same was done to the subgroups from the original line tilt-relevant group.

Mackintosh and Little observed that when the second problem was from the same dimension as the first, learning was achieved more rapidly. For example if the birds were initially given the problem with the color-relevant dimension and then transferred to another color-relevant problem, they performed better than birds that were given the initial orientation-relevant dimension problem and then transferred to the color-relevant problem. This result has been interpreted as demonstrating that pigeons learn to attend to stimulus dimensions (Mackintosh and Little, 1969),

although other interpretations may be constructed (Heinemann and Chase, 1970). This first group of birds could have learned to focus on the color dimension in the first problem. The focusing on the color dimension would lead to the enhanced processing of colored stimuli and this processing would provide an advantage when these birds were shifted to a second color problem. The second group of birds which were initially trained on line orientation problem and then shifted to the color-relevant blue - green problem, had to find out which was the relevant dimension, as well as to stop using the line orientation dimension as a solution to the problem. This ED shift obviously took longer to learn.

A second area suggesting a parallel between animals and humans in their attentional processes comes from research investigating spatial attention. The experiments of Heinemann and Rudolph (1963) and Heinemann and Kadison (1976) may provide us with examples of the involvement of spatial attention in pigeons. Heinemann and Rudolph (1963) trained three different groups of pigeons to peck a moderately illuminated key using a variable interval (VI) 1 min schedule of partial reinforcement. Each group experienced a different size of luminated area surrounding a central key to which the subjects were to respond. The largest area of luminance was the complete surface of the wall containing the response key and the two smaller training stimuli consisted of concentric areas around the

response key. A generalization test conducted under conditions of extinction followed this training. It consisted of exposing the birds to three different luminances, 1.5 ft. L, 15.4 ft. L. and 10.1 ft. L., the training luminance. One of the test stimuli was more luminant than the training stimulus and the other was less luminant than the training stimulus. All three stimuli were the same size as that used during training. During the test it appeared as though the birds pecked more about the luminated patch when the smaller stimulus patches were used during training. The birds trained with the small stimulus patches pecked more to the training luminance than to the less intense and more intense test stimuli. Birds trained with the completely luminated wall gave a flat generalization response curve, responding equally to the different stimulus intensities.

These results can be interpreted as reflecting the operation of spatial attention, although the authors chose not to do this. Suppose that the smaller stimulus patch was more effective at spatially focusing the bird's attention. If it is additionally assumed that attention enhances learning, then the birds trained with small stimulus displays should learn more about incidental features of the stimulus such as its luminance.

However, another interpretation that does not involve the concept of attention is possible, and this was the

interpretation favored by the authors. Jenkins and Harrison (1960) have reported that the degree of stimulus control accruing to a stimulus dimension is dependent upon the conditions of training. Specifically, an explicit discrimination procedure produces good stimulus control while a procedure not involving a discrimination results in little or no stimulus control. Heinemann and Rudolph suggested that the training procedure they used might have resulted in unintentional discrimination training in their small stimulus patch groups. In the group trained with the largest stimulus patch, unreinforced responses always occurred in the presence of the stimulus. However, in the groups trained with the two smaller patches, unreinforced responses were likely to have often occurred in the absence of the stimulus patch. This is because the smaller stimulus patch perimeters enclosed a smaller area around the response key and this permitted for any misdirected pecks to have effectively occurred away from the stimulus. Therefore, it could have been this unintentional discrimination training rather than spatial attention which produced different generalization test results among the three groups.

An experiment performed by Heinemann and Kadison (1976) was not subject to this interpretation. This experiment used a within subject explicit discrimination training procedure. Two stimuli were used, a dimly illuminated blank field and the same field containing a centrally located spot of more

intensely illuminated light. On separate trials each of these stimuli appeared on the center key of a three key intelligence panel. Two pigeons were required to peck the stimulus presented on the center key before they were to choose one of two subsequently illuminated sidekeys. The subject's task was to peck one sidekey if the brightly illuminated spot of light had been presented on the center key and to peck the other sidekey if the blank field without the illuminated spot had been presented on the center key. Correct choices were reinforced with access to food. These birds acquired the discrimination readily. The data of most interest came from a subsequent generalization test. The test stimuli were different luminances of the spot of light at different positions on the center key. Only correct responding was reinforced during the generalization test. When the illuminated spot of light was in the center of the center key, as it had been during training, the birds responded readily to its presence. When the illuminated spot was presented in alternative positions, near the perimeter of the center key, the birds tended to respond as if the illuminated spot was not present. In addition, the birds responded maximally to the change in illumination of the spot of light on the center key only when it was in the center position, as it had been during training. It was as though these subjects had not processed very effectively the change in illumination of the spot of light when it was

presented in a location which was different from that used during training. These results imply that stimuli presented to training locations are better processed than stimuli presented to other locations (Heinemann and Kadison, 1976).

This conclusion has also been reached in the study of human spatial attention (Posner, 1978). Posner, Snyder, and Davidson (1980) devised a detection task in which subjects were to respond in the presence of a capital letter presented in either of two locations. Trials consisted of the following events in order, a warning signal, the target stimulus after a variable foreperiod (FP) of between 800 and 1200 msec, the subject's response, and feedback. The warning signal consisted of a cue which might indicate the spatial location of the target stimulus. The target stimulus was one of a set of ten capital letters. The design included seventy-five percent test trials during which a test stimulus appeared and twenty-five percent catch trials, upon which no test stimulus appeared. During a test trial the warning stimuli included a left pointing arrow, a right pointing arrow, or a "+" sign. Each of these warning stimuli occurred equally often. Given an arrow cue, on 80% of the test trials, the test stimulus was presented in the indicated direction. On 20% of the trials, the test stimulus was presented on the side opposite that indicated by the arrow. When the subject was given a "+" sign on test trials, the spatial location of the target was equally probable.

Posner et al's results indicated that location cues had an effect on reaction time (RT). Target letters presented to expected locations were responded to more quickly than those presented to unexpected locations (252 msec vs. 299 msec). The neutral stimulus, "+", which did not signal location, had an intermediate effect on mean RT (271 msec). These results support the concept that the spatial focusing of attention leads to more efficient processing of stimulus information presented to these locations. The results are not inconsistent with Heinemann and Kadison's (1976) observation that pigeons were poor at recognizing a stimulus presented to a location other than the training location. Human subjects, and maybe pigeons as well, appear to have difficulty processing target stimuli when they appear in unexpected locations.

A third possible area suggesting parallels in attentional processes between humans and animals involves the study of FP effects. Previously, the ID - ED shift and the spatial attention experiments were discussed in terms of attention's specific effects upon stimulus processing. For example, in the ID - ED shift experiment it is claimed that focusing the subject's attention on the relevant dimension enhances the processing and therefore the learning of stimuli from that specific dimension. Similarly, in the spatial tasks considered above the focusing of the subjects attention to the relevant location is assumed to enhance the

processing of stimuli presented to that location.

In contrast, studies that have manipulated the duration of a FP after a warning signal have been discussed in terms of attention's general effects upon performance (Posner, Inhoff, Friedrich, and Cohen, 1987). For example, subjects given a warning signal have been shown to be more ready than subjects not given a warning signal to respond to visual stimuli presented at unpredictable locations. There exist two commonly held propositions about this more general enhancement of performance. The first proposition maintains that the effect of a warning signal upon performance is best described as a sensory effect that leads to enhanced stimulus processing. The second proposition, however, maintains that warning signal effects arise from a response bias, i.e., an increased tendency to respond whether or not a stimulus has been presented. If the effect of a warning signal is posited as a sensory effect then the enhanced processing should lead not only to improvements in speed of responding, but it should lead to improvements in the accuracy of responding as well. However, if warning signal effects are posited as a response bias effect then a speed-accuracy tradeoff should exist. This means that quicker responding should be accompanied by a decrease in accuracy.

Support for the response bias interpretation comes from a study reported by Posner, Klein, Summers, and Buggie (1973). Posner, et al studied warning signal effects on

choice reaction time using humans in a visual choice task. The trials began with no warning signal or a warning signal, a tone of 50 msec duration. On the warning signal trials the FPs were varied across blocks of trials between 50 msec and 800 msec. Upon the completion of the FP an "X" appeared with equal likelihood on either the right or left side of the focal point centered on the oscilloscope screen. The subject was to press as quickly as possible on the key which signified the stimulus location. At the end of the trial a visual feedback of error and RT information was given to the subject, and this was followed by the ITI which varied between two and five seconds. During the no warning signal block of trials the test stimulus was presented immediately upon the completion of the variable ITI. The order of the blocks of FP duration was selected through a random Latin square procedure.

On the no warning signal block of trials the reaction time was slowest compared to the trials containing a warning signal. This is the basic effect of a warning signal. The warning signal was not equally effective at all FPs. When RT was plotted against FP a "U" shaped function was observed. In addition, a plot of percent errors against FP revealed an inverted "U" shaped function. This pattern of data is most consistent with the response bias interpretation of warning signal effects since speed of responding is negatively correlated with accuracy. Thus, in this human paradigm at

least, the effect of the warning signal appears to be best understood in terms of an increased tendency to respond rather than an increased efficiency of sensory processing (for two reviews, see Hockey, 1984; Sperling, 1984).

There has been relatively little systematic work exploring warning signal effects in animals. A systematic study of warning signal effects is important because it would enable us to further explore any parallels in attentional processes that may exist between humans and animals. Warning signal effects can be studied in pigeons with the conditional discrimination paradigm. Conditional refers to the fact that the first stimulus displayed indicates to the subject how to respond to the onset of a second stimulus. The conditional discrimination trial typically begins with the presentation of a sample stimulus, followed by a choice between two comparison stimuli. The pigeon is to select the correct one of two choice stimuli, where "correctness" depends upon which of two sample stimuli have occurred on that trial. The trial then ends with the presentation of reinforcement for correct responding. In some experiments the pigeon has been required to peck a fixation point before the sample stimulus is presented (Macdonald and Grant, 1987). This trial initiating peck to a "warning signal" could serve the role of alerting subjects to the subsequent occurrence of the sample stimulus. In order to determine if this is the case, the FP, i.e., the

time between the warning signal and the sample stimulus can be varied. Notice that this manipulation is analogous to those used in human studies of alertness (Hockey 1984, and Posner, 1978).

In the studies to be reported here, an FP manipulation was examined using a conditional discrimination procedure like that described above. Following a warning signal an FP was initiated. At the end of the FP a sample stimulus was presented to the pigeon. Following the sample stimulus the pigeon was to select one of two response alternatives depending on which of two sample stimuli occurred on that trial. Training was carried out using a fixed FP. In order to determine if the duration of this FP determines discrimination performance, a generalization test with a range of randomly generated FPs was performed following the acquisition phase. Effects of the warning signal in this generalization test could arise through changes in accuracy and RT. Note that with this procedure the pigeon's accuracy and reaction times could be obtained simultaneously, making it possible to determine if the warning signal introduces a response bias or enhances the sensory processing of the sample stimulus. If the warning signal enhances processing of the sample, then the pigeons would be expected to perform more effectively at the FP used during training. In other words, they would demonstrate shorter RTs and be more accurate at the training FP. On the other hand, if the

warning signal caused the pigeons to adopt a response bias then a speed-accuracy tradeoff should be evident. Increases in speed of responding would be accompanied by decreases in accuracy, as they would be indiscriminately responding quickly. In terms of control by the fixed FP training we are asking the question does the manipulation of the FP during the generalization test effect both measures, accuracy and RT, in the same fashion or does the subject perform more effectively on one measure while performing less effectively on the other measure.

