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# Inter- and intradimensional discrimination and generalization of the pigeon nictitating membrane response.

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INTER- AND INTRADIMENSIONAL DISCRIMINATION AND  
GENERALIZATION OF THE PIGEON NICTITATING MEMBRANE RESPONSE

A Thesis Presented

by

ROBERT WAYNE SCHWARTZ

Submitted to the Graduate School of the  
University of Massachusetts in partial fulfillment  
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MASTER OF SCIENCE

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Department of Psychology

INTER- AND INTRADIMENSIONAL DISCRIMINATION AND  
GENERALIZATION OF THE PIGEON NICTITATING MEMBRANE RESPONSE

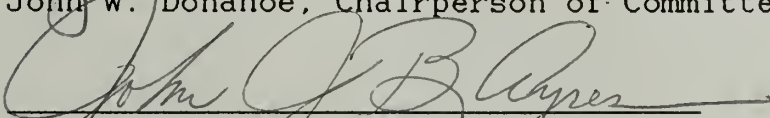
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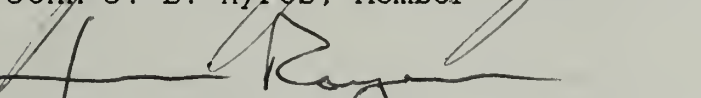
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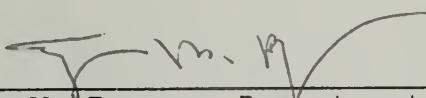
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## ABSTRACT

An attempt was made to show that differences in discrimination and generalization commonly demonstrated by the classical rabbit NMR preparation could be obtained in an NMR preparation using a common operant subject, the pigeon, thereby improving the liaison between operant and classical paradigms. After extensive preliminary studies, a total of 7 Ss were trained using either an intradimensional (ID) procedure with two tones, an interdimensional (BI) procedure with a white-light S-, or a tone control (CON) procedure. Conditioning developed to a high degree, and as expected discrimination was greater in the BI group; however, no discrimination was demonstrated by the ID group despite procedural changes intended to facilitate discrimination formation. Moreover, generalization testing produced little evidence of peaked generalization gradients. Results were attributed to a combination of alpha conditioning and generalization. The study proved valuable, however, by demonstrating the usefulness of CR topography measures for assessing subtle behavioral changes during training and testing.

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## CHAPTER 1

### INTRODUCTION

The White New Zealand rabbit has had a long, productive career in classical conditioning since the development of the rabbit nictitating membrane response (NMR) preparation by Gormezano, Schneiderman, Deaux, and Fuentes (1962) (Gormezano, Kehoe, & Marshall, 1983), but has been relatively unused as a research subject in operant studies (Rubin & Brown, 1969). The opposite holds true for the White Carneaux pigeon (*Columba livia*), which to date has been used in one published NMR conditioning study (Stickney, Donahoe, & Carlson, 1981). Successful NMR preparations have been developed in domestic chicks (Davis & Coates, 1978), lemon sharks (Gruber & Schneiderman, 1962), cats (Patterson, Olah, & Clement, 1977), and toads (Yaremko, Boice, & Thompson, 1969), but as with the pigeon these preparations have not been pursued beyond the establishment of membrane conditioning. The present study further develops the pigeon NMR preparation of Stickney, Donahoe, and Carlson (1981) by investigating the effects of two types of discrimination training procedures on stimulus generalization, and thus continues the process of establishing the preparation as a source of NMR data.

#### Simple Operant Discrimination Procedures

Several types of simple discrimination procedures have been investigated in operant studies, many of which used

pigeons as subjects (e.g., Thomas, Freeman, Svinicki, Burr, & Lyons, 1970). Switalski, Lyons and Thomas (1966) categorized these procedures as intradimensional (ID), interdimensional, or extradimensional. The category of interdimensional procedures was refined by Liu (1968) into within-modality (WI) and between-modality (BI) discriminations. The author suggests that extradimensional procedures also be divided into within- (WE) and between-modality (BE) discriminations.

In ID procedures, the reinforced stimulus (S+) and nonreinforced stimulus (S-) lie along the same dimension within the same sensory modality, and the stimuli used in generalization testing vary along the same dimension used in discrimination training. For example, Hanson (1959) trained pigeons to discriminate between two wavelengths of light, and then tested for generalization along the wavelength dimension. Bloomfield's (1967) discrimination procedure involved two straight lines of different angular orientations, and the generalization test stimuli therefore varied along the dimension of angularity.

As with ID procedures, WI procedures involve discriminations within the same sensory modality, but the S- is orthogonal to the S+ rather than within the same dimension; generalization testing is within the S+ dimension. Switalski, Lyons, and Thomas (1966, group 2) used this procedure in training a discrimination between a 555 nm wavelength light S+ and a white vertical line S-,

and then tested for wavelength generalization. BI procedures are identical to their WI counterparts, except that the S+ and S- involve different sensory modalities; for example, in one of Hoving's (1963, group 3) procedures, tones served as the S+ while a light served as S-, and generalization was tested along tone frequency.

Whereas ID, WI, and BI procedures involve testing for generalization along the S+ dimension, in WE and BE procedures generalization is tested along a stimulus dimension that was present during discrimination training but not used as either the S+ or S-. In WE procedures, this irrelevant dimension is within the same sensory modality as the S+ and S-; in BE procedures, the irrelevant dimension is within a sensory modality different from that used by the S+ or S-. Hoving (1963, groups 1 & 2) used the former procedure in an intensity discrimination between two tones of the same frequency, and then tested for generalization of frequency. Reinhold and Perkins (1955, group D) used the latter procedure in a discrimination between rough and smooth runways leading to goal boxes of the same color, and then tested for generalization of goal box color.

The interest of the present study was in the effects of different types of discrimination training on generalization to stimuli that were actually present during reinforcement in discrimination training; therefore, ID, WI, and BI were the procedures of choice. This study

investigated ID and BI procedures. Some of the expectations for the outcomes of these procedures were based on the results of the aforementioned operant ID and BI procedures.

### Results of Operant ID and BI Procedures

Comparisons of the degree of differentiation between S+ and S- in operant ID and BI procedures are not possible, since data from discrimination training are not reported. Comparisons of generalization data among these operant procedures are not straightforward because control group procedures and subject species vary across studies. Pigeons and presence/absence control groups (VI-1 reinforcement during stimulus-on periods/extinction during stimulus-off periods) were used by both Bloomfield (1967) and Hanson (1959) in their ID procedures. However, Hoving's (1963) BI procedure (group 3) used human subjects and did not use a control group but rather compared the generalization results to those of two WE procedures. Both Hanson (1959) and Bloomfield (1967) found that ID training produced generalization gradients that were much steeper (indicating less generalization among the test stimuli) than those of their control groups, were steeper on the side containing the S-, and were asymmetrical with the peaks of the gradients displaced from the S+ used in training in a direction away from the S- (peak shift). Hoving's (1963) BI procedure led to a relatively flat

generalization gradient compared to his WE groups. Moreover, the gradient was flat compared to gradients from operant control groups used in other studies (e.g., Hanson, 1959). This result is inconsistent with classical conditioning data from a BI procedure, and may be due to the fact that Hoving's procedure was not a straightforward BI discrimination: Generalization of tone frequency was tested after training with an S+ consisting of two tones of the same frequency but of different intensities presented equally often, and an S- consisting of a red light during which responding was reinforced on a DRL schedule.

Given the methodological inconsistencies between these operant studies, it is not possible to develop specific expectations about differences in the effects of ID and BI procedures. General expectations for stimulus generalization within an ID procedure, however, would be for asymmetrical and shifted gradients following ID training. Using operant data from ID and BI procedures in conjunction with classical conditioning data may allow the formation of specific expectations regarding the differences in discrimination and generalization between these procedures.

#### Results of Classical ID and BI Procedures

ID and BI procedures have been investigated using the rabbit NMR classical conditioning preparation. Liu (1968) and Moore (1972) tested for generalization along the tone

frequency dimension after an ID discrimination involving two tones and a BI discrimination involving a tone S+ and a light S-. The S+ for each group, including the presence/absence control group, was a 1200 Hz tone. The S- for the ID group was a 2400 Hz tone.

