TRACE CONDITIONING OF KEY PECKING IN PIGEONS AS A FUNCTION OF THE INTERSTIMULUS INTERVAL

by

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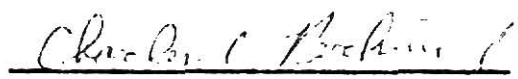

Major Professor

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Acknowledgements

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INTRODUCTION

In a classical conditioning procedure one stimulus such as a bell is followed by a second stimulus (e.g. food) regardless of what the subject does. The first stimulus is called a conditioned stimulus (CS) and the second an unconditioned stimulus (US). When the response to the CS alone changes after pairings of the CS and US, classical conditioning is said to have occurred. For example, in the classic Pavlovian experiment (Pavlov, 1927), sounding the bell resulted in conditioned salivation only after prior presentation of the bell followed by food.

Two studies described by Razran (Popov, 1930 and Ten Cate, 1923 in Razran, 1933) are appropriate for introducing the present classical conditioning research with pigeons. In both studies either noise and/or light (CS) was paired with the presentation of food (US) to pigeons. The CS always preceded the US, and after a number of such pairings the animals in both experiments showed increased activity upon presentation of the CS. In more recent research using a classical conditioning procedure, an 8 sec illumination of a response key (CS) preceded response independent presentation of grain in a standard operant box (Brown and Jenkins, 1968). With this change of apparatus, some of the conditioned behaviors of the pigeon are usually directed at the stimulus key and are recorded as pecks to the key. This procedure, called autoshaping, results in classically conditioned key pecking.

Using a delayed conditioning procedure, Ricci (1973) found that autopecking is maintained with relatively long simple and compound CS's (30 and 120 sec). Delayed conditioning differs from trace conditioning in which an interval (the trace interval) elapses between CS offset and US onset. The present study addresses the question, if a long CS in a delayed procedure results in autopecking, what would happen with a trace procedure?

According to previous classical conditioning research, after extended training the CR characteristically occurs during the trace interval. Pavlov (1927, p. 39) noted that in his dogs conditioned salivation tended to occur near the end of the trace interval just before the US (1 min CS, 1 min trace interval). Similarly, Ost and Lauer (1965) found that the conditioned salivary response occurred in the trace interval just before the US although their time parameters (1 sec CS and 2 to 15 sec between CS onset and US onset) were shorter than Pavlov's. Using an increase in heart rate as the CR and shock as the US with dogs, Church and Black (1958) also found that the CR occurred during the trace interval when the CS was of 2 sec duration and the interstimulus interval (ISI) was either 5 or 20 sec. In this case the latency of the CR was a direct function of ISI duration. For the nictitating membrane and eyelid responses no studies have been reported in which the trace interval is relatively long, but studies with short trace intervals suggest that these responses also tend to occur after CS offset and before US onset. Schneiderman (1966) showed that with a short CS

(0.2 sec tone), CR latency increases with ISI (0.25 to 2.00 sec) for the nictitating membrane response in rabbits. For the eyeblink response, the CR occurs during the trace interval with a 1.5 sec CS and 0.15 or 0.35 sec trace intervals (Hansche and Grant, 1960). In conditioned suppression, Kamin (1965) found that the CR, a decrease in rate of bar pressing, was evenly distributed throughout the CS and trace interval with ISI's on the order of 3 min and shock as the US, but he only exposed his animals to 5-10 days of training. That his results probably would have been different after extended training is indicated by a delayed conditioning study by Hammond and Maser (1970). They employed an ISI of 5 min with CS termination coinciding with US (shock) onset and found after extended training the decrease in the rate of bar pressing was greatest towards the end of the CS. The above examples substantiate the generalization that in trace conditioning the CR tends to occur primarily during the trace interval.

It should be noted how autopecking differs from the conditioned response in the typical classical conditioning experiment. Key pecking has often been classed as an operant response whereas few of the responses in the above examples would be so labelled. Also, in the above examples it is relatively arbitrary what stimulus modality is used for the CS, or as Pavlov stated it, "any agent in nature which acts on any adequate receptor apparatus of an organism can be made into a conditioned stimulus for that organism" (1927, p. 38). In contrast, the light must be localized on the

response key to produce autopecking. Classically conditioned key pecking is not acquired if a nonlocalized light (Wasserman, 1973) or a tone (Schwartz, 1973) serves as the initial CS. Given the importance of the localized CS, it will be interesting to see if the temporal distribution of CS and trace interval responding parallels the previous research with other responses in which the CR usually occurs during the trace interval.

A previous study concerned with response dependent effects (Jenkins, 1970) included a group which was trained with a response independent procedure similar to the one used in the present study. Pigeons were trained with a 3 sec CS (response key illumination) which was followed by response independent food presentation. A trace interval between the CS and food was successively lengthened from 0 to 9 sec in 4 steps. Jenkins only reported key pecking during the CS, and the rate was inversely related to the length of the trace interval.

The present study is the first systematic attempt to determine the relationship between the length of the trace interval and the performance within an autoshaping procedure. The effect of a trace interval is investigated in two groups of birds. It is successively lengthened from 0 to 16 sec in three steps for the 0-16 sec group, and for the 16 sec group the trace interval is 16 sec throughout training. For both experimental groups the CS is a constant 4 sec response key illumination and the US is 4 sec access to grain. The rates of responding during the CS and the trace interval in

the different conditions are obtained throughout.

METHOD

Subjects Sixteen mature White King pigeons obtained from a local supplier were maintained at 75% ad-lib weight by scheduled grain presentations and additional daily feedings in the home cages directly after experimental sessions. The subjects had free access to water in the experimental apparatus and to water and grit in the home cages. Home cages were in a room kept under constant illumination.