Another interesting aspect of Posner et al's (1973) study was the "U" shaped function of RT by FP that they obtained. It is instructive to consider what might be responsible for this. A plausible way of conceptualizing the effects of the warning signal in this procedure is in terms of the recruitment of a state of alertness (Posner, 1978, and Hockey, 1984). According to this view, the main factor causing long RTs during short FPs may have been the time necessary to recruit this "alertness" process. For instance, it is not unreasonable to suppose that the recruitment of a state of alertness would require some minimum amount of time. The long RTs that occur with increasing FPs must, however, have another explanation. One explanation stems from the fact that long time intervals have been shown to be more difficult to estimate than short time intervals. This observation has been made in studies with animals (Gibbon,

Church, and Meck, 1984) and humans (Kristofferson, 1984). For instance, in research with human subjects, Kristofferson, indicated that the Weber fraction plays a part in the discrimination of duration. Based upon this observation, we should expect that the estimation of longer FPs should be more variable than the estimation of shorter FPs. In other words, if the subject cannot easily estimate long intervals then the subject should be more uncertain as to when a particular long FP has timed out. This, in turn, should impair the subject's readiness for the event occurring at the end of the long FP. Thus, increasing timing inaccuracies with longer FPs would explain the gradually increasing RTs observed with increasing FPs (Posner et al, 1973).

This timing interpretation of FP effects was explored in the present experiments by training pigeons with either a short or a long FP. The pigeon's sensitivity to this manipulation was then assessed using a generalization test procedure in which performance was evaluated at a series of FPs. It is expected that the Long training group would have greater difficulty than the Short training group in estimating when the sample stimulus will be presented. This is because of the greater difficulty in estimating longer intervals than shorter intervals (Kristofferson, 1984). The Long training group's performance on the generalization task therefore, should gradually decline as the FPs in test

differ from the training FP. In other words, there should be a fair amount of generalization from the long training FP to other FPs. However, the Short training group's performance on the generalization task should more abruptly decline in performance as the test FPs differ from the training FP. This is because training with a short interval should be more discriminable from longer intervals than training with a long interval would be discriminable from shorter intervals. In other words, the Short training group should be more sensitive to changes in FP than the Long training group.

An additional group, a Mixed training group, was added to the experiment in order to explore warning signal effects between the span of the two training FPs. The Mixed training group was trained with an equivalent number of trials using both of the training FPs. This group should enable us to explore if the warning signal effect can be maintained over a range of FPs.

Experiment 1

The subjects in this experiment were three groups of White Carnaux pigeons. All of the pigeons received the same initial shaping within a specially prepared Skinner box. The intelligence panel of the Skinner box contained three response keys which are described below. The function of the shaping was to familiarize the pigeons with the visual

warning signal and the two choice response keys. The shaping was then followed by training at a particular FP. At the end of the FP, which had been initiated by responding to the warning signal, a burst of white noise occurred. The burst was either a soft intensity or a loud intensity and the pigeon was to respond to the appropriate choice key for the level of noise. A previous pilot study had determined that the pigeons were capable of discriminating the two levels of white noise after training at a specific FP. Each of the three training groups received different FP training procedures. The Short and Long training groups each received a single training FP. The Mixed training group received the short and long FPs divided into an equal amount of trials as the other two groups. During the test phase all of the groups received the same FP stimuli presented in a random order. RT and accuracy data were collected on each trial.

Method

Subjects - Nine White Carnaux pigeons were maintained at 80% of their free feeding weight. There were three pigeons in each training group. These pigeons only prior experience was in visual discrimination experiments. They had no experience with the auditory stimuli to be used here.

Apparatus - A three key Lehigh Valley pigeon chamber with a modified intelligence panel was used. Centrally located, 8 cm above the food magazine was an 8 cm by 8 cm

square Lexan panel through which the pigeon could observe the television monitor. In the center of this Lexan panel was cut an aperture of 4 cm in diameter, through which the pigeon could peck at a transparent panel located directly in front of the monitor screen. A slight movement of this panel activated a microswitch. The monitor was a Sony model PVM 400 (S) with a four inch black and white screen. At the same height as the aperture, and 3 cm to either side of the Lexan panel were backlit pigeon response keys, 2.5 cm in diameter. These two keys functioned as choice keys. A three inch loud speaker was located 4 cm to the right side and at the exact height of the aperture for the food magazine. This loud speaker produced the white noise. The white noise was generated by a Grason-Stadler model 1724 noise generator. The two bursts of white noise used in the experiment were 100 msec in duration. The difference in the intensity of the two sounds was 11.1 dB. An Alpha A-Bus model MB 120 interface connected the sound generator, intelligence panel, and monitor with a computer. Inserted into the Alpha A-Bus were an input card (Alpha IN-141) and a relay card (Alpha RE-140). The auditory stimuli, keylights, and reinforcement magazine were operated by the closing and opening relays that were part of the interface. The computer was a Tandy model 1000 with 640K RAM and model VM-4 monitor. It was used to control the order and duration of the auditory stimuli, the various experimental events, and to store the data. An

Alpha products CL-144 timer clock was inserted into the Alpha A-Bus in order to control the timing of trial elements, e.g., the FP, and duration of reinforcement. The CL-144 timer clock used an input from the computer clock. The trial and intertrial events were calibrated by comparing results printed out on the monitor with the results obtained from a Hunter Model 120A Klockounter (series D) which was placed in series within the electrical system. The programming made possible the manipulation of within trial events, the recording of trial data, and the collection of session summary statistics.

The program was used for the training procedure and the generalization test. During training a correction-rerun procedure was used with the training FPs. The difference between the training procedure and the generalization test is that the generalization test sessions included a warmup phase. The warmup consisted of twenty trials with the training FP. The test FPs were activated after the warmup phase of the generalization session were completed.

Procedure

Preliminary training - The pigeons were shaped to respond to the keys of the intelligence panel using the following procedure. A session consisted of three different types of trials and was 90 trials in length. The first series of thirty trials directed the pigeon's attention towards the monitor by reinforcing pecking behavior on the

transparent panel in front of the monitor. At the beginning of the trial the background of the screen was light gray and a set of thin black parentheses shaped arcs bounded the left and right borders of the screen. Each parenthesis extended from the top to the bottom of the screen. When the pigeon had pecked the center key in front of the monitor it was reinforced with grain from the lit magazine for 2 s. Then the monitor screen changed. Only the light gray background was visible for the 7 s ITI. At the conclusion of these thirty trials the monitor remained as it was during the ITI. Then a second type of trial began. Its start was signalled by the right-side response key lighting up and remaining lit until the pigeon pecked on it. The light was turned off by the pigeon's peck and the pigeon's behavior was reinforced as before. During the ITI only the monitor kept the pigeon chamber lit. After five consecutive trials with the right-side response key, the left-side response key lit up for the next five trials. This left-right alternation was carried out for a total of sixty trials. The pigeons were run with the shaping program until two weeks after they had begun to respond rapidly to all of the stimuli.

Experimental training - The initial training sessions consisted of 200 correct trials using a correction rerun procedure. A trial was composed of the following order of events: a visual WS, a time period (the FP) beginning with the pigeon's response to the central key, a burst of white

noise, the pigeon's choice response, reinforcement of the correct response or nonreinforcement of the incorrect response, and the ITI. The visual WS was a set of parentheses similar to the ones in the shape procedure except that they were white on a dark gray background. Upon the pigeon's response to the WS the computer program began timing the FP. For subjects in Group Short this FP was 588 msec and for subjects in Group Long this FP was 9250 msec. The subjects in Group Mixed received both training FPs in a random order, with the constraints that each FP occurred equally often and that the total number of trials was the same in all three groups. At the end of the FP a 500 msec burst of white noise was delivered into the pigeon chamber. The white noise was one of two intensities that was produced in a random order by the computer software. The program was arranged so that the correct response for the louder of the two white noise intensities was a peck on the left-side response key and the correct response for the softer white noise intensity was a peck on the right-side response key. Upon the termination of the white noise the choice keys lit up. The key lights were turned off by the pigeon's response to a choice key. When the pigeon responded the response was tallied by the computer and reinforcement was delivered for the correct response. The reinforcement consisted of 2 s of access to a tray of grain that was illuminated for the 2-s interval. During the ITI the monitor

screen was light gray for 6.5 s in the case of a correct response and 8.5 s in the case of an incorrect response. If an incorrect response had been made, then the trial was repeated until a correct response was made. In the event of a correct response the program generated the next trial in the sequence of that session. The pigeons were run until asymptotic performance was obtained by all of the pigeons. Then the length of the white noise burst was gradually reduced from 500 msec to 100 msec while the asymptotic level of performance was maintained. The reduction in the length of the white noise burst was accomplished over 26 training sessions. Next, partial reinforcement was introduced and the level of reinforcement was gradually decreased until the birds performed at the asymptotic level and the 50% level of partial reinforcement was reached. This was accomplished over 10 training sessions. When the performance had stabilized the generalization test was begun.

Generalization test - During the generalization test the subjects were exposed to a range of FPs which extended above and below their training FPs and included the training FPs. The generalization test was run for five sessions and each session consisted of 240 trials. Twenty of these trials, at the beginning of each session, were warmup trials using only the training stimuli for the particular bird. The next 220 trials were composed of the full range of FP/sound intensity combinations, presented in a randomized order.

There were 20 trials at each of the eleven FPs. Half of these contained the loud sound burst as stimulus, and the other half contained the soft sound burst. The length of the FPs in msec were 61, 133, 301, 588 (short training FP), 1212, 2365, 4695, 9250 (long training FP), 17278, 32020, and 60058. The correction-rerun procedure was not used during the generalization test. An 80% partial reinforcement schedule was used for correct responses at all FPs. The percentage of reinforcement was raised over the training level of 50% in an attempt to ensure that the total number of reinforcements received during the test sessions was comparable to that received during training. Additionally, in order to stabilize performance, the birds were given two days of retraining with the training procedure after each generalization session. The data collected and recorded on each trial were the FP, the sound intensity level, the response type, and the RT. All of these data were recorded on a floppy disk for further analysis.

Results

By the end of training, there was clear evidence that all subjects acquired the discrimination. There were seven subjects in the training groups at this point. One bird in Group Short failed to acquire the discrimination and one bird in Group Long died of unknown causes. Correct responding was averaged over the last five days of training.

Although the mean percent correct responding for Group Short ($M = 74.8$) and Group Long ($M = 82.4$) differed numerically, this difference was not statistically reliable, $t(2) = -0.61$, ($p = .604$). Subjects in Group Mixed also appeared to be more accurate with long FPs than short FPs ($M = 76.9$ and 81.9 , respectively). However, this apparent difference also did not reach conventional levels of statistical significance $t(2) = -3.75$, ($p = .064$).

The geometric mean RT data was also averaged over the final five days of training. This analysis revealed that subjects were equally quick to respond on trials with short and long FPs. Group Short ($M = 1.15$ s) and Group Long ($M = 1.48$ s) did not differ, $t(2) = -.57$, ($p = .628$), nor did the Group Mixed's performance at the short and long FPs ($M = 0.59$ s and 0.60 s, respectively). In contrast to the correct response measure, analysis of the geometric mean RT data with short and long FPs in Group Mixed did not even approach statistical significance, $t(2) = -.25$, ($p = .825$).