In contrast to operant results, clear comparisons of the results from these two procedures can be made for the rabbit NMR preparation. Liu (1968) showed that by the end of discrimination training, the degree of differentiation between S+ and S- was significantly greater in the BI group compared to the ID group. Because the level of responding to S+ was essentially the same in the two groups, the difference in discrimination was due to a difference in levels of responding to the S-s. Tone frequency generalization tests yielded statistically identical gradients for the two groups, and both were clearly steeper than the gradient for the control group. All of the gradients, including that of the control group, were slightly steeper on the side of higher tone frequencies. The expected gradient peak shift away from S- did not occur in the ID group. Moore (1972) further investigated peak shift with this preparation and found that if the S- was lower in frequency than the S+, peak shift was likely to occur (7 of 9 rabbits), whereas if the S- was higher in frequency than the S+ (as in Liu's ID group), peak shift was not likely (4 of 21 rabbits). Similarly, Jenkins and Harrison (1962) obtained a peak shift in an operant



paradigm with one of two birds trained with a tone S- of lower frequency than the S+; however, there are no operant data to suggest that peak shifting is unlikely if the S- is of higher frequency than the S+.

The results of the aforementioned operant and classical studies can be combined to yield specific expectations of the effects of ID training for the pigeon NMR preparation. Expectations for the BI procedure should be formed on the basis of the results from only the classical conditioning study (Liu, 1968), given the complications of Hoving's (1963) procedure. In light of the asymmetry found by Moore (1972) in obtaining a reliable peak shift, the ID procedure along the frequency dimension used an S- of lower frequency than the S+. It was expected that for each pigeon this ID procedure would produce a steep, asymmetrical (steeper on S- side) gradient that was shifted away from the S- frequency, as compared to the generalization gradients obtained from control birds. The control birds were given presence/absence discrimination training with the same S+ used with the ID group (as well as with the BI group). Liu's (1968) work yields clear expectations about how well discrimination between S+ and S- should develop in each condition. Her aforementioned findings suggest that responding to S+ should be essentially the same in the two groups, but that responding to S- in the BI group should be at a level markedly below that of the ID group.

These expectations drawn from the conglomeration of operant and classical data are limited by the same difficulties encountered in attempting to glean a clear picture of the operant data. A different species is favored in each paradigm--pigeons have seen much more use in operant than in classical work, and the converse is true for rabbits. Differences in control procedures also complicate comparisons between the paradigms of the effects of the different types of discrimination training. There is a notable exception to this latter incompatibility in the case of ID procedures: Presence/absence control groups were used by Liu (1968) in her classical work as well as by Hanson (1959) and Bloomfield (1967) in their operant studies.

In addition to the patterns of past research data, there are simple theoretical reasons for expecting the aforementioned outcomes of the present study. For example, according to Donahoe and Wessells (1980), almost any ID procedure would be expected to result in generalization gradients steeper on the S- side because

only those stimulus elements that [S+] does not share with either [background stimuli] or [S-] are reliably paired with reinforcement. Thus, stimulus control by [the background stimuli] and by those elements of [S-] which are not shared with [S+] should both be blocked...Since the elements shared by [S+] and [S-] should be found primarily on the side of the gradient nearest [S-], that side of the gradient should be most steepened by differential conditioning. (pp. 191-192)

Peak shift would also be expected after ID discrimination as a result of shared S+ and S- stimulus elements because

the generalization of extinction effects from [S-] might lower responding to [S+], thereby causing a stimulus more remote from [S-] to control a higher frequency of responding (Donahoe & Wessells, p. 193).

During presence/absence control training and BI training, few stimulus elements would be shared in the control group between S+ and the background stimuli, or in the BI group between S+ and the background stimuli or S-; therefore, neither generalization gradient asymmetry nor peak shift would be expected during generalization testing of these two groups. Finally, during training more stimulus control by S- would be expected in the ID group as compared to the BI group as a result of more shared elements between S+ and S- in the ID group; therefore, response frequency to S- should be substantially higher in the ID group than in the BI group.

The purpose of the present study, however, is not to test theoretical explanations of discrimination and generalization, but to improve the compatibility of operant and classical data in the area of discrimination and generalization by studying in a classical preparation (NMR) a species that has been widely used in operant research (pigeon), and by using a control procedure (presence/absence) that was used as a reference point in both classical and operant studies. Taken together, these two aspects of this study should not only broaden the base

of NMR data, but also begin the process of developing a better liaison between operant and classical data.

## CHAPTER 2

### METHOD

#### Subjects

The study started with nine naive White Carneaux pigeons (*Columba livia*), of which five were discontinued at various stages of training. Three of the discontinued pigeons were replaced, resulting in a final total of 7 and a grand total of 12 pigeons used. One of these replacement Ss (36) had had eight sessions of ID training with visual stimuli 5 months prior to the present study. All Ss were maintained at 80% of their ad libitum feeding weights throughout the study.

#### Apparatus

The two experimental chambers were of foam-plywood sandwich construction (walls and doors 4.8 cm thick), with 12.5 cm X 9 cm one-way observation windows in the doors. The gray interiors measured 46.5 cm high X 59.2 cm wide X 61 cm deep, and each was illuminated by a 15-watt A.C. incandescent light. The pigeon faced the observation window and, on each side of the pigeon, a speaker was mounted in the wall of the box. An exhaust fan was mounted on the outside of each chamber on the rear of the right side. For all groups during all sessions, background masking noise consisted of 80 dB white noise presented through the left speaker, and 70 dB noise generated by the exhaust fans. All tones were presented at 86 dB through

the right speaker. The restraint, transducer, and arrangement for presenting visual and airpuff stimuli are shown in Figures 1 and 2 (p. 13). The pigeon's body was restrained by a modified 2-qt. bleach bottle, and its head was secured by three headholders and a beakholder. The counterweighted transducer arm was connected to a suture in the NM by a very thin piece of rigid, wire (see inset of Figure 1). An auto battery supplied 12 V.D.C. to each phototransistive transducer, and the variations in voltage caused by NM movement were read by an analog/digital converter board in a slot of a Leading Edge model D microcomputer located in an adjacent room. The visual display consisted of a 28 V.D.C. IEE cell with a circular display of 1.9 cm (3/4 in.) in diameter, and was used to present a white light of  $200 \text{ cd/m}^2$  brightness filtered to block transmittance of ultraviolet light (Kodak Wratten filter #2E). The air jet, located 5 mm from the posterior area of the cornea, was 8.6 cm (3 3/8 in.) long with a 2.26 mm (.089 in.) diameter hole bored its entire length. Each jet was connected via 6.35 mm (1/4 in.) inside-diameter tubing to a volume-adjust valve, which was in turn connected to the solenoid valve that controlled the duration of each airpuff. On the other side of the solenoid valve was a constant  $5.2 \text{ kg/cm}^2$  (18 lbs./in.<sup>2</sup>) of air pressure supplied by an Ingersoll-Rand 3/4 h.p. storage compressor located in a nonadjacent room.

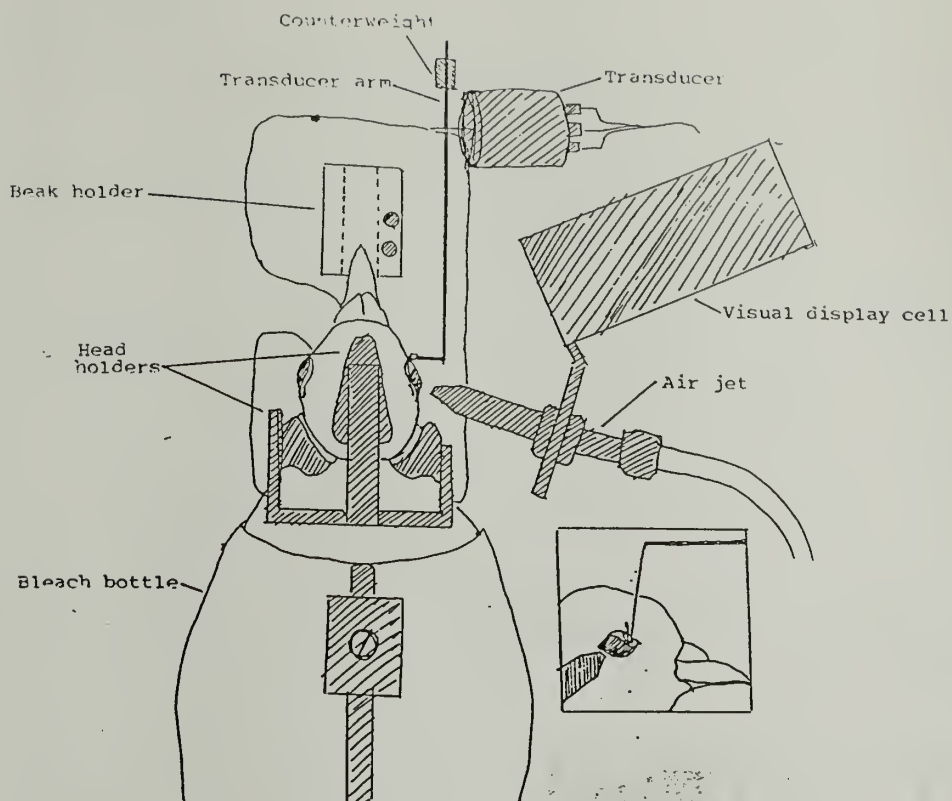


Figure 1. Top view of apparatus.