Apparatus A 34 X 38 X 32.5 cm (inside dimensions) plywood Skinner box was used. Inside there was a 2.0 cm diameter transparent Gerbrands response key 18.5 cm above the lower part of the opening for the Lehigh Valley grain feeder which was 4.0 cm above the floor of the box. A Grason Stadler stimulus projector was used to present stimuli on the key, and the house light (6 watt) was shielded by white translucent plastic flush with the ceiling of the box. The response key and feeder were mounted on a sheet metal panel forming one end of the chamber and the door containing a small plexiglass window opened from the side. Four identical boxes were programmed by standard electromechanical equipment in an adjoining room, and constant white noise (73-76 dB) in the room with the boxes, in combination with individual ventilation fans, presumably eliminated auditory cues both from the birds in the other boxes and from the programming equipment. Every closure of the response key circuit by the bird required 0.6 - .8 N force

and was accompanied by a click from operation of a feedback relay behind the response panel.

Procedure Each group of 8 birds was run in 2 squads of 4 subjects each. During preliminary feeder training the response key was inoperative and covered with tape. On the first day of feeder training each bird was individually held in front of the raised feeder until it started to eat. Then the experimenter released the bird and closed the door while the bird was eating. By manual operation of the feeder, the bird was exposed to successively shorter feeder presentations and longer intervals between presentations until it ate from the feeder during 4 sec grain presentations spaced at least 15 sec apart. The second day of feeder training consisted of exposing each bird to the schedule of 30 feeder presentations used subsequently but with the response key still covered and inoperative. If a bird failed to eat during the first 5 presentations, the experimenter manually extended the length of the feeder presentation. All birds ate during at least 3 of the last 5 food presentations on the second day of training.

On the next day the autopeck training began. Each trial consisted of a 4 sec key illumination (red) separated from 4 sec access to grain by the trace interval appropriate to the experimental condition. For the 0-16 sec trace group, the trace interval between CS offset and US onset was successively lengthened from 0 to 16 sec as the amount of key pecking stabilized in each trace condition (25 days of the 0 sec and 18 days for each of the 4, 8, and 16 sec conditions). The 16 sec trace group received 24 days of training with the 16 sec trace

condition. Training was continued in each condition until the amount of responding appeared to have stabilized for all birds. During the intertrial interval (ITI) from the offset of grain presentation to the next stimulus, the key was dark, and the period from onset of one grain presentation to the onset of the next was always 4 min. Each daily session of 30 trials lasted 2 hours. The house light was off only during grain presentation.

Trial by trial responding was recorded with Sodeco print out counters, and a separate bank of Sodeco counters served to record responding for an entire session. Responses were separately counted for successive 4 sec intervals from CS onset until US onset except in the 4 and 8 sec trace conditions for which each successive 2 sec interval of the trace was separately tabulated. Intertrial interval responses were also recorded for each trial and for each daily session.

RESULTS

In general, most pecking was confined to the CS with almost none during the trace interval and little during the ITI. The trace interval responding that did occur was confined mostly to the first interval after the CS during which responding was separately recorded. Excluding this first part of the trace interval, one can look at the rest of the interval for an indication of the amount of trace interval responding which does not include post-CS pecks. Accordingly, for the 0-16 sec group the last half of the

4 sec trace interval and the last three fourths of the 8 and 16 sec trace intervals are used as a measure of trace interval responding. This analysis showed there were a total of only 35 responses distributed among 4 of the 8 birds in the last 4 days of each of the three trace conditions. Similarly, in the 16 sec group only two birds were responsible for a total of 8 responses in the last 12 sec of the 16 sec trace interval over the last 6 days of the 16 sec trace condition.

Figure 1 shows the rate of pecking during the CS for each bird in the 0-16 sec trace group with individual sessions on the abscissa and rate (pecks/min) on the ordinate. As is evident from Figure 1, the amount of CS responding was quite variable among the birds although all birds responded some in all trace interval conditions. The rate of CS responding on the last 4 days of each condition was analyzed in a 2 x 4 x 4 (squads x days x treatments) analysis of variance. This showed a main effect of treatments ($F=5.48$; $df=3,18$; $p<.01$) and no main effects or interactions involving the squads or days variables. Scheffé multiple comparisons of the four treatment sums showed more responding in the 0 sec trace condition than in the 4, 8 ($p<.05$), or 16 sec ($p<.01$) conditions. Responding in the latter three conditions did not differ significantly ($p>.05$). Inspection of Figure 1 reveals that not all birds decreased their rate of responding upon transition to the 4 sec trace condition. Whereas this change in trace conditions appeared to strongly effect some birds (P-58, P-701, P-21, P-16), for others there was little systematic change in rate over conditions (P-100, P-33) or the

Figure Caption

Fig. 1. Daily rates of responding during the CS for each bird of the 0-16 sec group.