The greatest observable change in performance in the test phase was obtained with the geometric mean RT data. Figure 1-1 shows the geometric mean RT data broken down by FP for each of the training groups during the test phase. Group Short shows an increase in geometric mean RT with increasing FP. The other two training groups, Group Long and Group Mixed, show comparatively level performance across the range of test FPs. Statistical analyses of these data

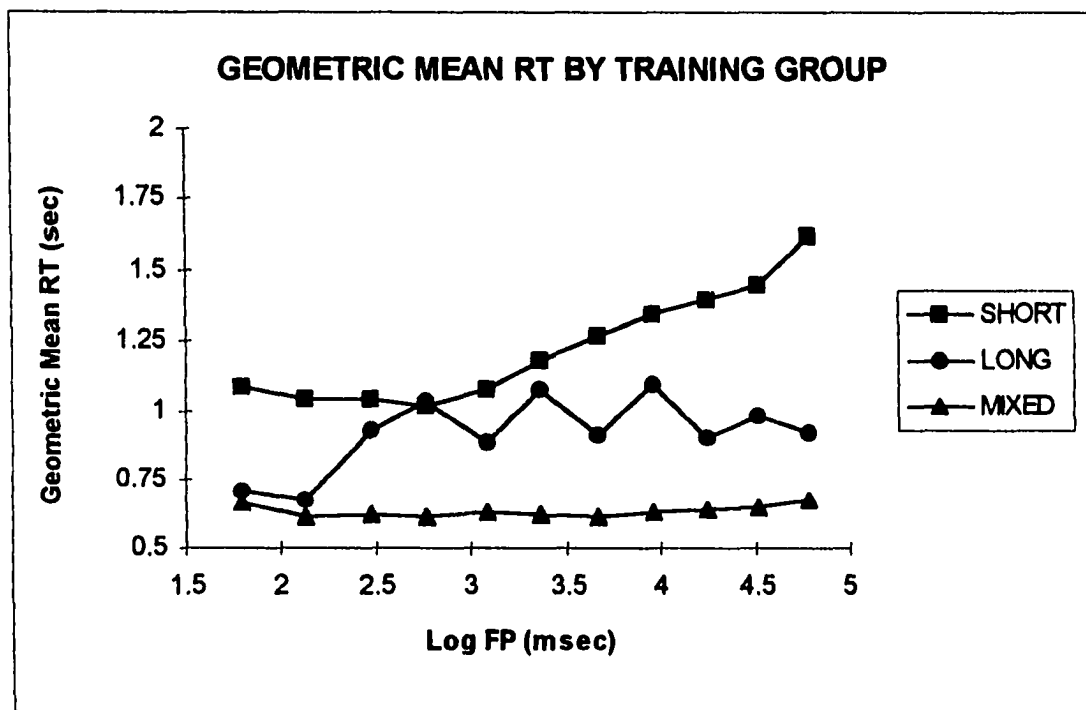


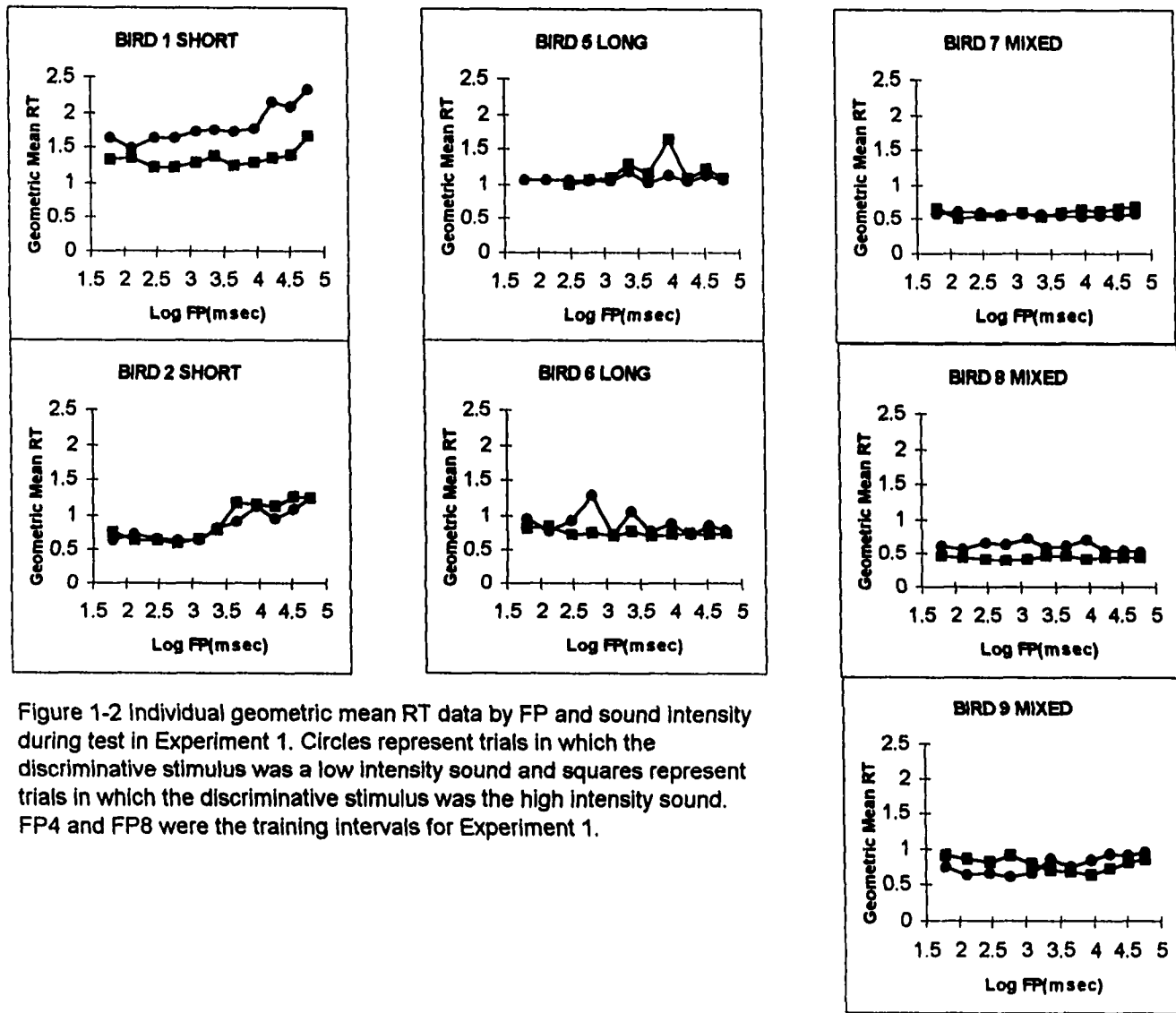
Figure 1-1 The geometric mean RT data are presented collapsed across sound level by training group. The training FPs were the fourth and eighth FP.

confirmed these impressions.

A three way ANOVA involving, Group, Sound intensity, and FP as factors was performed on the geometric mean RT data. A significant main effect of FP, $F(10,40) = 4.17$, ($p = .001$), was observed as was a significant Group by FP interaction, $F(10,40) = 2.49$, ($p = .007$). The main effect of FP and the Group by FP interaction appear to have arisen from the observed increases in the geometric mean RT with increasing FP in Group Short. The Group main effect did not reach significance, $F(2,4) = 4.76$, ($p = .162$).

The data for each individual subject, broken down by FP and sound intensity, are presented in Figure 1-2. Both of the birds in Group Short show for each sound level the same upturn pattern with increasing geometric mean RT as seen in the group data. Performance of the birds in the Group Long and Group Mixed was comparatively level across the range of test FPs. Furthermore, this pattern was true for each sound intensity.

The accuracy results were not as consistent as those obtained above. The group mean percent correct response data collected in the test phase are presented in Figure 1-3. The data in this figure have been collapsed across the sound intensity levels used on different trial types. The figure shows a decline in performance with increasing FP for Group Short and to a lesser extent for Group Mixed as well. Group Long's performance appears at near chance levels of accuracy



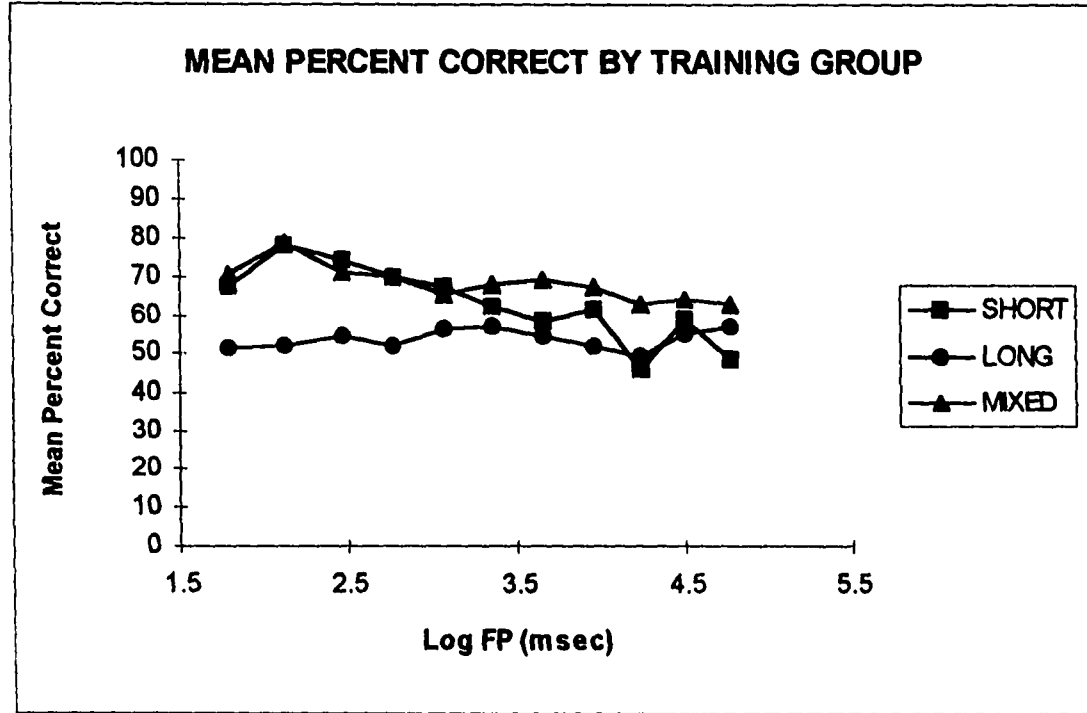


Figure 1-3 The percent correct responding data are presented collapsed across sound level by training group. The training FPs were the fourth and eighth FP.

across the range of test FPs. A three way ANOVA using Group, Sound intensity, and FP as factors was performed on the percent correct response data. Significant main effects for Group, $F(2,4) = 11.05, (p = .024)$, and FP, $F(10,40) = 3.71, (p = .001)$, were found. The Group by FP interaction did not reach statistical significance, $F(20,40) = 1.61, (p = .098)$. The FP main effect appears to be due primarily to changes within Group Short and Group Mixed.

Because of the small sample sizes used in the present study, it is informative to also examine the individual bird data. Figure 1-4 presents the data broken down by trial type for each subject across the various FPs during the test sessions. The most noteworthy feature of these data is the presence of a key bias displayed by subjects in the Group Long. Each of these birds displayed near perfect accuracy on one of the trial types and near imperfect accuracy on the other trial type, especially when tested with short FPs. This key bias was not due to any intrinsic property of the key or the discriminative stimulus as bird five favored the low intensity key while bird six favored the high intensity key. The response bias in these birds accounts for why Group Long responded at near chance levels in the collapsed data in Figure 1-3. This bias was not observed in acquisition, but emerged during testing.