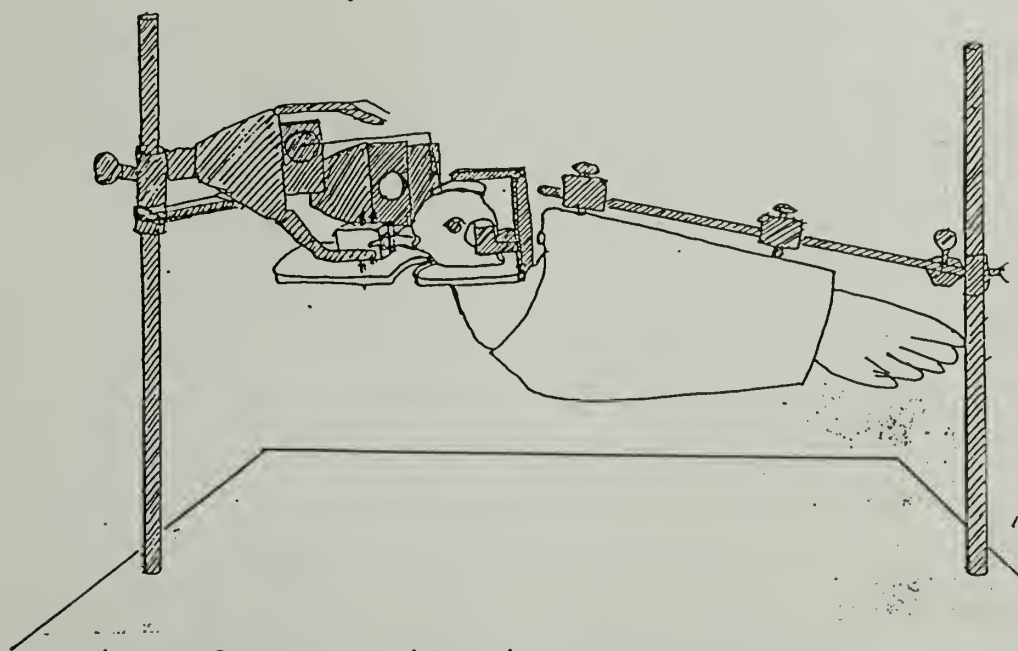


Figure 2. Left side view of apparatus.

The presentation of stimuli during all sessions was controlled by the same computer used for reading the transducer signals.

### Procedure

Each pigeon was randomly assigned to one of the three groups, and fitted with a suture of 6-0 silk surgical thread in the anteroventral area of its right NM. A small loop in this suture allowed the attachment of the transducer. After a day's recovery time, each pigeon was given an adaptation session; this was the same as forthcoming sessions except that no stimuli were presented and the NM was not attached to the transducer. The day following adaptation, each pigeon was given a baseline session during which no stimuli were presented, but NM movement was recorded. For the rest of the study, each session began with a 1-m adaptation period during which the membrane was attached but movement not recorded, and no stimuli except background noise were presented.

### Training

Discrimination training began the following day and consisted of one session every day for each subject. Initially, for all groups--ID, BI, and control (CON)--the S+ consisted of a 350 ms, 1000 Hz tone paired in forward-delay with a 10 cc airpuff unconditioned stimulus (US) of 100 ms duration, resulting in a 250 ms interstimulus interval (ISI). For the ID group, the S- was a 350 ms, 700



Hz tone, and for the BI group, it was a 350 ms presentation of the white light from the display cell. During each session the ID and BI groups were presented with 7 S+ and 7 S- trials randomly ordered and separated by a 2 m intertrial interval (ITI). The CON group received 7 S+ trials separated by the same ITI.

For session 3 the US intensity was increased for all groups to 15 cc, and for session 4 it was increased to 20 cc, where it remained for the rest of training. This change in US intensity was instituted because four Ss (1 ID, 2 BI, and 1 CON) were showing small and/or infrequent unconditioned responses (URs). One of the four Ss (ID) demonstrated no change and was discontinued after session 3, while the URs of the remaining three increased in magnitude and frequency. However, responding in these Ss (and another CON S) also later deteriorated, and they were discontinued (varying from sessions 9 to 17).

The main cause of the infrequent URs in these Ss appeared to be a simple insensitivity to the US. The placement of the suture and of the US were essentially identical for all Ss and sessions. One of the discontinued Ss kept its sutured eye closed continuously, which clearly rendered it insensitive to the US. The eyes of the other discontinued Ss, however, were open whenever monitored by the experimenter during training.

Except for US intensity, no changes were made in the training procedures for the BI and CON groups; however,

several procedural changes were made in the ID group throughout training in attempts to establish a reasonable level of discrimination between the S+ and S- (see Table 1, p. 17). The first change instituted after the increased US intensity was a change in the ratio of S- to S+ trials from 1:1 to 2:1. This was intended to increase exposure to S-, thereby enhancing the opportunity for extinction. Next, to reduce generalization between S+ and S-, the S- tone frequency was decreased from 700 to 300 Hz, resulting in a 400 Hz increase in the S+/S- tone frequency separation. The final procedural change, based on research indicating that ISIs greater than 250 ms produce greater discrimination (Chisholm, Hupka, & Moore, 1969), increased the ISI from 250 ms to 500 ms.

### Testing

Testing of each S in the BI and CON groups began the day following three consecutive training sessions of stable performance. For all groups, each 14-trial test session (one per day) consisted of two presentations of each of the following test stimuli, randomly ordered and separated by a 2 m ITI: 300, 700, 900, 1000, 1100, 1300, and 1700 Hz. Stimulus durations for the BI and CON groups were 350 ms, and 600 ms for ID Ss. For all Ss in the ID group, testing began after the 10th session of the final procedure change for that group. Subjects 116, 114, and 119 (one from each group) were tested until the responding of each extinguished to approximately 15-25% conditioned responses

Table 1

Summary of Training Procedures

Group <sup>c</sup>	Sessions in Each Condition <sup>a</sup>				300Hz S- 250ms ISI <sup>b</sup>	500ms ISI			
	10cc <sup>b</sup>	15cc	20cc	7S+ trs. <sup>b</sup> 7S- trs.			5S+ trs. 10S- trs.	700Hz S- <sup>b</sup>	
ID									
111(29)	1-2(2)	3(1)	4-end(26)	1-9(9)	10-end(20)	1-14(14)	15-end(15)	1-19(19)	20-end(10)
116(29)	1-2(2)	3(1)	4-end(26)	1-9(9)	10-end(20)	1-14(14)	15-end(15)	1-19(19)	20-end(10)
120(22) <sup>d</sup>			1-end(22)	1-2(2)	3-end(20)	1-7(7)	8-end(15)	1-12(12)	13-end(10)
BI									
114(15)	1-2(2)	3(1)	4-end(12)	1-end(15)				1-end(15)	
54(7) <sup>d</sup>			1-end(7)	1-end(7)				1-end(7)	
CON									
119(8)	1-2(2)	3(1)	4-end(5)	1-end(8)				1-end(8)	
36(7) <sup>d</sup>			1-end(7)	1-end(7)				1-end(7)	

<sup>a</sup>Numbers in parentheses indicate total sessions in each condition.

<sup>b</sup>Initial conditions.