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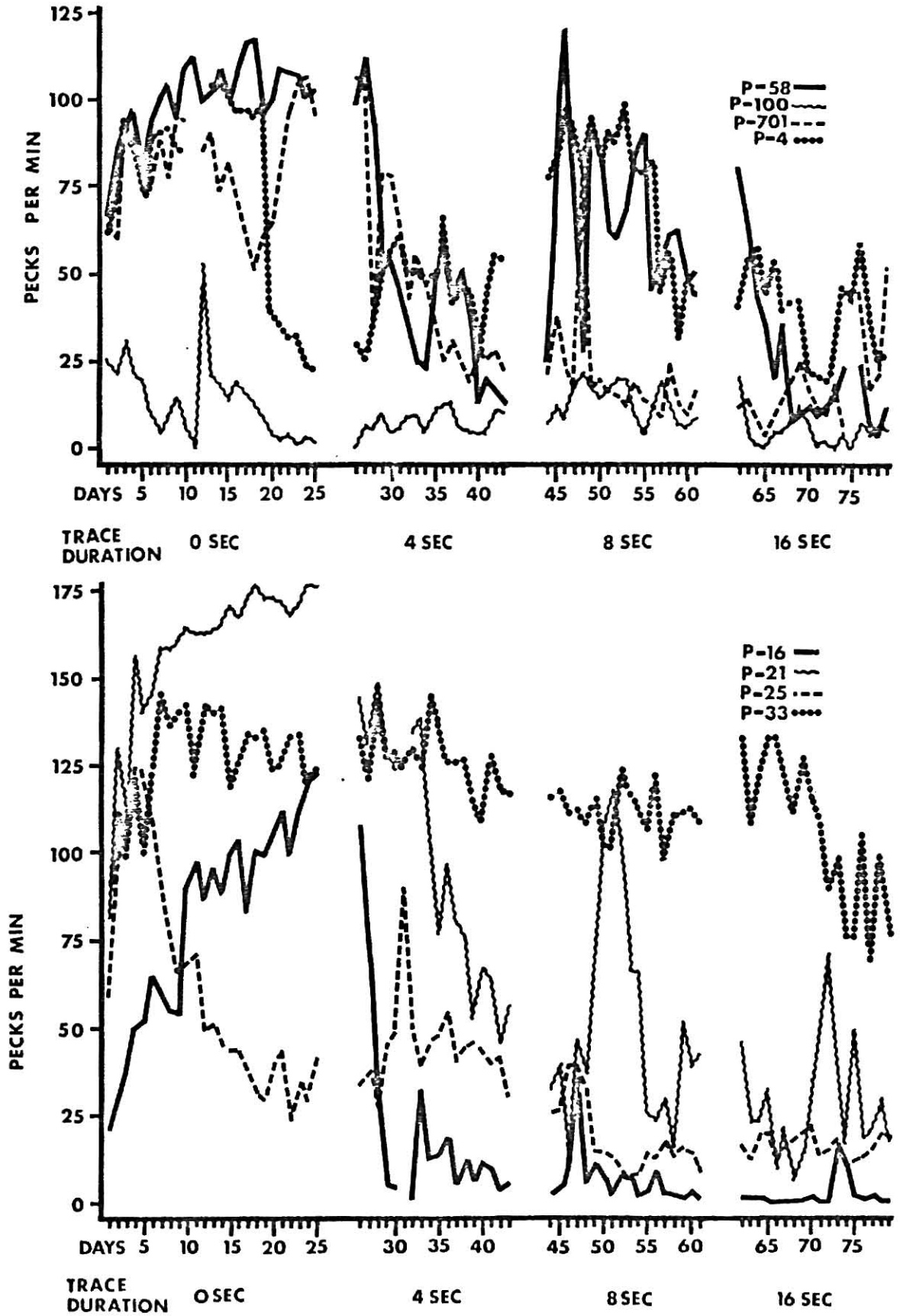
PECKS PER MIN
125
100
75
50
25
0
P-58
P-100
P-701
P-4
DAYS 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
TRACE DURATION 0 SEC 4 SEC 8 SEC 16 SEC
PECKS PER MIN
175
150
125
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75
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25
0
P-16
P-21
P-25
P-33
DAYS 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75
TRACE DURATION 0 SEC 4 SEC 8 SEC 16 SEC

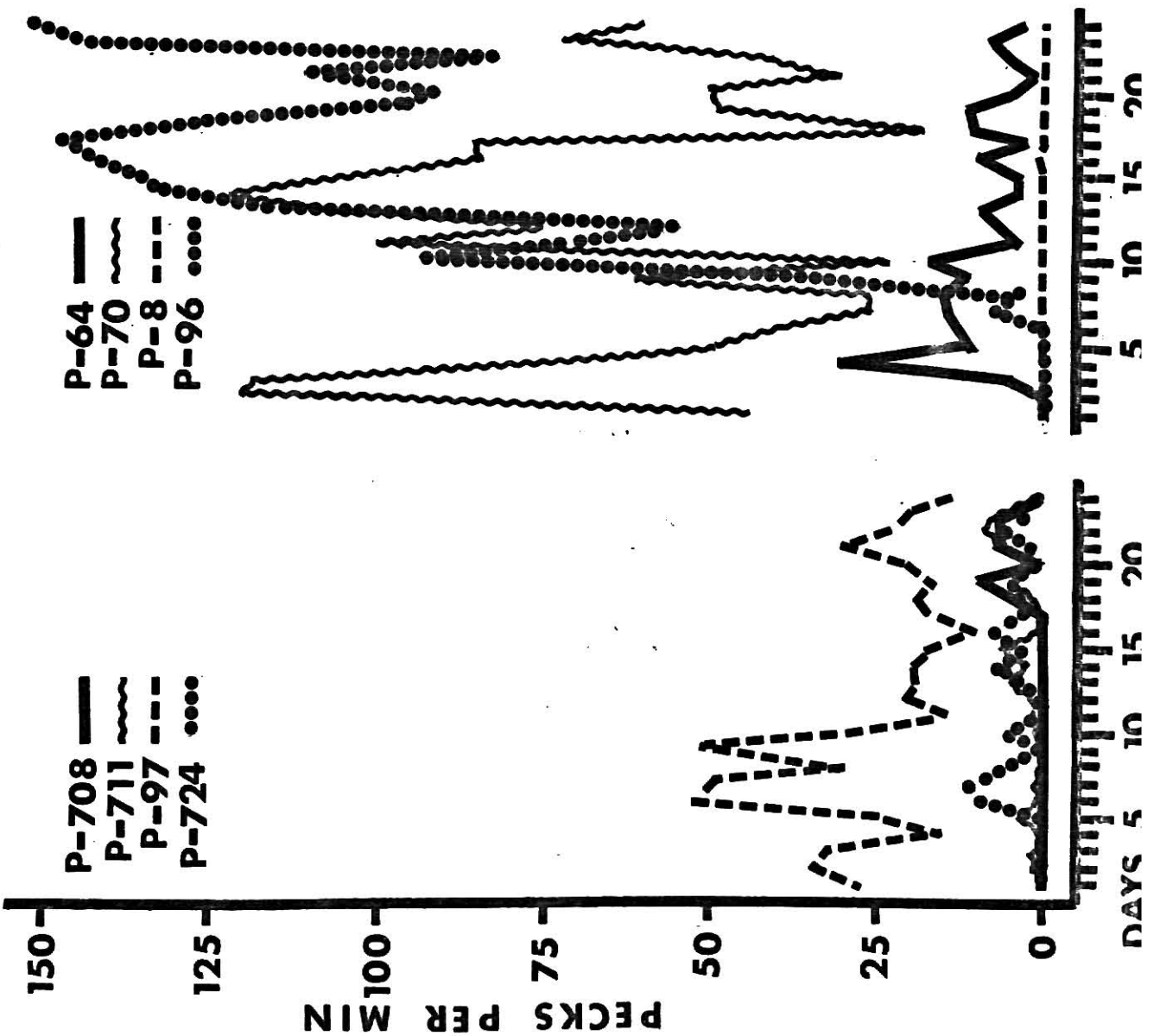
change occurred during different stages of training (P-4, P-25). Another indication that the 0 sec condition resulted in more responding than did the 16 sec condition is found by looking at the between groups comparison and considering the last four days for each group. The rate of pecking for the 0-16 sec trace group in the 0 sec condition was higher than the rate for the 16 sec trace group in the 16 sec condition ($U=15$, $p<.05$). The rate of reaching asymptote was not different for the two groups, but this may have been due to the marked variability in responding.