Another noteworthy aspect of these data are that with few exceptions the birds in Groups Short and Mixed tended to

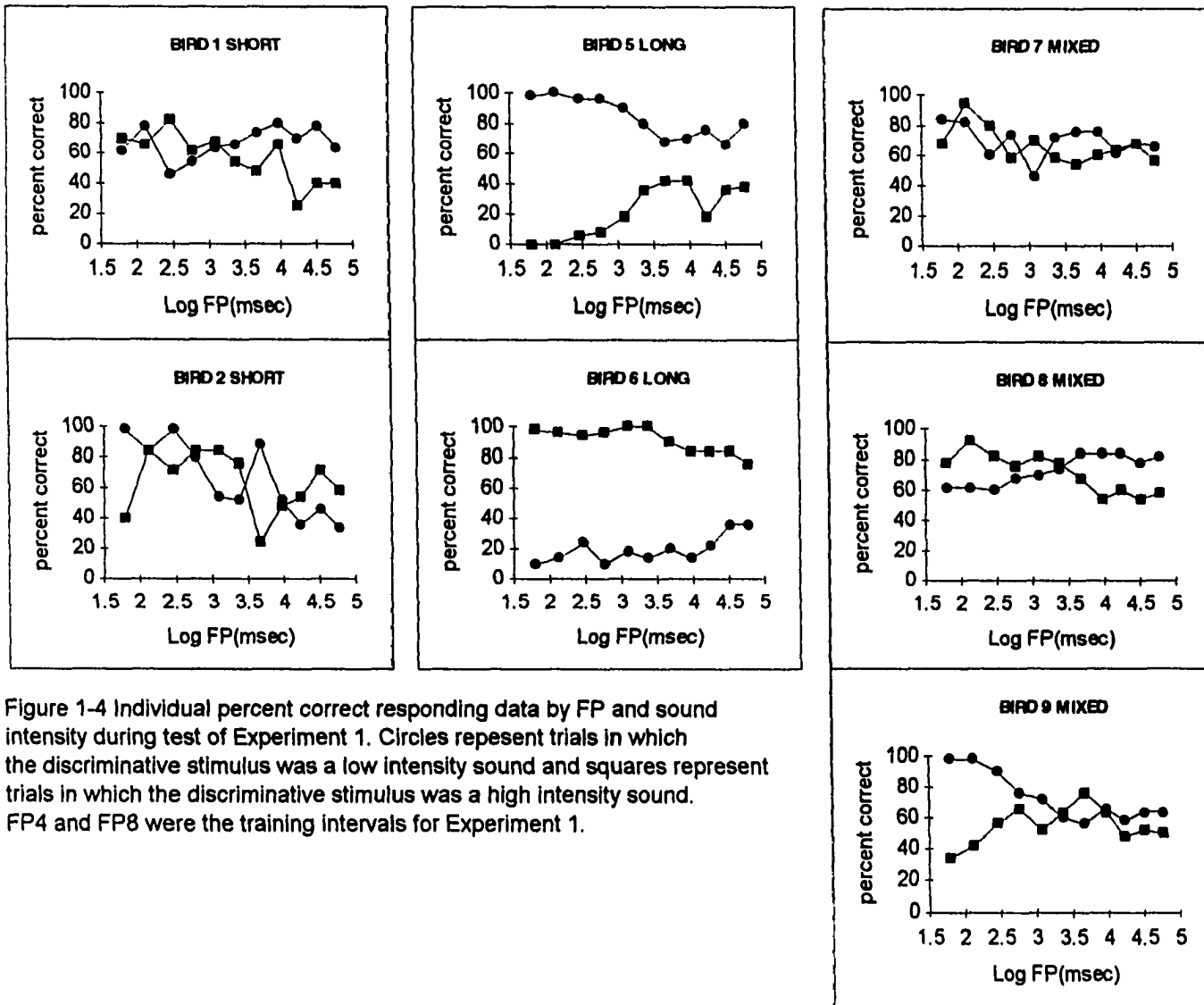


Figure 1-4 Individual percent correct responding data by FP and sound intensity during test of Experiment 1. Circles represent trials in which the discriminative stimulus was a low intensity sound and squares represent trials in which the discriminative stimulus was a high intensity sound. FP4 and FP8 were the training intervals for Experiment 1.

perform less accurately with increasing FPs. This observation supports the significant main effect of FP seen in the group data.

Discussion Experiment 1

The present study was meant to explore the effects of varying the FP upon performance in an auditory choice task, after subjects were trained using a single FP. Human studies have suggested that training with a single FP might alter performance to a test stimulus presented at the end of the FP, either by inducing a bias to respond more quickly, or by increasing the efficiency of stimulus processing. The present experiment attempted to address two issues. The first issue was to explore whether training with a specific FP would influence pigeons performance on a choice task when FPs were varied during a test. In addition it hoped to determine whether the effect of training with a single FP would be best described in terms of a response bias or in terms of stimulus processing. The second issue was to explore the effect of training at short versus long FPs. Due to there being greater timing inaccuracy with long FPs, it was anticipated that Group Long would be less affected by FP variations during the test than Group Short.

Data from the present experiment do suggest that an alertness effect can be observed in pigeons. In general, subjects performance was influenced by FP variations in the

test. A response bias interpretation of this alertness effect would have been supported if either Group Short or Group Long demonstrated a speed-accuracy tradeoff during the test phase. An efficiency of processing effect of alertness position would have been supported if Group Short or Group Long performed with the highest accuracy and shortest latency at their respective training FPs. The results of Group Short offer some support for the efficiency of processing view. The birds of this group performed most quickly at their training FP, and increasingly slowed down with longer FPs. However, while the accuracy data for Group Short can be viewed as in the proper direction, a decline in performance with increasing FP (see Figure 1-3), this result was not supported statistically. The lack of statistical power was the most probable cause for the lack of statistical support.

Turning to the second issue, the difference in performance between Group Short and Group Long, we find that Group Short's performance has varied with FP. Unfortunately, the birds in Group Long demonstrated a strong key bias. The key bias made it impossible to make a comparison of the effect of FP variation between Group Short and Group Long. The presence of a strong response key bias by the subjects in Group Long made it desirable to modify the procedure in the following experiment in order to more fully assess the effects of training with a long FP.

Experiment 2

The second experiment was performed in order to explore the effects of training with a long FP when no response bias occurs during testing, and to replicate the results of Group Short and Group Mixed. Four major changes in procedure of the first experiment were made in an attempt to increase the power of the experiment and to eliminate the response bias seen in Group Long. The first change was to increase the difference between the two white noise intensity levels from 11.1 dB to 20.25 dB. This increased difference between the sound intensity levels made the discrimination task easier. The second change was to darken the choice keys. Remember that the choice keys Experiment 1 lit up after the sound intensity stimulus was presented. This darkening of choice keys was done in order to reduce any affects that the key lights might have on the subjects. For instance, the birds might respond as in an autoshaping procedure to the sudden onset of the key lights. The third change in procedure was to eliminate the retraining sessions that occurred between the test sessions of Experiment 1, as well as the reinforced warmup trials at the beginning of each test session. The elimination of retraining and warmup trials was performed in order to remove any potential biasing effects these trials might have on performance during the generalization test. And fourth, the training period was extended for all groups.

The amount of training was increased considerably beyond asymptote in order to stabilize performance.

The same three types of training groups, short, long, and mixed, were trained as in the first experiment. Additionally, an attempt was made to measure the bird's location within the chamber during the FPs in training and in test. This consisted of measuring the bird's responses to the three response keys during the FP prior to the onset of sound. It was hoped that this measurement would demonstrate if the birds tended to favor one response key over another prior to the presentation of the choice stimuli.

Method

Subjects - The subjects were ten White Carnaux Pigeons maintained at 80% of their free feeding weight. Groups Short and Mixed each contained three pigeons. The remaining four pigeons were in Group Long. Several of these pigeons were in the previous experiments. The new birds were naive with respect to auditory stimuli but had been used in visual experiments.

Apparatus - The apparatus remained the same. The difference in the sound intensities was increased from 11.1 dB to 20.25 dB in order to increase the discriminability of the auditory stimuli. The lower level of white noise remained at the same level as in the previous experiment because of difficulties in rewiring the setup. The software

was altered in order to record the pigeons' responses to the response keys during the FP in addition to the previously collected types of data.

Procedure - The birds that were not used in the previous experiment were first trained using the preliminary shaping procedure of Experiment 1. There were three birds assigned to the short FP training group, four birds assigned to long FP training group, and three birds assigned to mixed FP training group.

All of the birds were then run in a new training procedure which consisted of 100 training trials per session with a correction rerun for trials on which an incorrect response was made. The three different training groups were the same as in the first experiment, short, long, and mixed FP groups. Birds that were in the previous experiment were maintained in the same training groups in this experiment. The major change for the birds was the lack of response key lights after the sound termination. The birds were gradually shaped to respond in the absence of the key lights by gradually dimming them over several sessions. During training all correct responses were reinforced initially. However, before the generalization test was to begin the birds were shifted to a schedule on which 50% of the correct responses were reinforced. Training was continued until the mean RT for correct responses per session was stable. The total length of training was ninety-eight sessions. The last

fifty sessions of the training provided baseline data which were examined for patterns in the pecking behavior of the birds during the FP.

The design of the generalization test differed from that used in Experiment 1 with respect to the presentation of reinforced training trials. In the first experiment each generalization session contained twenty warmup trials of the training stimuli and an additional two training sessions were administered between each testing session. This should tend to maximize any effects around the training FP. In the present experiment there were no additional training FP trials presented during the generalization test.

The generalization procedure consisted of 30 sessions which were each 100 trials long. The training FPs were included within the ten FPs used for the generalization sessions. Each session was composed of a random order of trials containing five trials of each of the twenty different FP-sound intensity combinations. The correction rerun procedure was eliminated for the length of the generalization test. The FP durations used for the generalization (in msec) were 7.3, 408, 603 (training), 1325, 2688, 5231, 10300 (training), 19842, 39095, and 76105. Note that although these values differ from those used in Experiment 1, the specific values and the range of values are quite comparable to those used in Experiment 1. The schedule of partial reinforcement was enriched to 70% of

correct responding to the sound intensity from the 50% at the end of training. This was done in order to maintain the level of responding during the test phase. In order to avoid problems with birds stopping during the session the trial was terminated and the next trial started, if a bird did not respond within sixty seconds after the discriminative stimulus was presented.

The data collected on each trial consisted of the bird's pattern of pecking to the response keys on each trial during the FP, the type of response, and the RT. The correct responding per session for each stimulus combination was recorded. The peck data collected during each individual session was summed according to the FP. The final peck before test stimulus presentation data was collected by individual trials along with the choice and RT data for the trial.

Results

Training - By the end of training, there was clear evidence that all subjects acquired the discrimination. Correct responding was averaged over the last five days of training. The mean percent correct responding for Group Short ($M = 96.3$) and Group Long ($M = 91.2$) were not statistically different, ($t(5) = 1.08$, $p = .238$). Subjects in Group Mixed also displayed equally accurate scores on trials with short and long FPs ($M = 98.1$ and $M = 93.9$),

respectively, $t(2) = 2.63$, $p = .119$). Note that the amount of correct responding observed here appeared to be greater than that observed in Experiment 1. This suggests that the changes in procedure, increasing the sound level difference and leaving the response keys unlit, improved the discrimination.

The geometric mean RT data was also averaged over the final five days of training. This analysis revealed that subjects were equally quick to respond on trials with short and long FPs. Although Group Short ($M = 1.25$ s) and Group Long ($M = 2.63$ s) marginally differed statistically, $t(5) = -2.37$, ($p = .064$), Group Mixed's performance at the short ($M = 1.14$ s) and long FPs ($M = 1.16$ s) was almost identical, $t(2) = -0.17$, ($p = .88$).

In order to assess the birds' location in the chamber during the FP, pre-stimulus key peck responses directed to each of the keys, the center key and each of the two sidekeys, were recorded throughout training. The responses were tallied into three sets of bins, at the beginning, middle, and end of trials with a long FP. On trials with a short FP this interval was the size of the FP. These intervals were 561-msec long or 17, 33-msec bins. Each of these intervals was regarded as "filled" if a response occurred at any time during the 33-msec period. Thus, a large amount of pretrial responding would be represented by a high percentage of these intervals being filled.

Figure 2-1 contains for each group the percentage of intervals in which a response occurred, over the last 50 training sessions. During the short FP key pecks were directed towards the center key for birds of the Short and Mixed training groups. Group Long also responded primarily to the center key in the beginning of the long FP. A comparison of the center key responding of all of the training groups revealed that there were no significant differences between these groups, $F(2,7) = .709$. This means that the training did not have a different effect on responding for the beginning interval. Another important aspect of these data is that the Long and Mixed groups displayed a substantial drop in overall responding toward the middle and end of the long FP. Measures at the middle and end of the long FP show a pattern of decreased responding to the center response key. This drop in center key responding was accompanied by a small increase in responding to the side response keys for both Group Long and Group Mixed. This increase in side response key responding favored the soft sound intensity over the loud sound intensity for most of the birds in Group Long and Group Mixed. This implies that the birds were somewhat biased towards responding to the "soft" intensity key, but notice that this effect is not very large.