<sup>c</sup>Numbers in parentheses indicate total training sessions for each S.

<sup>d</sup>replaced a discontinued S.

(CRs) during a session, requiring 13, 20, and 12 sessions, respectively. The remaining Ss showed little or no indication of extinction, and testing of these Ss was discontinued after each had been tested for at least 28 days.

## CHAPTER 3

### RESULTS AND DISCUSSION

#### Data Analysis

Computer software converted the transducer signals into mm of NM movement; any movement greater than or equal to 2 mm was counted as a response. The printouts produced by this software were examined trial-by-trial by the experimenter to determine the occurrence and characteristics of CRs, including proportion of trials with CRs, peak amplitude, onset latency, duration, area under the response curve, and peak time of the response. The printouts were later examined trial-by-trial a second time by the experimenter. An independent scorer examined 50 trials and the resulting 94% agreement with the experimenter's scoring was considered evidence of scoring reliability.

There was little evidence of alpha responding (responses of less than 75 ms latency). BI S 54 responded twice early in the first training session with latencies less than 75 ms, and in the second training session ID S 111 responded once to S- with short latency. Because of these findings, responses beginning at CS onset were counted as CRs. Pilot work with this preparation suggested a 50 ms minimum UR latency (R. Burns, personal communication, February, 1988); therefore, during training trials in which S+ was paired with the US, responses

starting between CS onset and 50 ms after nominal US onset were considered CRs. During unpaired trials (S- and generalization test trials), responses beginning between CS onset and CS termination were counted as CRs.

### Training

To assess the level of spontaneous responding in this preparation, the baseline session was divided by the computer software into 14 "dummy trials" in which NM movement was recorded, but no stimuli were presented: Seven "S+ trials" and seven "S- trails." This session was scored as a regular training session, using the criteria described above. Three Ss showed responding during the baseline session: ID S 116, BI S 54, and CON S 36, with proportions of CRs of .08, .14, and .31, respectively. Baseline responding and ITI responding were not assessed during training or testing. Because less than half of the Ss showed responding during this session, and two of these three Ss responded only once or twice, spontaneous responding was considered to be low.

To determine if the basic expectations of the training phase had been fulfilled, training data were evaluated first on a general level using proportion CRs. For example, Figure 3 (p. 34) shows that, as expected, conditioning to S+ developed to high levels in all groups by the end of training, as reflected by the high proportions of CRs (.85 to 1.0). It was also expected that

conditioning to S+ would progress at approximately the same rate in all groups, as indicated by similar overall averages of proportions CRs during training. Table 2 (p. 22) shows that responding to S+ in the CON group was lower than in the ID and BI groups, but neither difference was statistically significant. The lower average responding in the CON group was caused by CON S 119 conditioning slower than the other bird. Previous work (Liu, 1968) suggested that responding to S- among BI Ss would be substantially lower than in the ID group. Table 2 shows, however, that there was essentially no discrimination between S+ and S- in the ID group, despite the several procedural changes made during the training of that group. Therefore, a more detailed analysis of the CR data, including CR topography, was undertaken to determine if the procedural changes had any apparent effects, and to determine the probable causes of the high level of S- responding in the ID group.

#### CR Topography Data

Figures 4-10 (pp. 35-41) show that, in general, the proportion of CRs is as informative as the more detailed measures of CR topography for indicating level of conditioning and discrimination. (The figures are organized in the same fashion as Table 2; that is, all training figures for ID Ss are followed by those of BI Ss, which are followed by those of the CON Ss. The same is true for the testing figures, which follow the training figures. Note that some ordinate axis scales for peak

Table 2

Mean Proportion CRs During Training

Group	N	S+		S-	
		<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
ID	3	.80	.27	.80	.30
BI	2	.84	.23	.30	.26
CON	2	.62	.36	---	---

amplitude, duration, and area are different for the same topography measures; one transducer [T6] produced lower voltage changes to NM movement than did the other [T4], and scale changes were made to reduce the effect of this difference. The difference between the transducers had no apparent effect on any of the other measures.) In some cases the measures of peak amplitude, duration, and area seem to indicate a higher level of discrimination than the proportion CRs measure, but this effect must be attributed to the influence of the US during S+ trials. During S+ trials, if a response began before the US onset (plus 50 ms for UR latency) it was counted as a CR, but its overall magnitude was usually increased by the subsequent UR elicited by the US; therefore, on the average the measures of CR peak amplitude, duration, and area were greater during S+ trials.

ID Procedural Changes

Each of the four procedural changes made in the ID group had some apparent effect on conditioning or



discrimination. The first change, increasing the US intensity, apparently caused a permanent increase in proportion CRs of both S+ and S- responding in ID S 111 (see Figure 4, p. 35). However, because this procedural change was instituted early in training, the increase in responding shown by this S may have been due simply to training. The second and third changes (increasing the ratio of S- to S+ trials and increasing the S+/S- tone frequency difference, respectively) had only transient effects on discrimination in ID S 120 (see Figure 6, p. 37, proportion CRs). The final change, doubling the ISI, apparently caused a temporary increase in S+ and S- CR peak times for ID S 111 (see Figure 4, p. 35), along with a temporary increase in S+ CR latencies for ID Ss 116 and 120 (see Figures 5 & 6, pp. 36-37). Increases in S+ CR latencies were also produced by increasing the ISI by Ebel and Prokasy (1963) and by Prokasy and Papsdorf (1965).

#### Accounting for ID Results

Three potential sources for the high level of S- responding in the ID group are pseudoconditioning, alpha conditioning through sensitization (Donahoe & Wessells, 1980, p. 93; Gormezano & Moore, 1969, p. 190), and generalization from S+.

Pseudoconditioning is defined by Marx (1969)

as the strengthening of the relationship between a response and a previously neutral stimulus by means of repeated elicitation of

the response by another stimulus in the absence of pairing of the two stimuli. (p.29)

Since pseudoconditioning should also produce a high frequency of S- responding in the BI group, this explanation can be ruled out by the relatively low frequency of S- responding demonstrated by the BI group.

Alpha conditioning through sensitization is defined as "augmentation of the alpha response [AR] by the UCS" (Gormezano & Moore, 1969, p. 190). Alpha conditioning would produce a relatively high frequency of short-latency alpha responses to both S+ and S- early in training (Grant & Adams, 1944). As training progressed the frequency of these responses would be expected to slightly decrease. This decrease in short-latency responses would be indicated for any particular S by an increase in that S's average response latency over training, assuming that the average is representative of the frequency of short-latency responses.

For each S the average response latency for the first half of training was compared to the average for the second half. Concurrent with this analysis was a comparison of the average proportion CRs between the first half and second half of training, in order to detect any general relationship between degree of conditioning and response latencies. Both of these analyses (response frequency and response latency) were conducted for both S+ and S- (see Table 3, p. 25). These analyses indicated that in general,



for both S+ and S-, as proportion CRs increased, response latencies decreased. Grouping all Ss together, statistical comparisons between the first half and second half of training for S+ showed that the increase in response frequency was significant ( $t[6]=3.56$ ,  $p<.05$ ) and the decrease in response latency was significant ( $t[6]=3.01$ ,  $p<.05$ ). Similar comparisons for S- did not attain statistical significance. Figures 4-10 (pp. 35-41) show that, with the exception of the response latencies of the second half of training for ID S 116, the averages in Table 3 are indicative of general trends and are not artifacts of extremely long or short latencies. These results are the opposite of those predicted by an explanation of alpha conditioning through sensitization, and are in agreement with previous work (Ebel & Prokasy, 1963; Gormezano, Kehoe, & Marshall, 1983, pp. 216-217) finding that "true CR" latencies decrease as conditioning progresses.

Given the lack of evidence for pseudoconditioning and alpha conditioning, generalization from S+ is the most plausible explanation for S- CRs in the ID group, since it accounts for the lack of discrimination in the ID group while allowing for the discrimination in the BI group, where little or no generalization from S+ to S- would be expected.

Training began in the ID group with an S+/S- frequency difference of 300 Hz, only slightly above the 200 Hz difference that failed to produce discrimination in a

rabbit NMR study by Chisholm, Hupka, and Moore (1969). The 300 Hz difference was chosen as ample due to an operant pigeon study which produced high degrees of discrimination with differences as low as 50 Hz (Jenkins & Harrison, 1962), a decision which failed to take into account the much longer stimulus durations (33 s) used in that study. The relatively short stimulus duration and small S+/S- difference used at the outset of ID training made generalization from S+ to S- highly probable.