The daily response rates to the CS for individual birds in the 16 sec trace group are plotted in Figure 2 in a manner analogous to Figure 1. As one might infer from a comparison of Figures 1 and 2, the rate of responding of the two groups on the last four days of the 16 sec trace condition did not differ significantly ($U=24$, $p>.2$). This showed that previous training with shorter trace intervals did not result in enhancement of pecking with the long trace interval. Such an effect might have been expected if the experience with the shorter ISI's aided the pigeon in bridging the interval between CS offset and US onset.

At asymptote nearly all responding was confined to the 4 sec CS and the ITI. For each bird in the 0-16 sec trace group the mean rate of ITI pecking during the last 4 days of each of the four trace conditions was calculated. These rates ranged from 0 (P-16) to 2.40 (P-25) pecks per min. Similarly, in the 16 sec trace group, the rate of ITI responding in the last 6 days ranged from 0 (P-724) to 1.52

Figure Caption

Fig. 2. Daily rates of responding during the CS for each bird of the 16 sec group.


P-64
P-70
P-8
P-96
P-708
P-711
P-97
P-724
PECKS PER MIN
150
125
100
75
50
25
0
5
10
15
20
DAYS

(P-96) pecks per min. There appeared to be no overall systematic relationship between the amount of responding during the CS and the ITI.

The tables in the Appendix contain each bird's daily total number of responses during the CS, successive intervals of the trace interval, and the ITI. Days without entries in both the figures and the appendix indicate that data were not recorded. With one exception the experimental conditions were appropriate when no data were collected. On day 20 there was a feeder malfunction which eliminated some or all of the scheduled food presentations for pigeon 724.

DISCUSSION

Pavlov (1927) noted that for optimal conditioning the "mental trace" of the CS should be as fresh as possible. This observation was supported in the present study. For the 0-16 sec group, the 0 sec condition resulted in more CS pecking than any of the three other conditions, and comparing across groups, the 0 sec condition resulted in the acquisition and maintainance of more pecking than did the 16 sec condition.

A consistent finding in the present study was that nearly all responding occurred during the CS and the ITI preceding the CS, not during the trace interval. This temporal distribution of responding is similar to the results of a previous autopecking study with delayed conditioning (Wasserman, 1973) in which the rate of pecking decreased between CS onset and US onset for two thirds of

the subjects when a 8 sec CS was followed immediately by 4 sec grain access. However, the autopeck response is quite different from the results with other classically conditioned responses (see Introduction) in which the CR occurs in temporal proximity to the US during the trace interval. Wasserman noted that the temporal distribution of autopeck responses does not always show the "inhibition of delay" characteristic of most trace conditioned responses. This may indicate that autopecking does not have a preparatory response function. According to Perkins (1968), all classically conditioned responses serve to prepare the organism for the US in the sense that conditions during the US are more reinforcing if preceded by a CR. For example, the CR of salivation prior to eating may increase the ease with which the dry food is chewed and swallowed and thus increases its primary reinforcing value. In a later discussion Perkins (1971) suggested that some classically conditioned responses such as key pecking are acquired because they enhance the intrinsic reinforcing value of the situation during the CS when the US is anticipated--not necessarily because they prepare the organism for the impending US. It should be noted that a secondary reinforcement process is not involved in this account of classical conditioning--the key peck occurs because of the intrinsic reinforcing value of the response. If key pecking prepares the bird for grain consumption, then it is difficult to explain the temporal location of the response during the CS in a trace conditioning procedure instead of just before the US. With extended training the conditioned response tends

to be strongest just before the US in the case of the conditioning of salivation, eyeblink, nicitating membrane, and suppression of the bar press.

Several variations of the present experiment would help clarify the relationship between the location of the CS and the temporal distribution of responding. It is possible that in the present study the relative saliency of the illuminated response key is primarily responsible for the lack of trace interval responding. Replacing the dark key periods with key illumination of another color or always illuminating the response key with one color except during the CS are two possible ways to investigate the problem. The lack of trace interval pecking cannot be attributed only to the decreased saliency of the darkened response key because some birds pecked the non-illuminated key during the ITI. Also, it would be interesting to see if a very brief CS would maintain CS or trace interval responding in an autopeck trace procedure. If these variations in the procedure still result in little trace interval responding, the argument against a preparatory response explanation of autopecking would be strengthened.

Myers (1958) used a response independent procedure similar to the one in the present experiment, but he implied that the behavior obtained was primarily due to previous response dependent training. It is not clear if the behavior he obtained would have been different if response independent training had been substituted for the response dependent training. The 10 sec CS and trace interval should maintain autopecking, but the relatively short (10 sec) ITI used by Myers would de-

crease the amount of autopecking (Perkins and Ricci, unpublished study). It would be interesting to replicate Myers' study with response independent training to determine if response independent effects could account for his results.