Generalization Test - The data collected during the generalization test were formed into three ten session

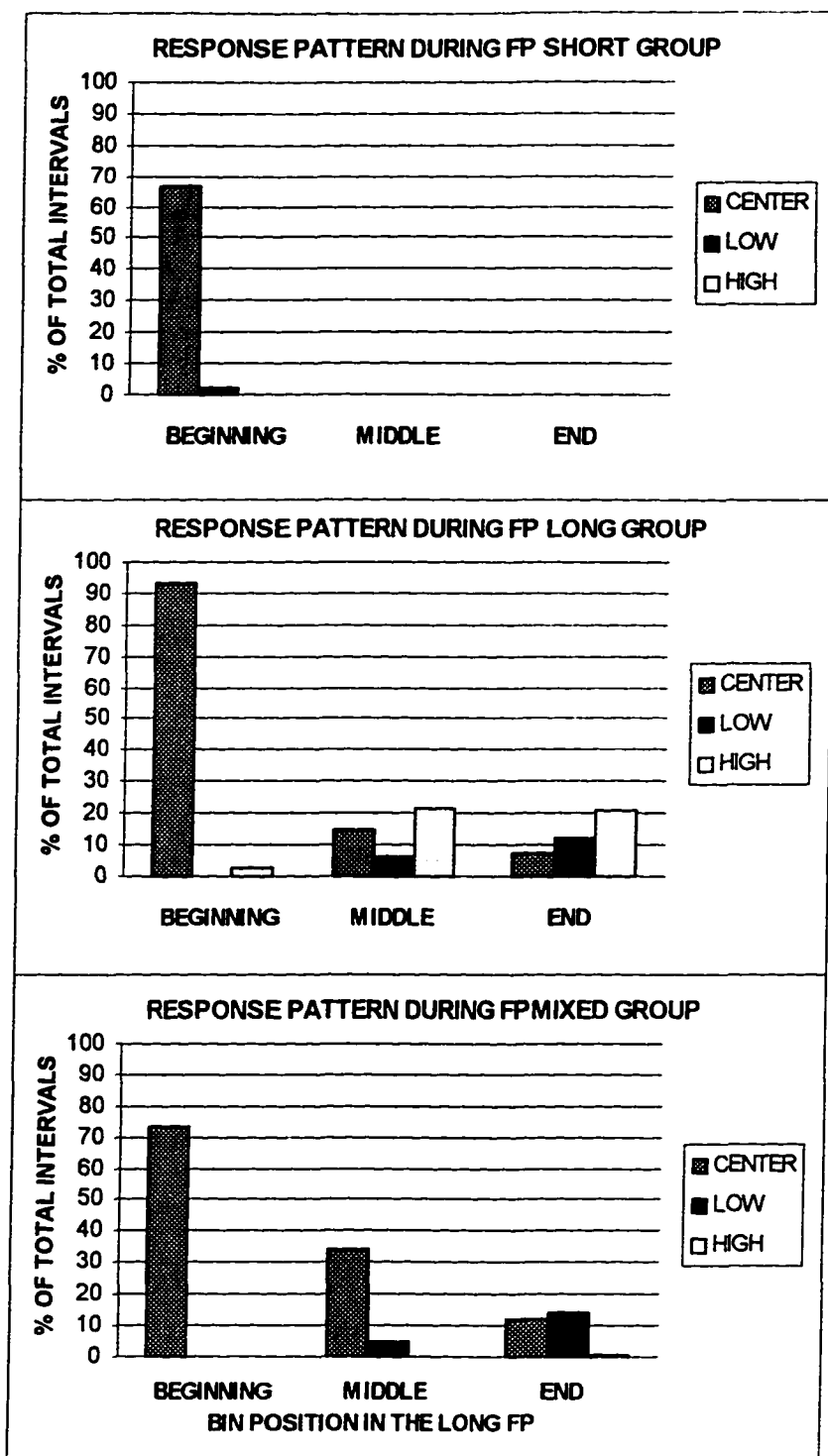


Figure 2-1 The percentage of filled response intervals is portrayed by training by training group for the sum of the last fifty training sessions. The low and high in the legend refer to the low and high sound intensity choice keys.

blocks for statistical analyses. The data were analyzed by four-way ANOVAs. The factors were Training group, Blocks of sessions, Sound level, and FP.

The geometric mean RT data will be discussed first followed by percent correct responding data. Figure 2-2 shows the geometric mean RT data in blocked form. They are collapsed over sound level and organized by group. The greatest difference in the Groups effect is shown to have happened during the first block. The greatest change among the groups appears to be the reduction in latency of Group Long from the shortest FP test intervals to the longest FP test intervals. Group Short demonstrated an increasing latency following a minimum at its training FP. Group Mixed's performance was comparatively level across the range of test FPs following a decrease in latency from the first to the second test FPs.

Most of these impressions were statistically confirmed. The overall statistical analysis did not yield a significant Groups effect, $F(2,7) = 1.76$. However, the main effects for Blocks, ($F(2,14) = 4.15, p < .05$) and FP, ($F(9,63) = 2.89, p < .01$) were significant. Three of the first order interactions were significant. They were Blocks by Group, $F(4,14) = 4.19, (p < .05)$, Blocks by FP, $F(18,126) = 2.15, (p < .01)$, and FP by Group, $F(18,63) = 2.12, (p < .05)$. The only second order interaction that was significant was the Blocks by Group by FP interaction, $F(36,126) = 1.92$

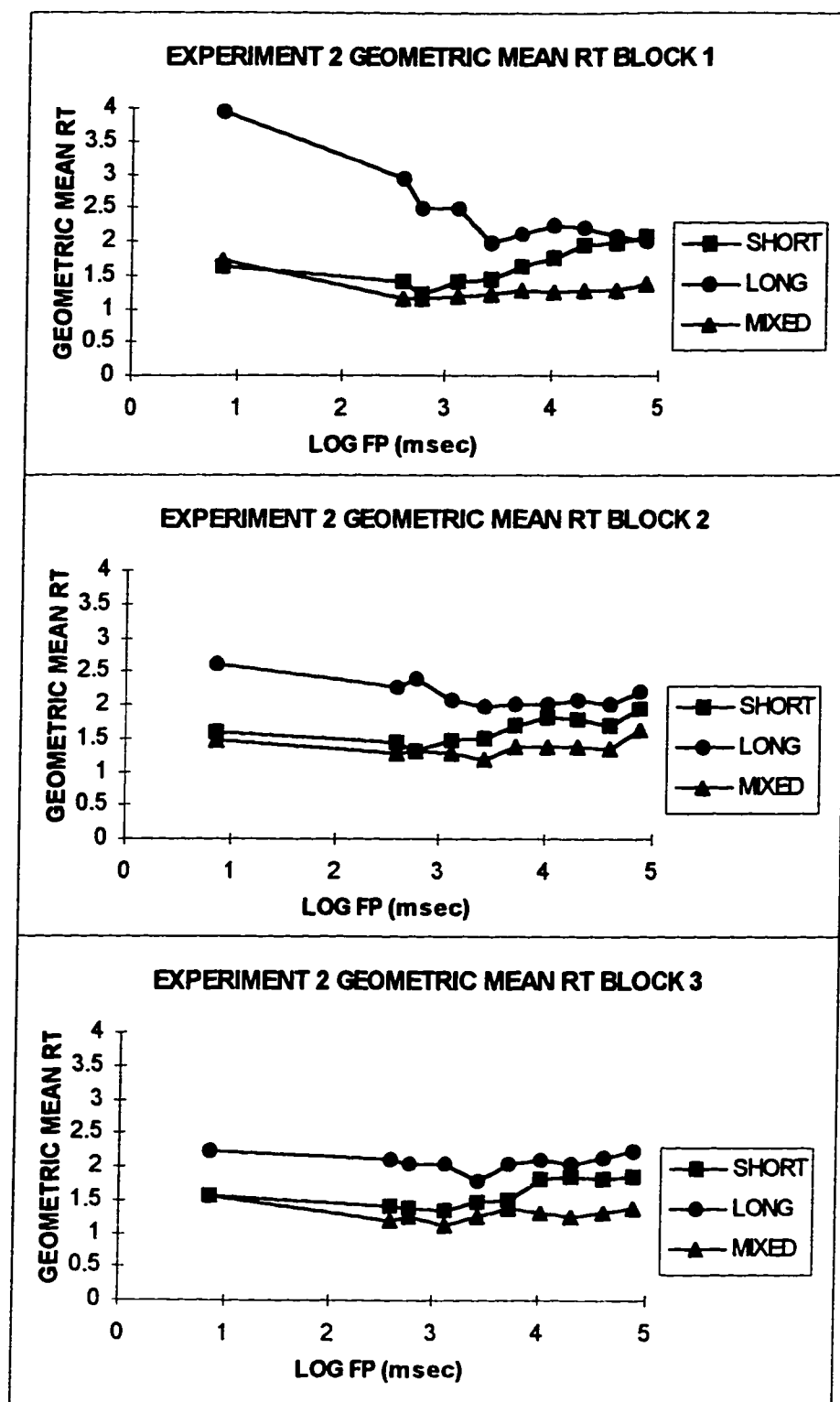


Figure 2-2 The results for the test phase by group and by block are shown. The training FPs are the third and the seventh data points.

($p < .01$). None of the portions of the analysis relating to sound level were significant.

In order to examine this three way interaction a pooled error term was calculated from the error terms of the overall analysis and Satterthwaite's procedure was followed in order to calculate the degrees of freedom for this error term (Kirk, 1968, pp. 214-217, and Keppel, 1982, pp. 441-448). This new error term was then used to assess the individual blocks data. The Group by FP interaction was found to be statistically significant only in the first block of data, $F(18,132) = 2.38$, ($p < .01$). The data from the first block were then analyzed for simple main effects of the groups using the pooled error term. Only the results of the Long training group were statistically significant, $F(9,132) = 6.63$, ($p < .01$). This shows the greatest change over FPs to actually have been due to the long FP training.