Finally, it is of peripheral interest to note that for all Ss CR duration and area under the response curve were highly correlated (see Table 4, p. 28; see also Figures 4-10, pp. 35-41). This suggests that throughout training the shape of each CR curve remained essentially the same regardless of the duration, and that the two measures are redundant.

#### Testing

As with the training data, the testing data were first evaluated on a general level using overall group averages of proportion CRs, and then were analyzed in more detail using proportion CRs data from individual Ss and data from the various measures of CR topography.

Analysis of the overall group averages of proportion CRs illustrates that the group gradients fail to even approximate those of past operant (e.g., Hanson, 1959) and classical studies (e.g., Liu, 1968) (see Figure 11, p. 42).

In addition, the only clear differences between the gradients are significantly lower frequencies of responding across all frequencies in the CON group whether compared to the ID group ( $t[3]=6.20$ ,  $p<.01$ ) or BI group ( $t[2]=4.43$ ,  $p<.05$ ).

Table 4

Correlations Between Area and Duration: Training

Group	S+	S-
ID		
111	.81	.98
116	.90	.86
120	.80	.95
BI		
114	.91	.97
54 <sup>a</sup>	.95	---
CON		
119	.98	---
36	.99	---

Note. For all correlations  $p<.001$ .

<sup>a</sup>Only one S- CR.

Examination of the individual gradients (see Figures 12-18, (pp. 43-49) confirms that there was little evidence of peaked generalization gradients developing in any of the Ss (with perhaps the exceptions of CON Ss 119 and 36).

Analyses of proportion CRs from individual Ss showed

that over testing, four Ss demonstrated substantially greater reductions of proportion of CRs than the remaining three. Table 5 (p. 30) shows that when the average proportion CRs over all frequencies for the first five testing sessions is compared with that of the last five sessions, ID S 116, BI S 114, and CON Ss 119 and 36 demonstrated substantially greater extinction than ID Ss 111 and 120, and BI S 54. In addition, those Ss clearly more resistant to extinction also demonstrated significantly shorter CR latencies overall testing sessions as a group than the group that extinguished ( $t[5]=11.19$ ,  $p<.001$ ), and these latencies were approximately within the 50-100 ms range generally considered to be ARs (Grant & Adams, 1944). Taken together, these three findings (resistance to extinction, shorter latencies, and latencies within AR range) suggest that, despite evidence from training to the contrary, alpha conditioning to S+ may have developed to an extent in Ss 111, 120, and 54.

A more subtle pattern that developed in the individual gradients for proportion CRs was a tendency for tones lower in frequency than S+ to elicit more CRs than those whose frequency was higher than S+ (see Table 6, p. 31). Although the difference was small, it was sufficiently consistent between Ss so that the average proportion CRs of all Ss to frequencies below S+ was significantly higher than to frequencies above S+ ( $t[6]=3.24$ ,  $p<.05$ ). Since all test frequencies were the same intensity, this suggests

that the lower frequencies were somewhat more salient than the higher frequencies. This is supported by the fact that, in their pigeon operant studies, Jenkins and Harrison (1960; 1962) varied the amplification of different tones (in which direction is not clear) to maintain constant tone salience across frequencies. The apparent greater salience of lower frequencies in the present study may have had a small influence on the frequency of S- CRs during training of the ID group.

Table 5

Mean Proportion CRs for First Five (F) and Last Five (L) Sessions of Testing

Group	F		L	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
ID				
111	.94	.05	.87	.14
116	.98	.04	.52	.11
120	.96	.06	.88	.07
BI				
114	.85	.11	.45	.22
54	.92	.10	.98	.04
CON				
119	.71	.18	.42	.15
36	.90	.08	.44	.24



For training data, the more detailed CR topography measures were not any more informative about the level of discrimination than was the measure of proportion CRs, but these measures were useful for other purposes. The same is

Table 6

Mean Proportion CRs for Frequencies Below (B) and Above (A) S+ During Testing

Group	B		A	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
ID				
111	.93	.07	.87	.13
116 <sup>a</sup>	.78	.26	.73	.29
120	.97	.05	.91	.08
BI				
114 <sup>a</sup>	.78	.18	.65	.28
54	.98	.07	.96	.08
CON				
119 <sup>a</sup>	.66	.26	.50	.19
36 <sup>a</sup>	.76	.18	.48	.33

<sup>a</sup>These birds showed extinction as measured by the proportion of CRs.

true for the test results: Figures 12-18 (pp. 43-49) show that the measure of proportion CRs is as informative as the topography measures about discrimination between the test tones. However, the topography measures reveal that for

two of the three Ss showing resistance to extinction (ID S 111 & BI S 54), response magnitude decreased substantially during testing (see Table 7). Similar decreases in CR magnitude occurred in three of the four Ss that extinguished as measured by the proportion of CRs. In addition, one S whose responding extinguished substantially in terms of CR frequency (BI S 114) showed changes in CR topography preceding those of CR frequency. Figure 15 (p. 46) shows that, for this S, while the proportion of CRs remained high in sessions 8 through 12, CR duration and

Table 7

General Trends of CR Topography Measures During Testing

Group	Pk Ampl	R Lat	Area	Dur	Pk Time
ID					
111	↓	---	↓	↓	↑
116 <sup>a</sup>	---	---	---	---	---
120	---	---	---	---	---
BI					
114 <sup>a</sup>	---	---	↓	↓	↓
54	↓	---	---	---	---
CON					
119 <sup>a</sup>	↓	---	↓	↓	↓
36 <sup>a</sup>	↓	---	---	---	---

<sup>a</sup>These birds showed extinction as measured by the proportion of CRs.

area decreased substantially. These findings indicate that the extinction process begins with a decrease in response magnitude, and suggests that those Ss showing decreases in CR magnitude would have eventually extinguished in terms of CR frequency. Thus, CR frequency is an insensitive measure of extinction.

As in training, correlations between CR area and duration were highly significant, although somewhat lower than in training (see Table 8).

Table 8

Correlations Between Area and Duration: Testing

Group

---

ID

111 .87\*\*

116<sup>a</sup> .78\*\*

120 .80\*\*

BI

114<sup>a</sup> .93\*\*

54 .48\*

CON

119<sup>a</sup> .96\*\*

36<sup>a</sup> .66\*\*

---

<sup>a</sup>These birds showed extinction as measured by the proportion of CRs.

\*  $p < .01$ .

\*\*  $p < .001$ .