Stimulus contingent and response dependent effects have often been confused. For example, in a symposium paper prepared in 1966, Jenkins (1970) discussed the pigeon's behavior in a situation which one would expect to be conducive to autopecking as due entirely to response dependent, i.e. operant, effects. As was mentioned in the Introduction, Jenkins used a 3 sec CS and successively lengthened the trace interval from 0 to 9 sec with response independent food presentations as the US. As in the present study, there was a decrease in the amount of responding to the CS as the length of the trace interval was increased. Staying within the response dependent framework of the research he was reporting, Jenkins attempted to account for the responding to the CS in terms of the traditional operant processes of conditioned reinforcement, generalization, and delay of reinforcement. Of these "lower-order" conditioning processes, only delayed primary reinforcement could account for the pecking to the CS. In later research, Brown and Jenkins (1968) investigated the effects of response independent pairings of either 3 or 8 sec changes in response key illumination (CS) with food presentation. Responding was established to the CS when it was coterminous with food presentation. In this case it was suggested that at least some of the responding may have been due to "some form of classical conditioning" (p.7). Thus one

can surmise that for Jenkins the unexpected behavior obtained in the earlier study resulted in recognition of the possibility of response independent effects with continued investigation.

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APPENDIX A

Responses per minute for the 0-16 sec group for the CS, successive intervals of the trace interval (2 sec for the 4 and 8 sec conditions and 4 sec for the 16 sec condition), and the ITI. Blank entries indicate data was unavailable.

SQUAD I — 0 sec trace interval

Day		1	2	3	4	5	6	7	8	9	10	11	12	13
P-701	CS	64.5	60.5	92.5	88.0	78.0	74.0	88.0	77.5	95.0	93.5		85.0	89.0
	ITI	25.8	4.7	1.8	2.1	1.3	1.3	1.0	1.8	2.3	0.5		0	0
P-58	CS	67.0	84.5	90.0	96.5	80.5	92.5	99.0	104.0	95.0	108.5	112.0	99.5	101.5
	ITI	54.8	5.4	3.1	4.1	3.9	4.9	34.6	18.6	10.3	7.8	5.7	1.0	6.5
P-4	CS	62.0	72.5	93.5	86.5	71.0	88.0	90.0	91.5	85.5	85.0			104.0
	ITI	18.1	3.9	4.4	4.1	1.3	3.9	5.9	9.0	2.8	5.2			1.3
P-100	CS	24.5	21.5	30.5	21.0	19.0	10.0	4.0	9.5	12.0	6.0	0	52.5	20.5
	ITI	4.9	1.8	1.3	5.7	0.3	0	0	0.3	0.5	0	0	0.3	0

SQUAD I (cont.) **0 sec trace interval**

Day		14	15	16	17	18	19	20	21	22	23	24	25
P-701	CS	73.5	81.5	74.5	60.5	51.0	60.0	64.0	79.0	96.0	104.0	105.5	95.5
	ITI	0	0	0	0	0	0	7.8	0.8	3.6	8.8	20.2	12.9
P-58	CS	107.5	100.0	106.5	115.5	116.5	96.0	99.0	108.0	107.5	107.0	101.0	102.0
	ITI	3.4	3.1	3.4	1.0	3.9	2.6	0.5	0.8	3.4	2.8	4.1	4.7
P-4	CS	104.0	101.5	95.5	96.0	93.5	97.5	40.5	37.0	32.0	32.5	24.0	22.5
	ITI	1.6	3.4	0.5	1.0	0.3	0.3	1.6	0.5	4.4	4.7	3.1	0.5
P-100	CS	17.5	13.0	18.5	15.5	12.5	9.0	4.5	2.5	3.0	2.0	2.5	2.0
	ITI	0	0	0	0	0	0	0	0	0	0	0.5	0.3

SQUAD I (cont.)

4 sec trace interval

Day		26	27	28	29	30	31	32	33	34	35	36	37	38
P-701	CS	106.0	104.0	35.5	78.0	77.5	64.0	42.5	54.5	45.5	37.5	25.5	30.0	24.0
trace		10.0	12.0	0	5.0	5.0	2.0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	3.2	5.6	1.3	3.7	3.2	1.1	0.3	1.8	0.3	0.8	1.6	1.1	0.3
P-58	CS	98.0	111.5	92.5	50.5	53.0	45.5	31.5	24.5	22.5	47.5	56.0	44.0	49.5
trace		21.0	17.0	11.0	8.0	2.0	2.0	0	0	0	0	3.0	2.0	1.0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	7.6	6.8	4.2	8.2	3.4	2.9	6.3	16.6	31.8	17.4	19.5	14.2	15.5
P-4	CS	29.0	25.0	35.5	50.5	57.5	60.5	50.0	50.5	46.5	50.0	65.0	38.5	46.0
trace		0	0	3.0	3.0	4.0	3.0	5.0	4.0	0	2.0	3.0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	1.1	1.8	1.3	1.6	1.3	0.8	4.7	1.6	0.3	0	0.5	0	0
P-100	CS	0	5.5	5.0	9.5	4.0	6.0	8.5	8.5	5.0	10.5	11.5	12.5	5.0
trace		0	0	0	1.0	0	0	1.0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0	0.5	0	0	0	0	0	0	0	0	0	0	0