The individual bird data are presented in a columnar fashion by group (Figure 2-3) with each of the sound levels represented separately. Note that the training FPs were the third (2.78 log ms) and the seventh (4.01 log ms) FPs. An inspection of the individual bird data shows that Group Long's apparent difference was due primarily to two of the four birds in this group on one trial type. The ordinate axis of birds 4230 and 5605 was expanded to include the long latency on the first FP. Note, however, that all of the three birds in Group Short demonstrated a pattern of

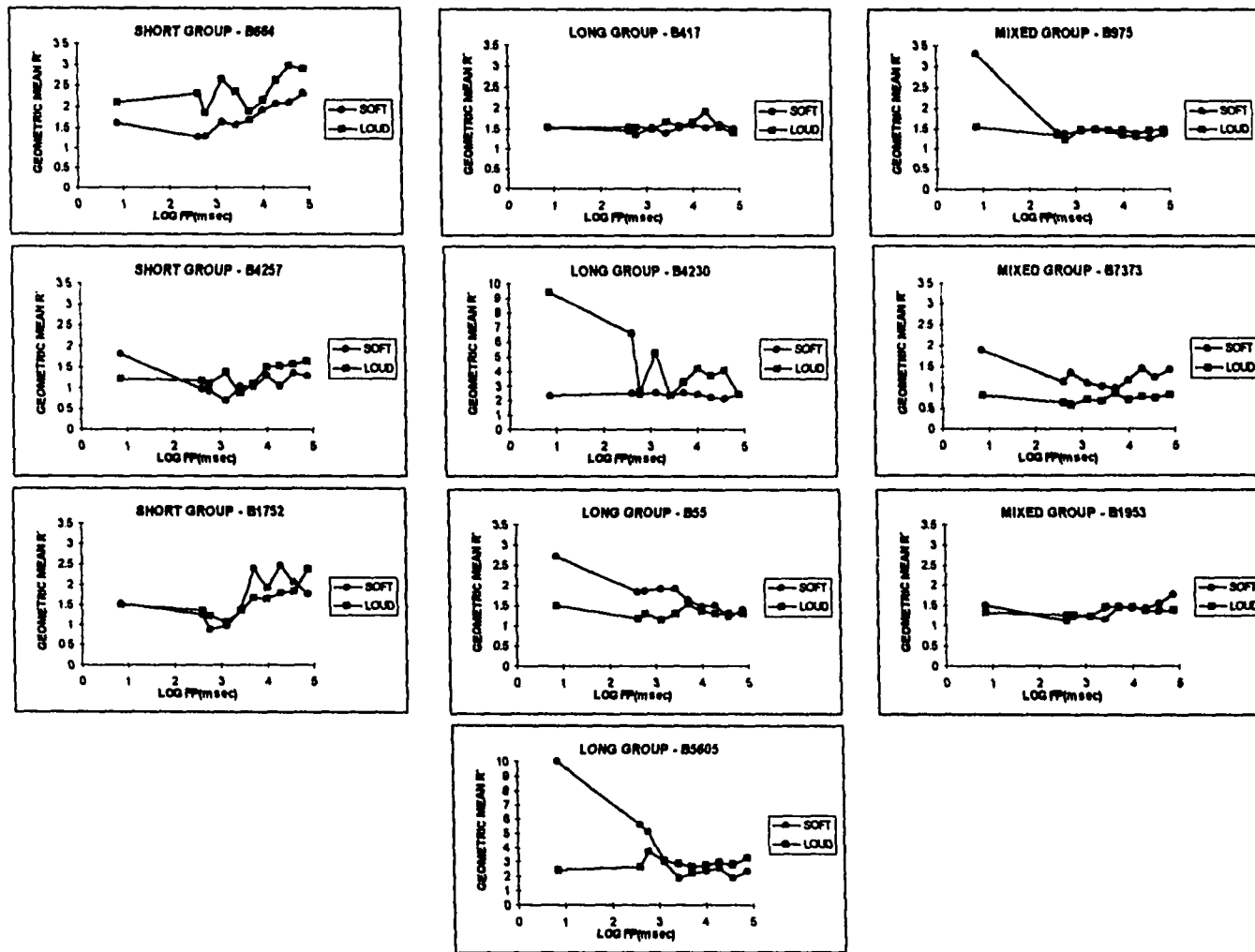


Figure 2-3 The individual bird geometric mean RT data is shown in columns by group. These data are of the first block of ten sessions. It should be noted that Birds 4230 and 5605 of Group Long have an elongated ordinal scale due to their response latency on the initial FP. The soft sound and the loud sound are circles and squares, respectively.

increased latency for the longer test FPs on each trial type.

There exists a discrepancy when consulting the individual subject data and the group data for Group Short. In spite of the fact that all of the subjects in Group Short increased their RT's as FP increased, the analysis performed on the group data failed to reach statistical significance. This was likely due to the pooling of error terms across groups. The large variation in performance of the birds in Group Long resulted in a larger variance for this group relative to the other groups. Additionally, the pooling procedure enlarged the overall error variance making it more difficult to detect an apparent effect in Group Short. In an attempt to reduce this increased variability in the data, the RT data from all subjects were subjected to a log transformation and the analyses on the grouped data were rerun. The data are presented in Figure 2-4. A three way analysis of the log data identical to that performed on the nontransformed data also revealed the Group by Block by FP interaction to be significant, $F(36,126) = 1.68$, ($p < .019$).

A pooled error term and degrees of freedom were calculated on the log transformed data according to the procedures mentioned above. As was the case with the non-transformed data, the Group by FP interaction was significant in the first block, $F(18,131) = 4.94$, ($p < .01$). The Group by FP interaction was marginally significant in

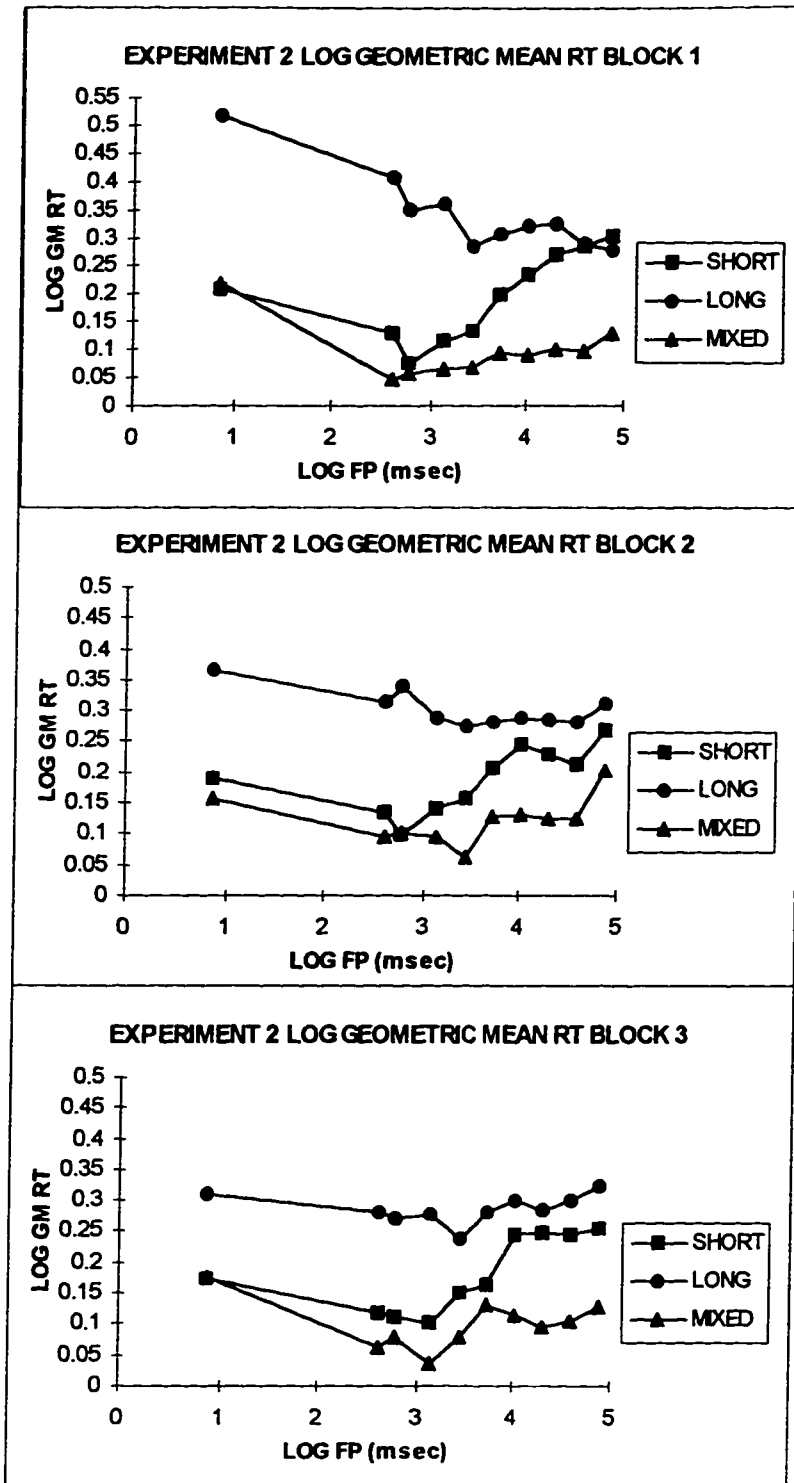


Figure 2-4 This is a plot of the log transformation of the geometric mean data by group for each block.

the second block, $F(18,131) = 1.65$, ($p < .10$). Subsequently the simple main effects were calculated for each of the groups in these two blocks. The simple effects analysis performed on each group in the first block indicated that all of the training groups were significantly influenced by variations in FP. The Group Short result was, $F(9,131) = 7.00$, ($p < .01$), the Group Long result was $F(9,131) = 7.82$, ($p < .01$), and the Group Mixed result was $F(9,131) = 2.88$, ($p < .01$). The simple effects analysis performed on the second block data only revealed that Group Short was sensitive to FP, $F(9,131) = 3.29$, ($p < .01$). It should be noted that this result can be viewed in the data (see Figure 2-4). Notice that by the second block subjects in Group Long are responding more similarly at each FP relative to the first block. Taken together these data suggest that the effect on RT of training with a short FP is at least as large as the effect on RT of training with a long FP. Furthermore, the effect of training with a short FP appears to be more long lasting. This description of the data appears to agree more with the individual subject data than does the non-transformed data.

The correct responding data were also analyzed in block form. Figure 2-5 depicts the percent correct responding for each group as a function of blocks of generalization sessions and log FP. They are collapsed by sound level. The greatest apparent change in performance across the FP was

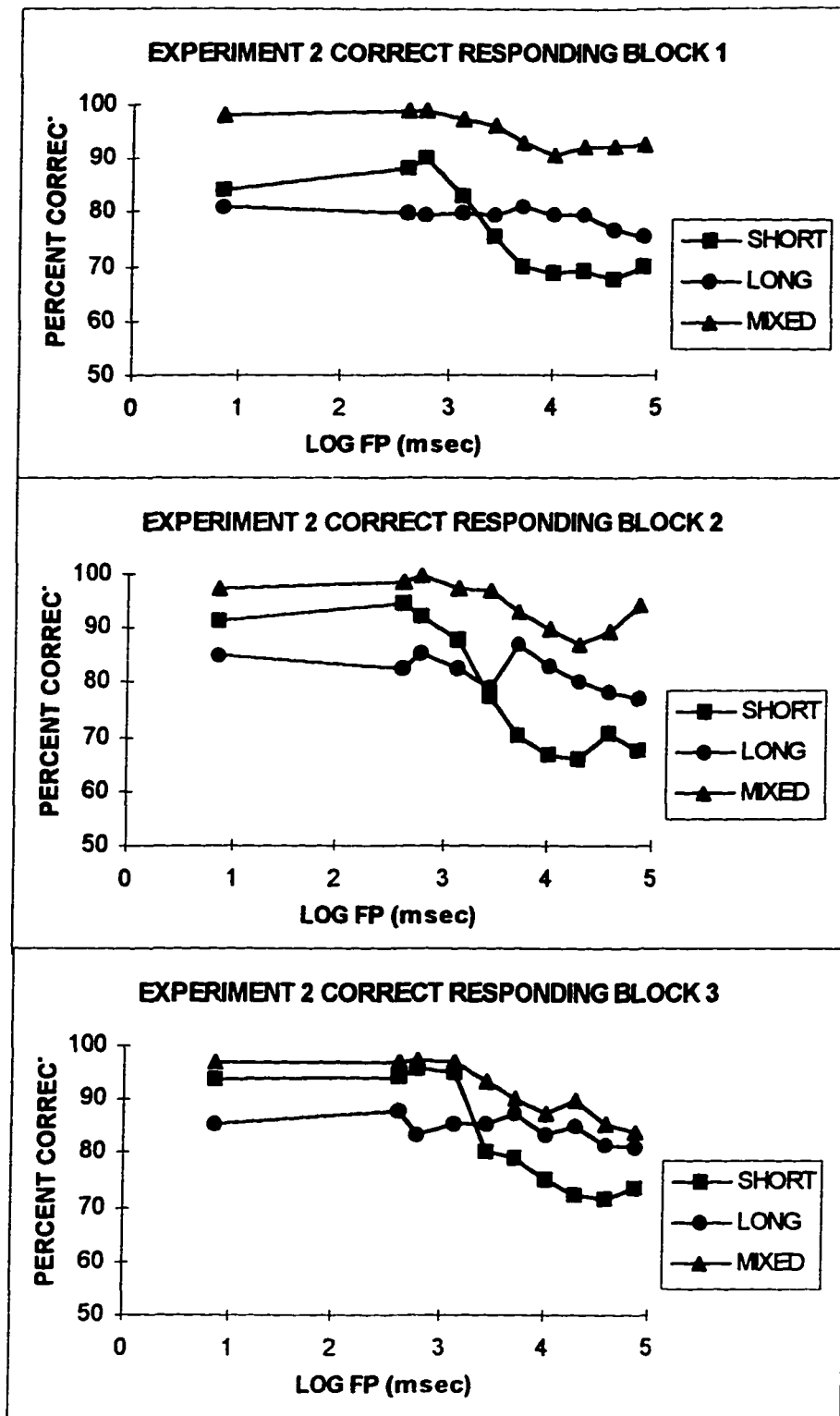


Figure 2-5 The results for the test phase by group and by block are shown. The training FPs are the third and the seventh data points.

seen in Group Short (Figure 2-5). Performance in this group declined in all test FPs that were longer than the training FP (log msec = 2.78). In contrast, Group Long and Group Mixed demonstrated comparatively level performance across the range of test FPs.