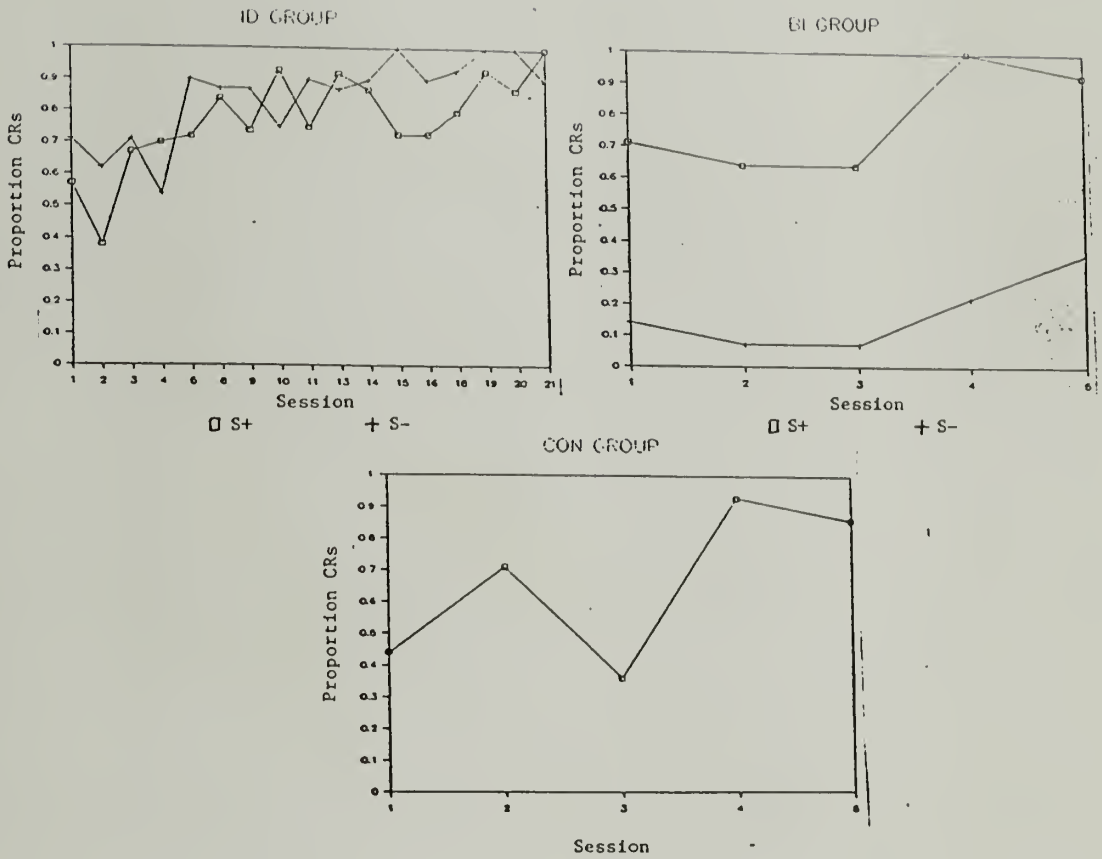


Figure 3. Mean proportion CRs of intradimensional (ID), interdimensional (BI), and control (CON) groups during training.

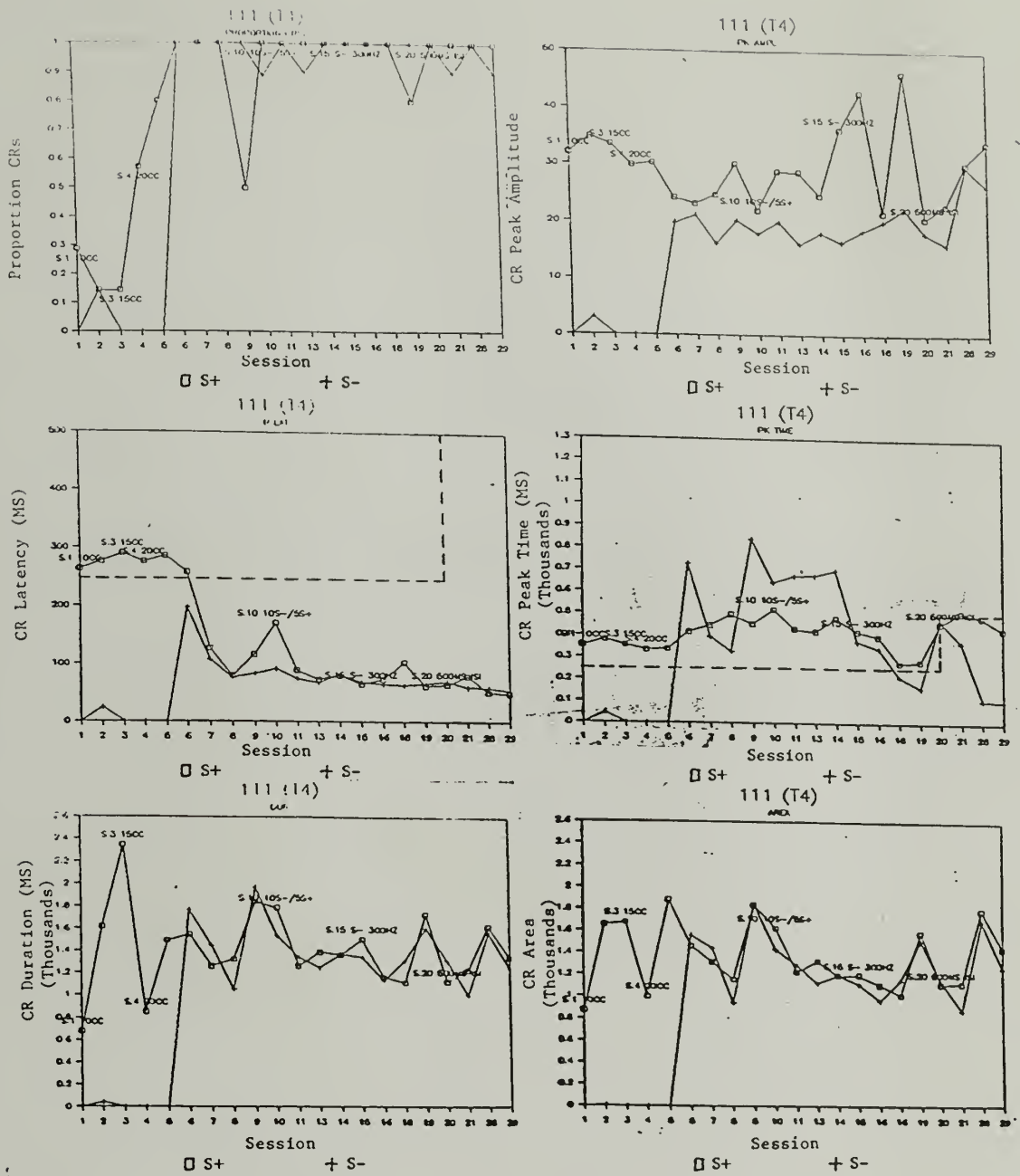


Figure 4. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency during training of ID S 111. Dashed lines indicate ISI shifts from 250 ms to 500 ms. Number in parentheses following subject number indicates transducer used.