SQUAD I (cont.)	4 sec trace interval					8 sec trace interval				
Day	39	40	41	42	43	44	45	46	47	48
P-701 CS	19.5	25.5	25.2	27.5	22.0	21.0	37.5	23.5	16.5	78.5
	0	0	0	0	0	0	2.0	0	0	0
trace	0	0	0	0	0	0	0	0	0	0
interval						0	0	0	0	0
						0	0	0	0	0
ITI	0	0.3	0	0	0	0	1.1	0.3	0	3.2
P-58 CS	38.5	13.0	19.5	16.0	12.5	25.0	65.0	118.5	83.5	27.5
	0	0	0	1.0	0	1.0	12.0	24.0	7.0	10.0
trace	0	7.0	0	0	0	0	0	0	0	0
interval						0	13.0	0	0	0
						0	0	0	0	0
ITI	21.3	8.9	11.8	6.3	8.7	7.0	7.2	5.4	3.5	2.1
P-4 CS	45.0	26.5	46.0	54.0	53.5	77.0	83.5	96.5	92.0	78.5
	1.0	2.0	3.0	2.0	6.0	13.0	17.0	10.0	12.0	11.0
trace	0	0	0	0	0	4.0	0	0	0	0
interval						8.0	0	0	0	0
						0	0	0	0	0
ITI	1.8	2.6	0.3	4.7	2.4	1.1	0	3.5	2.9	3.2
P-100 CS	4.0	4.0	5.0	10.5	10.0	7.0	12.0	8.0	16.5	20.5
	0	0	2.0	1.0	2.0	0	0	0	1.0	1.0
trace	0	0	0	1.0	4.0	0	1.0	0	0	0
interval						0	11.0	0	0	0
						1.0	1.0	0	0	0
ITI	0	0	0	0	0	0	0	0	0	0

SQUAD I (cont.)

8 sec trace interval

Day	49	50	51	52	53	54	55	56	57	58	59	60	61
P-701 CS	17.0	20.0	16.0	14.5	12.0	17.5	13.5	12.0	9.0	23.5	12.5	8.5	15.5
	0	0	1.0	0	0	0	0	0	0	0	0	0	0
trace	0	0	0	0	0	0	0	0	0	0	0	0	0
interval	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
ITI	0.3	0	0	0.3	0	0	0	0	0	0.8	0	0	0
P-58 CS	92.5	84.0	62.5	59.5	67.5	82.0	88.0	45.5	53.0	60.5	62.0	47.5	49.5
	7.0	13.0	4.0	6.0	9.0	12.0	10.0	6.0	5.0	4.0	6.0	5.0	3.0
trace	0	0	0	0	0	0	0	0	0	0	0	0	0
interval	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
ITI	14.7	4.3	5.6	7.5	11.5	8.6	12.1	11.3	17.2	2.1	18.0	17.4	9.4
P-4 CS	94.0	81.5	90.5	87.0	97.5	79.0	78.0	56.5	45.0	55.0	31.0	46.0	43.0
	14.0	5.0	10.0	6.0	8.0	3.0	3.0	1.0	1.0	1.0	1.0	4.0	1.0
trace	0	0	0	0	0	0	0	0	0	0	0	0	0
interval	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
ITI	0	0.5	0	0.5	0.3	0	0.3	0	0	1.6	0.3	1.6	0
P-100 CS	17.0	14.0	17.0	20.0	19.0	9.5	4.5	12.0	18.5	12.0	7.0	5.5	8.0
	0	0	0	0	1.0	2.0	0	0	1.0	0	0	0	1.0
trace	1.0	0	0	0	0	0	0	0	0	0	0	0	1.0
interval	0	1.0	0	0	0	0	0	0	0	0	0	0	1.0
	0	0	0	0	0	0	0	0	0	0	2.0	1.0	1.0
ITI	0	0	0	0	0.3	0	0	0	0	0.3	0	0	0

SQUAD I (cont.) **16 sec trace interval**

Day	62	63	64	65	66	67	68	69	70	71	72	73	74
P-701 CS	12.0	13.5	9.0	3.0	9.0	13.5	15.5	24.0	14.0	12.0	9.5	17.5	6.5
	0	0	0	0	0	0	0.5	1.0	0.5	0	0	0	0
trace	0	0	0	0	0	0	0	0	0	0	0	0	0
interval	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
ITI	0	0.3	0.3	0	0.3	1.1	0	0	0.6	0	0.3	0.3	0.6
P-58 CS	79.0	65.0	44.0	35.5	20.0	35.0	7.5	9.5	11.0	9.0	11.5	13.5	23.0
	4.0	5.0	4.0	5.0	1.5	6.0	1.0	0	0.5	1.0	1.5	2.5	0.5
trace	0	0	0	0	0	0	0.5	0	0	0	0.5	0	0.5
interval	0	0	0	0	0.5	1.0	0	0	0	2.0	0	0	0
	0	0	0	0	0	1.0	0	0	0	0	0	0	0
ITI	35.0	17.5	24.7	16.9	27.8	33.3	23.3	10.6	12.8	13.3	9.7	10.3	12.5
P-4 CS	40.0	54.5	57.5	44.0	53.0	39.5	42.0	41.5	23.0	20.5	20.0	31.5	45.5
	0.5	3.0	1.5	1.0	3.0	1.5	1.5	0.5	0	0	0	2.5	0
trace	0	0	0	0	0	0	0	0	0	0	0	0	0
interval	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0.5	0	0	0	0.5	0	0	0	0
ITI	0	0	0.3	0	1.7	0.3	0	0.6	0.6	0.3	2.2	0.3	0.5
P-100 CS	20.0	4.0	0.5	0	3.5	4.0	7.5	12.0	7.5	0.5	1.0	0	3.5
	2.0	0.5	0	0	0	1.0	0	0	0.5	0	0	0	0
trace	0	0	0	0	0	0	0	0	0	0	0	0	0
interval	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
ITI	0	0.3	0	0	0	0	0	0	0	0	0	0.3	0