The percent correct responding data were organized in block form and analyzed in the same fashion as the geometric mean data, by a four way ANOVA. The factors were Training group, Blocks of sessions, Sound level, and FP. A significant main effect of FP was found, $F(9,63) = 16.91$, ($p < .001$), as was a significant FP by Groups interaction $F(18,63) = 4.91$, ($p < .01$).

In order to establish the meaning of the significant FP by Groups interaction a series of repeated measures analyses of the correct responding data using the first block data and a pooled error term was performed. Group Short yielded the only significant results $F(9,63) = 7.42$, ($p < .01$). Group Long, $F(9,63) = .31$, and Group Mixed, $F(9,63) = 1.05$ results did not approach statistical significance. These statistical results confirm that the main strength of the significant interaction came from the sharp drop in correct responding by Group Short after its training FP, log msec = 2.78.

An inspection of the individual bird data supports the statistical conclusions reached in the group analysis. The individual bird data, Figure 2-6, show the same decline in

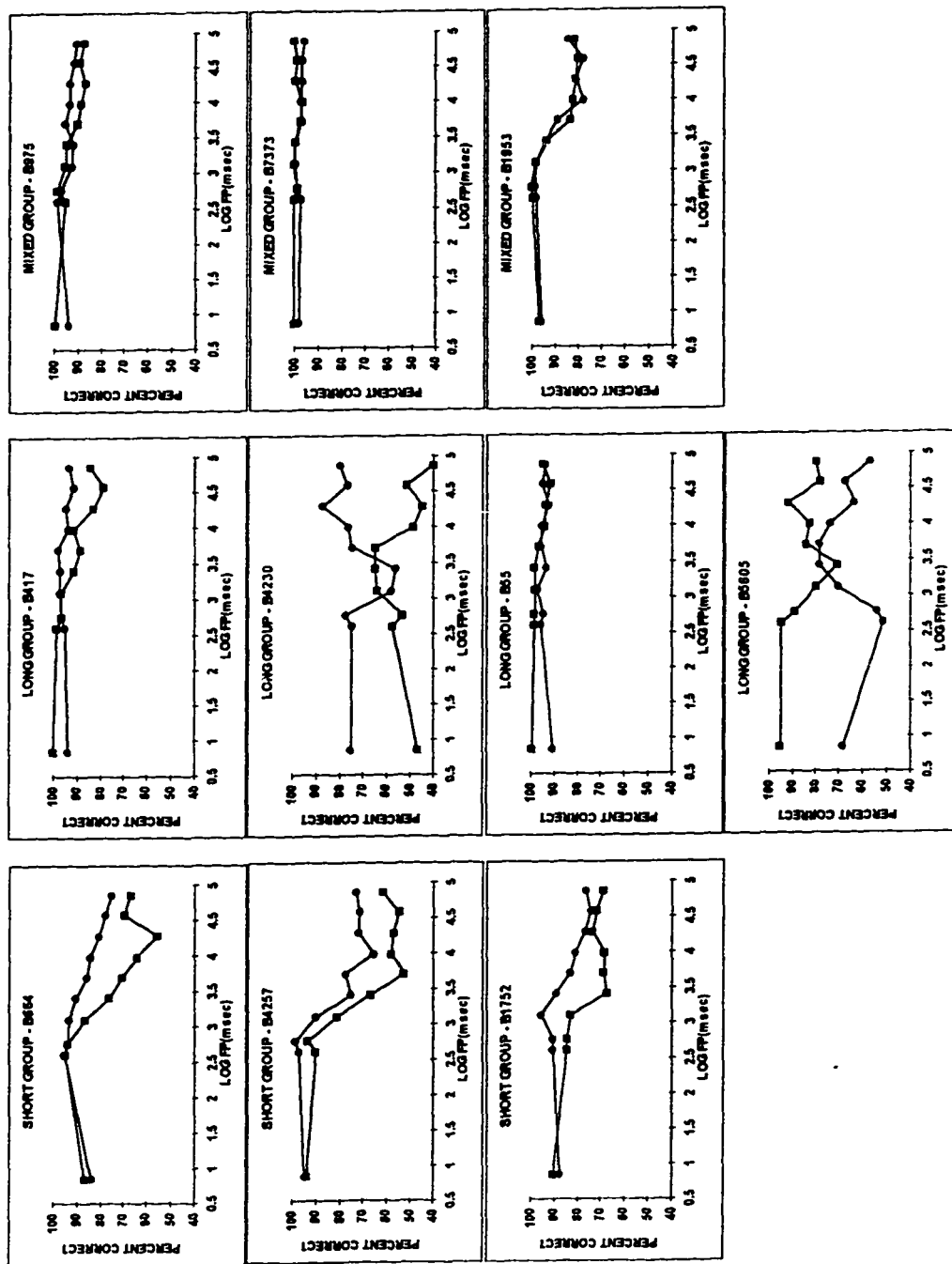


Figure 2-6 The individual bird percent correct responding is shown in columns by group. These data are of the first block of ten sessions. The soft sound level is represented by circles and the loud sound level is represented by squares.

performance for all three birds of Group Short as was observed in the blocked group data. Two of the birds in Group Long had near perfect performance on trials with each sound intensity across the full range of test FPs. More importantly, note that there is no evidence of a response bias in these birds. The remaining two birds in Group Long (B4230 and B5605) were the birds that displayed a strong response bias in Experiment 1. In the present experiment those birds were somewhat more accurate to one sound intensity than they were to the other. However, performance was at or near chance levels on trials with the sound intensity that produced less accurate responding. Strong evidence for biased responding would consist of above chance accuracy on one trial type and below chance accuracy on the other trial type. This, in fact, was the pattern displayed by these birds during the test phase of Experiment 1. Apparently, the procedures used in Experiment 2 greatly attenuated the response bias in these birds. Finally, in Group Mixed, only one of the birds demonstrated a decline in accuracy across the range of test FPs.

Discussion Experiment 2

The procedural changes introduced in Experiment 2 greatly attenuated the key bias shown by the subjects in Group Long from Experiment 1. Further, the procedures used in Experiment 2 successfully trained naive birds in Group

Long without any response bias. It is unknown which procedural change was effective in reducing the response bias, however, whatever the reason, Group Long's data in Experiment 2 are rendered more interpretable. The main result obtained in this experiment was that the discriminative performance of Group Short, and to a lesser extent Group Long, was sensitive to FP variations during the test. In addition, Group Mixed was relatively insensitive to FP variation during the test. These findings will be discussed in the general discussion.

General Discussion

In order to begin an exploration of whether the FP manipulation operates in similar ways in pigeons and humans, the present experiments asked if this FP manipulation could be shown to influence performance in a discrimination task using pigeons. Additionally, it should be noted that studies in the literature using human subjects refer to the alerting function of the warning signal at the beginning of the FP and these studies are regarded as studies involving alertness (Posner et al, 1972, 1978, 1980, and Klein and Kerr, 1974) It is in this sense that the term alertness is used. This "alertness" was studied in the present experiments by giving the pigeons a warning signal prior to the presentation of the discriminative stimulus on every trial. In two of the groups this warning signal always

signalled a fixed FP. It was hypothesized that the warning signal would alert the subjects to the subsequent presentation of the discriminative stimulus. The effects of this training were measured through a test using randomly generated FPs. It was further hypothesized that the birds performance during the test would be influenced by changes in the FP if the training FP indeed alerted the subjects as to the onset of the discriminative stimulus. The data from this test suggested that training with a fixed FP did appear to result in the warning signal acquiring control of behavior. There were two main observations from the present experiments relevant to this claim and they were most visible in Group Short. First, it was observed that as the duration of the test FP varied from that of the training FP, both accuracy and RT were impaired. This supports the idea that the birds were more able to process the stimulus when it was presented at the training FP. Second, it appeared as though birds trained with a short FP were more impaired than birds trained with a long FP during the test with variable FPs. All of the birds in the group trained with a short FP demonstrated a decrease in accuracy as well as an increase in latency with the longer FPs during the test sessions. However, only some of the subjects on some of the trial types in Group Long increased their response latency with the shorter FPs. Moreover, the subjects in this group also failed to demonstrate a corresponding decrease in accuracy

with the shorter test FP durations. The issues arising from these two results will be discussed in turn.

First, I shall consider the observed change in performance of Group Short. Accuracy was best and latency was quickest when the stimulus was presented at the training FP. This pattern of data can be thought of as reflecting increased efficiency in the processing of stimuli presented at the training FP. This increased efficiency is demonstrated by the better performance on both measures of Group Short. To my knowledge this is the first time that this phenomenon has been shown to work in this way in a recognition task with pigeons. That is to say, similar to the effects mentioned when discussing alerting effects in humans see below, Klein and Kerr, 1974).

These data are surprising in light of the previously mentioned results investigating alertness effects using a detection task with humans. Posner et al (1973) used a visual detection task and varied FP across experimental conditions. They observed that when subjects were quickest to respond, speed and accuracy traded off. In this case, increases in speed led to decreases in accuracy. In other words, while the alert subjects were biased to respond quickly they did so at the cost of being less accurate. In contrast, alert pigeons performed quickly and more accurately, as though the alert pigeons were not biased to

respond quickly but were better prepared to process the stimuli.

In comparing Posner et al's results with the current experiment it should be recognized that there were many procedural differences in addition to the obvious species difference. Any one of these differences could account for the disparate patterns of results. For example, the current experiment used an auditory choice task whereas, Posner et al used a visual detection task. Also, the range of FPs used in the current experiment extended beyond one minute, whereby, Posner et al used FPs in the range of one second. The stimulus in Posner et al's study remained on until the subject responded, whereas in the present study the stimulus was presented for only a brief period of time after which subjects were to respond. In addition, the subjects in Posner's study were speed stressed through verbal instructions to respond as quickly as possible, whereas, the birds in the present experiments were not trained with a speed stress.

Of these many procedural differences a particularly noteworthy factor might have been the use of a brief or continuous signal presented at the end of the FP. Klein and Kerr (1974), in discussing visual signal detection with human subjects noted that a difference in performance was obtained due to the use of continuous or brief durations for the test stimuli. Note that "continuous" test stimuli do not

terminate after a brief interval but rather are terminated by the subject's response. Humans under these conditions have been observed by Posner et al to show a speed-accuracy tradeoff as described previously. Human experiments using brief exposures to test stimuli, however, have demonstrated improvements in both speed and accuracy (Leavitt, 1969). This improvement was also observed in the present experiments, although the effect was most obvious when pigeon subjects were trained with a short FP.