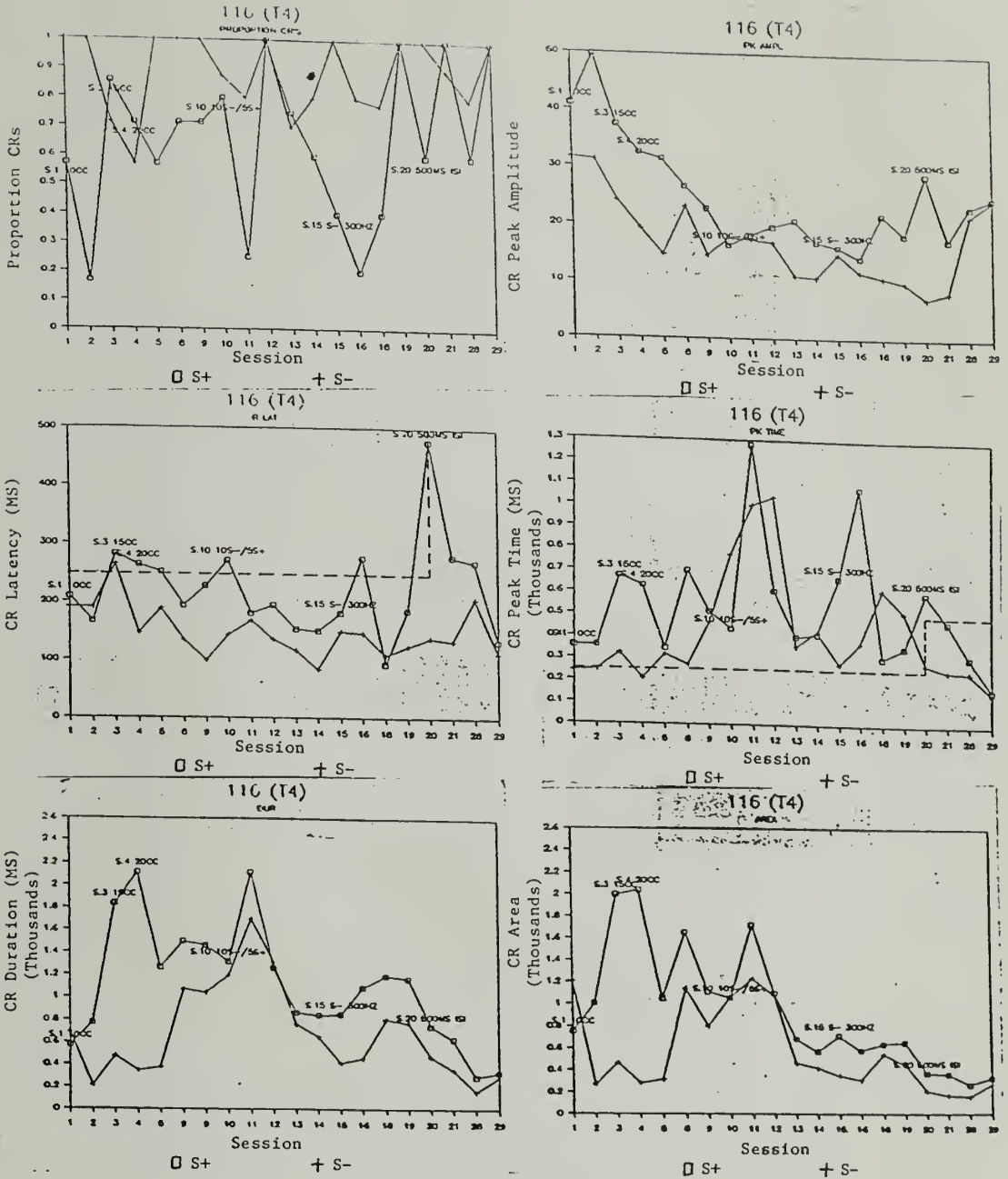


Figure 5. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency during training of ID S 116. Dashed lines indicate ISI shifts from 250 ms to 500 ms. Number in parentheses following subject number indicates transducer used.

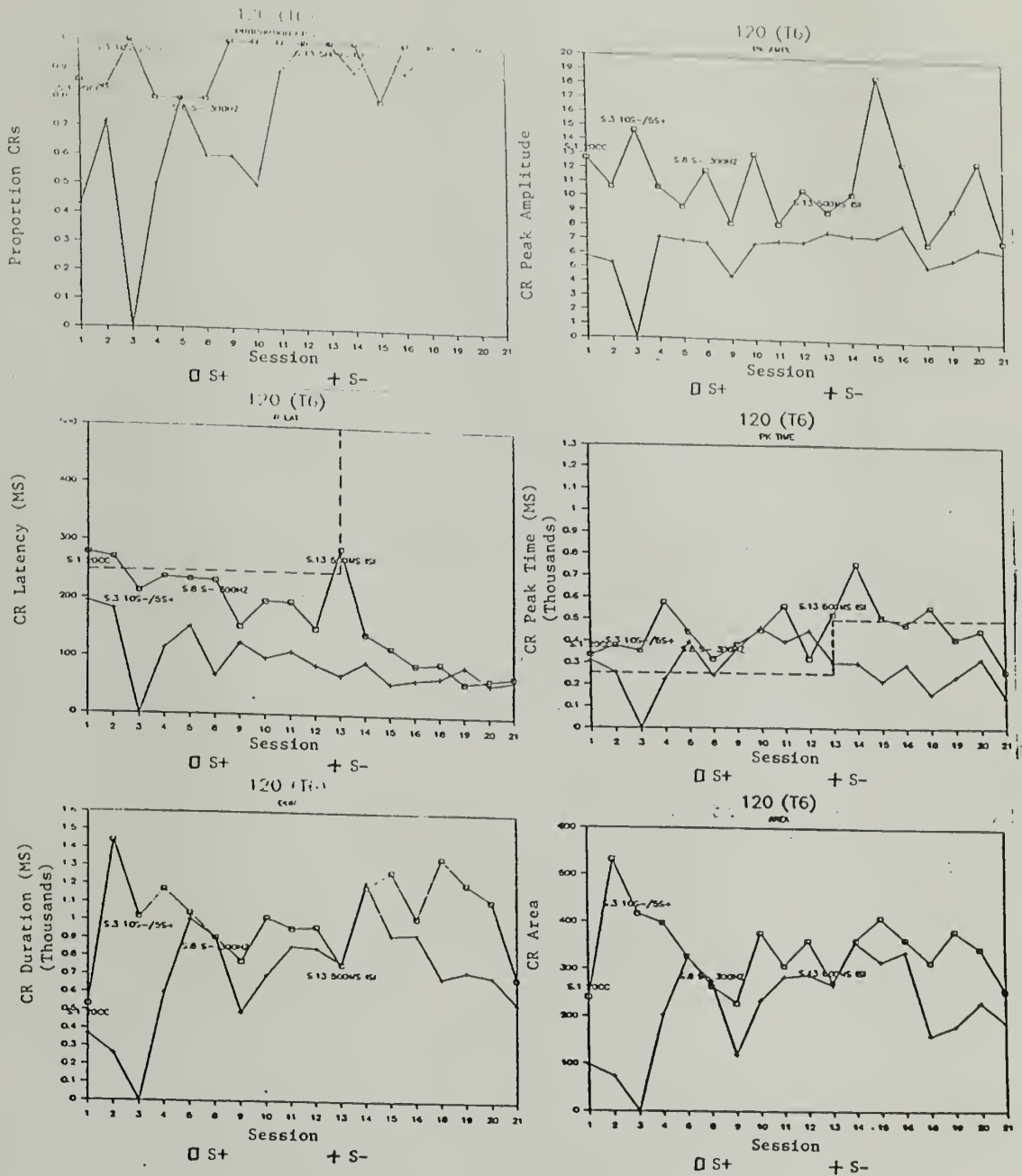


Figure 6. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency during training of ID S 120. Dashed lines indicate ISI shifts from 250 ms to 500 ms. Number in parentheses following subject number indicates transducer used.

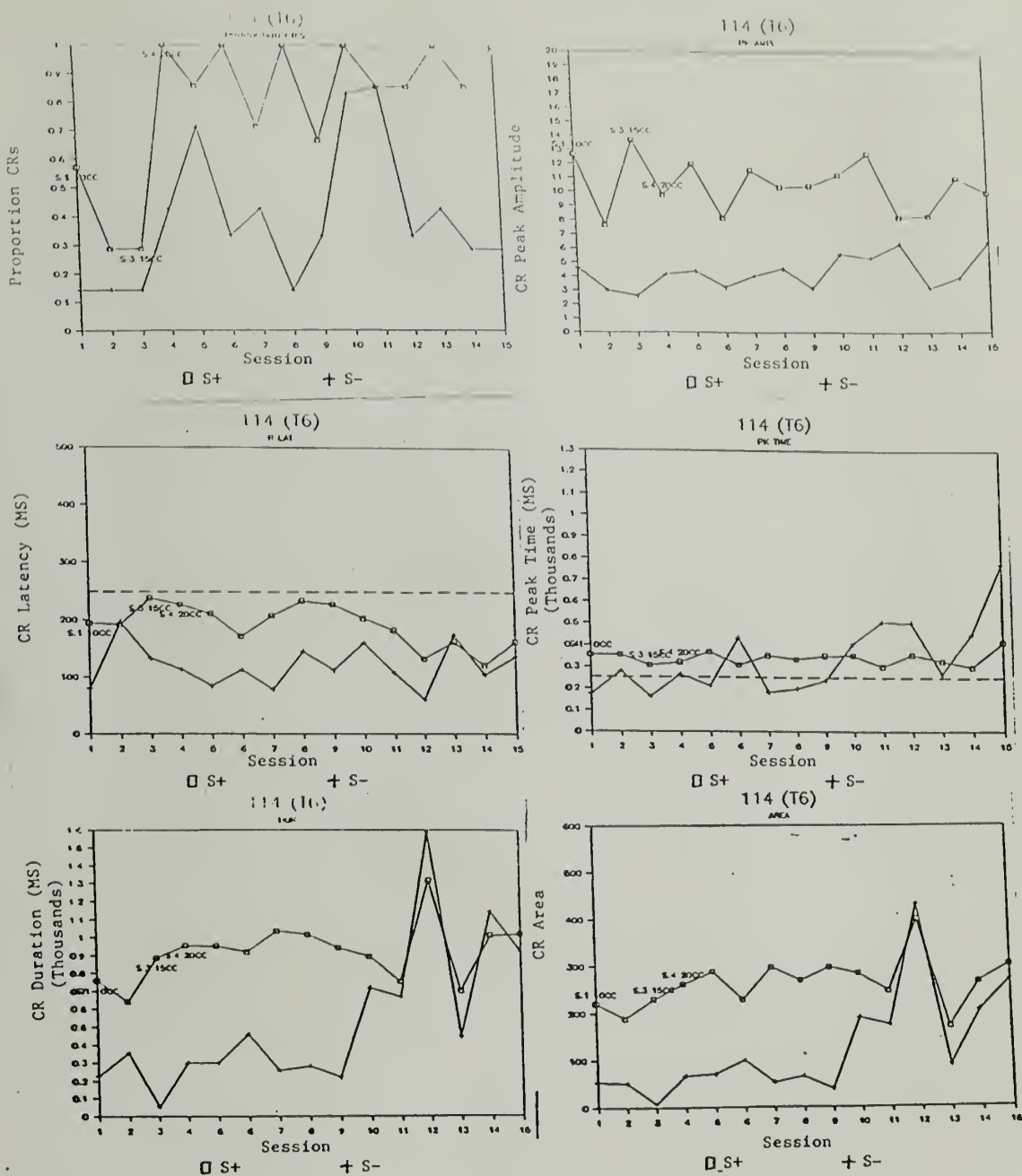


Figure 7. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency during training of BI S 114. Dashed lines indicate US onset time. Number in parentheses following subject number indicates transducer used.