SQUAD I (cont.) 16 sec trace interval

Day		75	76	77	78	79
P-701	CS		44.5	17.0	20.5	51.0
			1.5	0.5	1.0	2.0
trace			0	0	0	0
interval			0	0	0	0
			0	0	0	0
	ITI		0.3	0	0	0
P-58	CS		23.5	7.5	3.5	10.5
			1.0	0	1.5	1.5
trace			0	0	0	0
interval			0	0.5	0	0
			0	0	0	0
	ITI		13.6	26.9	16.7	27.5
P-4	CS	41.5	58.0	37.5	24.0	26.0
		1.0	0.5	0	0	0
trace		0	0	0	0	0
interval		0	0	0	0	0
		0	0	0	0	0
	ITI	0	0.8	0	0.6	0.3
P-10	CS	0	7.5	3.5	5.5	5.0
		0	0	0.5	0	0
trace		0	0	0	0	0
interval		0	0	0	0	0
		0	0	0	0	0
	ITI	0	0	0	0	0

SQUAD II — 0 sec trace interval

Day		1	2	3	4	5	6	7	8	9	10	11	12	13
P-16	CS	20.5	18.5	37.0	50.5	52.0	64.5	60.0	55.5	53.5	88.5	96.0	86.0	95.0
	ITI	34.4	3.4	2.8	0.8	4.1	3.9	0	1.0	0	0.5	0	0	0
P-21	CS	81.5	129.5	110.5	156.0	141.5	145.5	159.0	158.5	160.5	164.0	163.0	162.5	163.0
	ITI	50.1	2.3	0	4.1	4.7	0.3	4.1	3.4	1.6	0.8	3.6	21.4	73.9
P-25	CS	59.5	96.5	108.5	124.5	123.5	109.5	90.5	79.0	67.0	68.0	70.5	49.5	50.5
	ITI	52.5	26.4	20.4	6.2	5.4	2.1	4.9	1.3	0.8	0.3	0.8	1.3	0.3
P-33	CS	91.0	111.5	99.0	121.5	99.5	124.5	146.0	136.0	140.5	143.0	122.5	144.0	140.0
	ITI	121.2	3.1	0.3	0.3	0	0	0	0	0	2.1	0	0	0

SQUAD II (cont.) 0 sec trace interval

Day		14	15	16	17	18	19	20	21	22	23	24	25
P-16	CS	88.5	99.5	103.5	83.0	100.0	99.5	105.5	112.0	99.5	111.0	120.0	122.5
	ITI	1.0	0	2.6	0	0	0	0	0	0	0	0	0
P-21	CS	164.0	171.0	167.5	173.0	175.5	173.0	173.0	172.0	167.5	171.5	177.0	176.0
	ITI	30.7	19.6	18.1	18.9	8.0	5.9	7.2	17.1	7.5	1.8	15.2	8.8
P-25	CS	46.5	43.5	43.5	39.5	32.0	29.5	40.0	42.5	23.5	34.0	29.5	41.5
	ITI	0.5	1.8	4.9	2.1	0.8	0.8	0.5	1.3	0.3	0.3	0.5	0.5
P-33	CS	142.0	118.0	127.0	134.0	132.5	136.0	123.5	124.5	132.5	134.0	118.5	123.0
	ITI	0	0	0	0	0	0	0	0	0	0	0	0.3

SQUAD II (cont.) 4 sec trace interval

Day		26	27	28	29	30	31	32	33	34	35	36	37	38
P-16	CS	107.5	69.5	31.5	5.0	3.5		0.5	32.5	12.0	13.0	18.0	5.0	11.0
trace		21.0	10.0	4.0	0	0		0	5.0	3.0	1.0	0	0	0
interval		0	0	0	0	0		0	0	0	0	0	0	0
	ITI	0.3	0	0	0	0		0	0	0	0	0	0	0
P-21	CS	144.5	132.0	147.5	130.5	124.5		133.5	138.0	102.0	77.0	97.0	80.5	76.0
trace		12.0	5.0	7.0	11.0	5.0		7.0	8.0	7.0	3.0	7.0	4.0	3.0
interval		0	0	0	0	0		0	0	0	0	0	0	0
	ITI	101.6	3.7	3.2	3.2	6.1		0	1.8	2.6	1.6	1.3	1.6	2.1
P-25	CS	33.5	37.5	28.0	45.0	48.5	90.0	50.0	39.5	45.0	47.5	54.5	40.5	44.0
trace		14.0	10.0	9.0	12.0	11.0	12.0	8.0	5.0	14.0	8.0	16.0	16.0	9.0
interval		7.0	0	1.0	1.0	1.0	0	1.0	0	0	0	0	0	0
	ITI	0.5	0	1.1	0	18.9	23.7	23.2	7.9	12.6	10.8	17.9	28.4	24.2
P-33	CS	133.0	121.5	142.5	127.0	128.5	123.5	130.0	124.5	144.0	137.0	125.5	125.5	126.5
trace		26.0	25.0	22.0	14.0	21.0	16.0	20.0	23.0	23.0	24.0	18.0	25.0	11.0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0	0.3	0	0	0.3	0	0.3	0	0.3	0	0	0	0

SQUAD II (cont.)		4 sec trace interval					8 sec trace interval				
Day		39	40	41	42	43	44	45	46	47	48
P-16	CS	5.5	10.5	8.5	3.5	5.0	2.5	3.5	10.0	36.0	5.0
		0	0	1.0	0	0	0	0	0	4.0	0
trace		0	0	0	0	0	0	0	0	0	0
interval							0	0	0	0	0
							0	0	0	0	0
	ITI	0	0	0	0	0	0	0	0	0	0
P-21	CS	52.5	67.0	64.0	45.5	55.5	32.5	39.5	11.0	46.5	37.0
		0	4.0	7.0	1.0	2.0	2.0	1.0	4.0	3.0	5.0
trace		0	0	0	0	0	0	0	0	0	0
interval							0	0	0	0	0
							0	0	0	0	0
	ITI	0.8	0.5	0.3	0	1.6	0	0.5	0.3	0.3	0
P-25	CS	45.5	44.5	40.0	41.0	30.5	25.5	26.5	39.0	39.5	33.5
		8.0	10.0	4.0	6.0	3.0	10.0	5.0	11.0	6.0	11.0
trace		0	0	0	0	0	0	0	0	0	0
interval							0	0	0	3.0	1.0
							0	0	1.0	0	0
	ITI	18.9	19.2	20.8	5.8	2.1	1.6	2.1	19.0	18.5	10.2
P-33	CS	114.5	108.5	128.5	119.5	117.0	115.5	117.0	111.0	111.5	108.0
		17.0	19.0	20.0	20.0	12.0	13.0	24.0	15.0	21.0	16.0
trace		0	0	0	0	0	0	0	0	0	0
interval							0	0	0	0	0
							0	0	0	0	0
	ITI	0	0	0.5	0	0.3	0	0.3	0.3	0	0