Klein and Kerr explained these human results using the model of phasic alertness proposed by Posner (1978). Phasic alertness can be defined in terms of the change of state of an organism following a warning signal. According to Posner (1978) once a stimulus has been presented, information about that stimulus gradually accumulates within memory. The rate of accumulation is assumed by Posner to be independent of the state of alertness. Posner posits, however, that alertness does affect when the subject will respond on the basis of the accumulated stimulus information. In particular, alert subjects will require less accumulated stimulus information in order to make the decision to respond. In a continuous stimulus condition, it follows that when alert subjects are compared to nonalert subjects, the alert subjects will respond with less stimulus information available to them because they are responding more quickly. This will result in faster responding accompanied by

decreases in accuracy, i.e., a speed-accuracy tradeoff should be observed. However, when a brief stimulus is presented, the alert subjects will respond with more stimulus information available to them than the nonalert subjects. This is true because by the time the decision to respond has been made, the stimulus information will have decayed more from memory in nonalert subjects than in alert subjects. This will result in the faster responding being accompanied by greater accuracy, i.e., increased efficiency of responding. Note that this was the pattern of data seen in the present studies. Using Klein and Kerr's resolution of the difference in results obtained in experiments with brief or continuous stimuli as an explanation, we should now consider the possibility of a parallel in alertness effects between humans and animals. An extension of these ideas could compare the use of brief and continuous stimuli with pigeons using the paradigm developed here to see if this variable would lead to a predictable pattern of results. In addition, the current experimental paradigm can be used to evaluate this manipulation with humans. Adopting this recognition task for this purpose would extend the work of Posner which was accomplished with a detection task. These types of studies would add to our ability to determine if alertness operates in similar ways across species.

The second issue to be addressed from the results of the current studies concerns the greater sensitivity to FP

changes seen in the group trained with a short FP compared to the group trained with a long FP. Recall that Group Short was more consistently impaired at non-training FPs during testing than was Group Long. This greater sensitivity to FP variations seen in Group Short makes sense when we consider the role of timing processes in mediating alertness effects. A result which has been observed in both the human and animal timing literatures is that subjects are more accurate at estimating short versus long time intervals (Kristofferson, 1984, Gibbon, Church, and Meck, 1984). Suppose that the level of alertness depends upon accurate timing. This assumption is reasonable when one considers that a subject has to know when the stimulus is going to occur in order to be ready for its occurrence. It follows from this idea that subjects trained with short FPs should be more alert than subjects trained with long FPs. This is because subjects trained with a short FP should be better able to estimate the duration of their training FP than subjects trained with a long FP. This greater ability of Group Short to estimate their training FP is what should make these birds more sensitive to changes in FP during the test session. In other words, these subjects also should be better able to notice differences in FP from training to test.

If these speculations are correct, then how should Group Mixed react to FP variation in the test? Recall that

this group received training with both short and long FPs. Based on the previous discussion, one would expect Group Mixed to be more alert at the short training FP than at the long training FP. Therefore, the pattern of data we should expect to see in Group Mixed should resemble the pattern of data in Group Short more than the pattern of data displayed by Group Long. The actual data on this point are somewhat ambiguous. Although not statistically significant, there was a tendency for subjects in Group Mixed to decrease their accuracy with increasing FPs. This pattern was also seen in Group Short, although it was a reliable effect in this group. On the other hand, the latency data revealed that Group Mixed did demonstrate a statistically significant increase in RT with the lengthening of FPs in Experiment 2. It is important to note that Group Short also displayed increasing RTs with increasing FPs, but that Group Long displayed decreasing RTs with increasing FPs (see Figure 2-4). This constitutes some evidence favoring the view that subjects in Group Mixed are more alert at the short than long FP.

Another issue related to the timing analysis of alertness concerns the relative degree of alertness between Group Short and Group Mixed at the short FPs. Subjects in Group Short displayed an alertness effect which persisted longer than in the other groups. In Experiment 2 only Group Short significantly increased their RTs as a function of FP

in block two of testing. This supports the idea that Group Short was somewhat more alert than Group Mixed at the short FP. One reason for this fact could point to the presence of long FPs during training in Group Mixed. These long FPs could have induced more uncertainty in timing the FPs in this group. Consequently, this would have decreased the level of alertness in this group.

Throughout this document reference has been made to the concepts of attention and alertness in explaining the effects of FP variation upon choice performance. It is worth mentioning at this point, however, that alternative accounts not using the concepts of attention and alertness are also possible. One such account is based upon the notion of response incompatibility. According to this view once birds in Group Short have exceeded their training FP, they may have performed other behaviors which were incompatible with their capacity to respond quickly and accurately. Since these birds never experienced long FPs during training, they may have withdrawn a considerable distance away from the response keys during the long FPs in the test sessions. This could have impaired their performance during the longer test FP trials. Groups Long and Mixed on the other hand, would be expected to remain close to the response keys throughout the long FPs, because subjects in these groups had experienced reinforcement at long FPs during the training phase. Thus, subjects in Group Short might be expected to perform more

poorly at long FPs than the other groups simply because they were further away from the response keys than subjects in the other groups at the time that the stimulus was presented.

This interpretation was evaluated by examining the responses made by the subjects to any one of the three response keys during the last portion of the FP, but just prior to presentation of the auditory stimulus during a test trial. Responses that occurred prior to the auditory stimulus could have been made to either the warning key or to one of the two choice keys. Pre-stimulus responses to any one of these keys could be taken as a measure of the bird's proximity to the choice keys during the final portion of the FP. If the response incompatibility account is correct, then subjects in Group Short should rapidly decrease their number of pre-stimulus pecks with increasing FP duration because they are presumed to be withdrawing from the key.

Figure 2-7 shows for each group the average percentage of trials in which there occurred a pre-stimulus peck as a function of log FP during the first block of test sessions. A trial was judged to have a pre-stimulus peck if the bird made a key peck response on any one of the keys in the .67s interval just preceding the onset of the auditory discriminative stimulus. The figure depicts a decline in pre-stimulus pecks made for each training group as the FP duration was increased. Group Short appears to show the

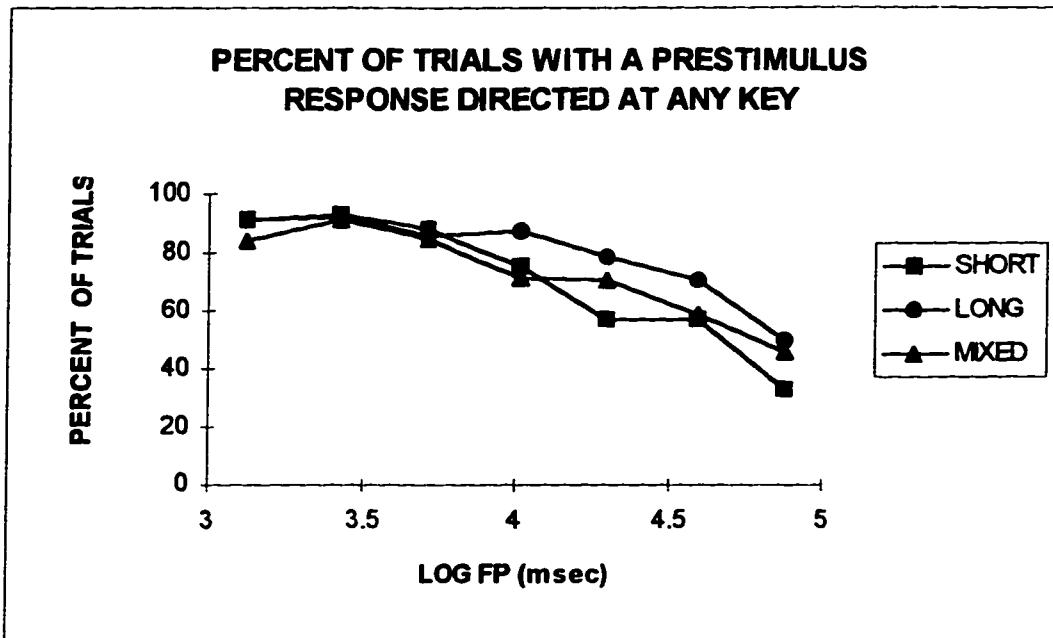


Figure 2 -7 These data were collected during the test phase of Experiment 2. They represent correct responding during the last part of the test FP for the fourth through tenth FP.

fastest decline in pre-stimulus pecks as the FP was increased, and Group Long appears to show the slowest decline. A Groups by Foreperiod ANOVA performed on these data, however, failed to reveal any significant group differences although it did reveal that there was a general decline in pre-stimulus pecks with increasing FP ($F(6,42) = 42.31, p < .0001$). These observations do not allow the response incompatibility explanation to be strongly supported. However, given the supportive trend in the data greater statistical power would be required to more fully evaluate this prediction.

The second alternative account not requiring attention to be mentioned is based on the notion of generalization decrement. Investigators have noted that performance often deteriorates as the stimulus is changed from a training phase to a test phase. For example, if a bird is trained to peck on a red stimulus in order to obtain food but is then tested with an orange stimulus, it will be less likely to respond to the orange stimulus because of generalization decrement. In the current experiments it seems possible that the birds perceived the discriminative stimuli differently in the training and test phases. The effective discriminative stimuli learned during the training phase may have consisted of a configuration of the auditory intensity cues with the temporal cues that accompanied the FP used in training.

This means that during the test phase subjects would react as if they were perceiving a new discriminative stimulus when the auditory stimuli were presented at each new test FP. Hence, due to generalization decrement performance should decline somewhat during the test. Moreover, this account can be used to explain why Group Short was more affected by FP variation than Group Long. Group Short would be expected to suffer greater generalization decrement than Group Long, because of the former group's greater ability to estimate temporal durations. In other words, the configural cues controlling performance in Group Short are more temporally accurate than the configural cues controlling performance in Group Long.

The generalization decrement account cannot be easily dismissed by the current studies. Further experimentation, however, would be required to determine if pigeons are able to configure temporal cues with auditory intensity cues. One possible approach that could easily be adapted to the paradigm developed here was suggested by Garner (1978). Such research would be the first step in validating the existence of configural processes in the discrimination learning procedures investigated here.

Summary

The purpose of the current studies has been to explore the effects of alertness upon discriminative performance

using a choice task with animals. Prior work with human subjects has established that alertness affects performance in at least two ways. First, alertness can increase subject's tendency to respond to all stimuli. This response bias can result in a speed-accuracy tradeoff. Second, alertness has been shown to result in an increased efficiency in responding. Alert subjects have sometimes been shown to improve their speed and accuracy over nonalert subjects. If these alertness effects can similarly be shown with pigeons, then this would begin to point to some possible parallels between pigeons and humans in the processes that mediate alertness.

The results of the current studies support this parallel between pigeons and humans and, more importantly, offers some suggestions for further research. The main result in the current studies was that pigeons were faster and more accurate in choice responding when they were alert than nonalert. However, the current studies used brief auditory intensity stimuli. As noted above, human subjects have shown differences in performance depending upon whether brief or continuous stimuli are used (Klein and Kerr, 1974). The brief presentation of stimuli results in increased speed as well as accuracy in humans, as was observed in the current studies with pigeons. In studies with humans the use of continuous stimuli, on the other hand, has resulted in a speed-accuracy tradeoff. It would be instructive to

determine if this were also true for pigeons. If so, then this additional empirical parallel would strengthen the view that common mechanisms may underlie alertness effects in pigeons and people.

Another place where empirical parallels might be explored between animals and humans is the study of task differences. The current studies used a recognition task to assess the effects of alertness. Studies with humans (Posner, 1978) have used detection tasks to assess the effects of alertness. It is currently unknown whether this variable is important, both in pigeons and human paradigms. The procedures developed here are potentially useful in addressing these issues.

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