SQUAD II (cont.) **8 sec trace interval**

Day		49	50	51	52	53	54	55	56	57	58	59	60	61
P-16	CS	10.0	7.5	1.5	7.0	6.5	2.0	3.0	6.5	2.5	2.0	1.5	2.5	1.0
		0	0	0	0	0	0	0	0	0	0	0	0	0
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0	0	0	0	0	0	0	0	0	0	0	0	0
P-21	CS	68.0	106.0	117.5	103.0	67.0	66.5	26.5	21.0	29.5	16.0	51.0	40.0	42.5
		9.0	14.0	12.0	5.0	0	1.0	0	0	1.0	0	1.0	1.0	0
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0	0	0	0	0	0	0	1.1	0.5	0.3	3.2	2.4	6.2
P-25	CS	14.5	14.5	13.0	10.0	7.0	8.0	13.5	13.0	17.0	13.0	15.5	14.0	9.0
		3.0	4.0	2.0	1.0	2.0	5.0	4.0	2.0	2.0	1.0	2.0	1.0	1.0
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	4.0	12.9	17.4	19.8	16.9	20.3	9.7	11.3	23.6	33.5	118.0	155.8	95.2
P-33	CS	115.5	102.5	101.5	123.5	116.0	113.0	107.0	122.0	98.5	109.5	110.5	111.5	108.5
		26.0	21.0	22.0	18.0	24.0	13.0	11.0	14.0	8.0	17.0	17.0	21.0	15.0
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0	0	0	0	0	0	0	0	0	0	0	0	0

SQUAD II (cont.) **16 sec trace interval**

Day		62	63	64	65	66	67	68	69	70	71	72	73	74
P-16	CS	0.5	0.5	0	0	0	0	0	0	1.0	0	0	15.0	11.5
		0	0	0	0	0	0	0	0	0	0	0	1.0	0
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0	0	0	0	0	0	0	0	0	0	0	0	0
P-21	CS	45.5	22.5	23.5	32.5	9.0	21.5	5.5	13.0	35.0	48.5	70.0	37.5	17.0
		0	0	2.0	1.0	0	0.5	1.0	0.5	2.0	1.0	5.0	1.5	0
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0.3	6.1	9.4	6.4	2.8	4.2	1.4	3.3	1.4	8.6	5.6	0.8	0
P-25	CS	15.5	12.5	19.0	19.5	13.5	15.5	17.5	19.5	22.0	13.0	15.0	8.0	9.0
		0.5	2.5	2.0	1.5	4.5	1.5	1.5	3.0	0.5	0.5	0	0	0.5
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0.5	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	1.0	0	1.0	0	0	0	0
	ITI	66.4	46.7	135.0	173.1	168.9	84.7	71.7	135.0	138.6	59.2	58.1	113.1	124.2
P-33	CS	132.5	107.0	123.0	132.5	132.5	123.0	111.0	126.5	115.0	107.5	89.0	99.0	75.5
		11.0	10.0	9.0	14.0	10.0	12.0	15.0	10.0	15.5	14.5	14.0	8.0	6.0
trace		0	0	0	0	0	0	0	0	0	0	0	0	0
interval		0	0	0	0	0	0	0	0	0	0	0	0	0
		0	0	0	0	0	0	0	0	0	0	0	0	0
	ITI	0	0	0	0	0	0.3	0	0	0	0	0	0.3	0

SQUAD II (cont.) 16 sec trace interval

Day		75	76	77	78	79
P-16	CS	2.0	0.5	1.0	0	0
		0	0	0	0	0
trace		0	0	0	0	0
interval		0	0	0	0	0
		0	0	0	0	0
	ITI	0	0	0	0	0
P-21	CS	49.0	18.0	20.0	29.0	17.5
		1.5	0	1.5	1.0	0.5
trace		0	0	0	0	0
interval		0	0	0	0	2.0
		0	0	0	0	1.0
	ITI	1.4	3.6	6.9	8.6	0.3
P-25	CS	11.0	12.5	15.0	19.0	18.5
		1.5	0	0	1.5	0.5
trace		2.0	0	0	0	0
interval		1.0	0	0	0	0
		0.5	0	0	0	0
	ITI	207.8	112.8	215.6	172.5	200.3
P-33	CS	75.5	105.0	69.0	99.5	77.0
		9.0	10.5	7.5	14.5	8.5
trace		0	0	0	0	0
interval		0	0	0	0	0
		0	0	0	0	0
	ITI	0.3	0	0	0	0

TRACE CONDITIONING OF KEY PECKING IN PIGEONS AS A FUNCTION OF THE INTERSTIMULUS INTERVAL

by

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Pigeons were given trace conditioning training with an autopeck procedure. For one group of 8 birds the trace interval between the 4 sec CS and 4 sec response independent grain access was 0, 4, 8, and 16 sec in successive stages. Another group of 8 birds received training with the 16 sec trace interval and two subsequent conditions with a compound conditioned stimulus. These conditions were first 4 and 16 sec components and then five 4 sec components.

The shorter trace intervals resulted in more pecking to the CS, and throughout there was almost no pecking to the response key during the trace interval. Only the 5 component compound CS supported key pecking just before the US.

The lack of trace interval responding is contrasted with other classically conditioned responses and is discussed in relation to a preparatory response analysis of classical conditioning.