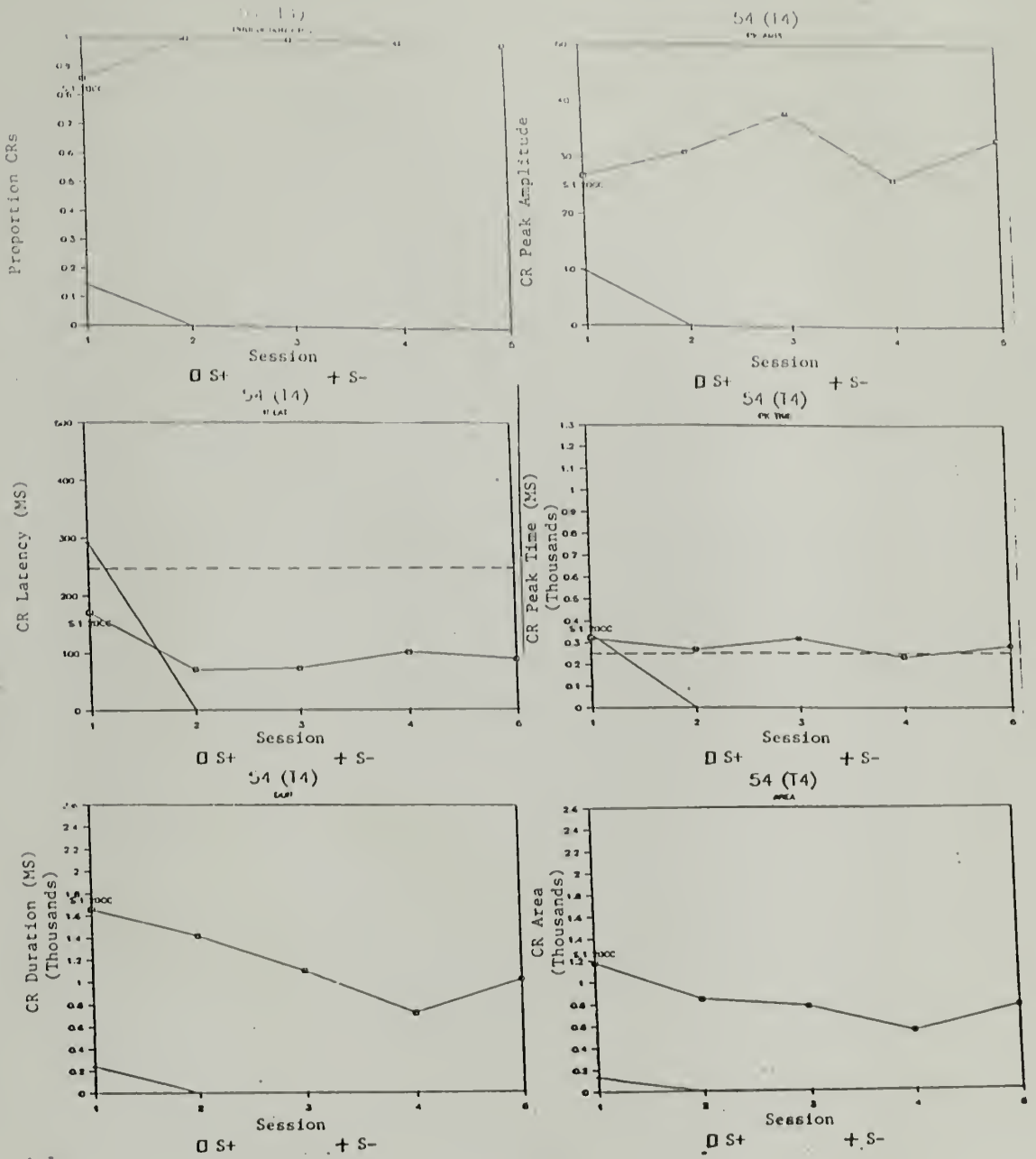


Figure 8. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency during training of BI S 54. Dashed lines indicate US onset time. Number in parentheses following subject number indicates transducer used.

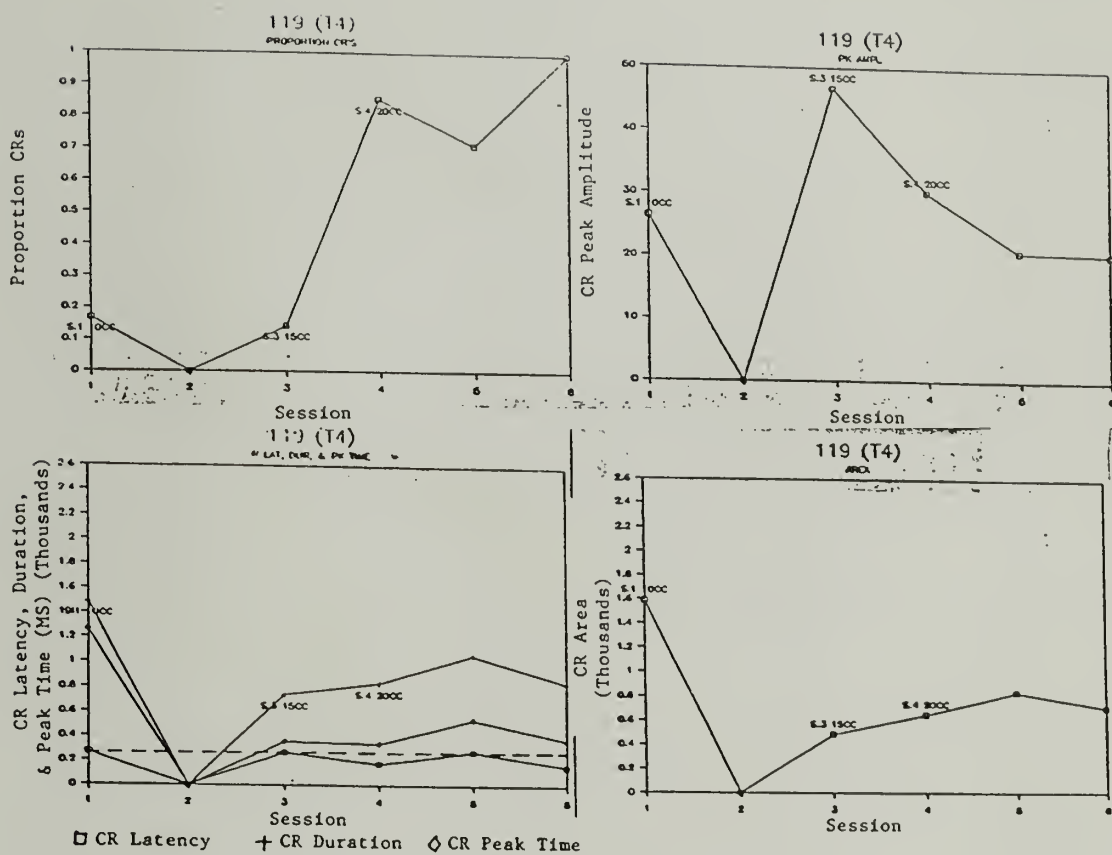


Figure 9. Mean proportion CRs, CR peak amplitude, area under the CR curve, CR latency, duration, and peak time during training of CON S 119. Dashed line indicates US onset time. Number in parentheses following subject number indicates transducer used.

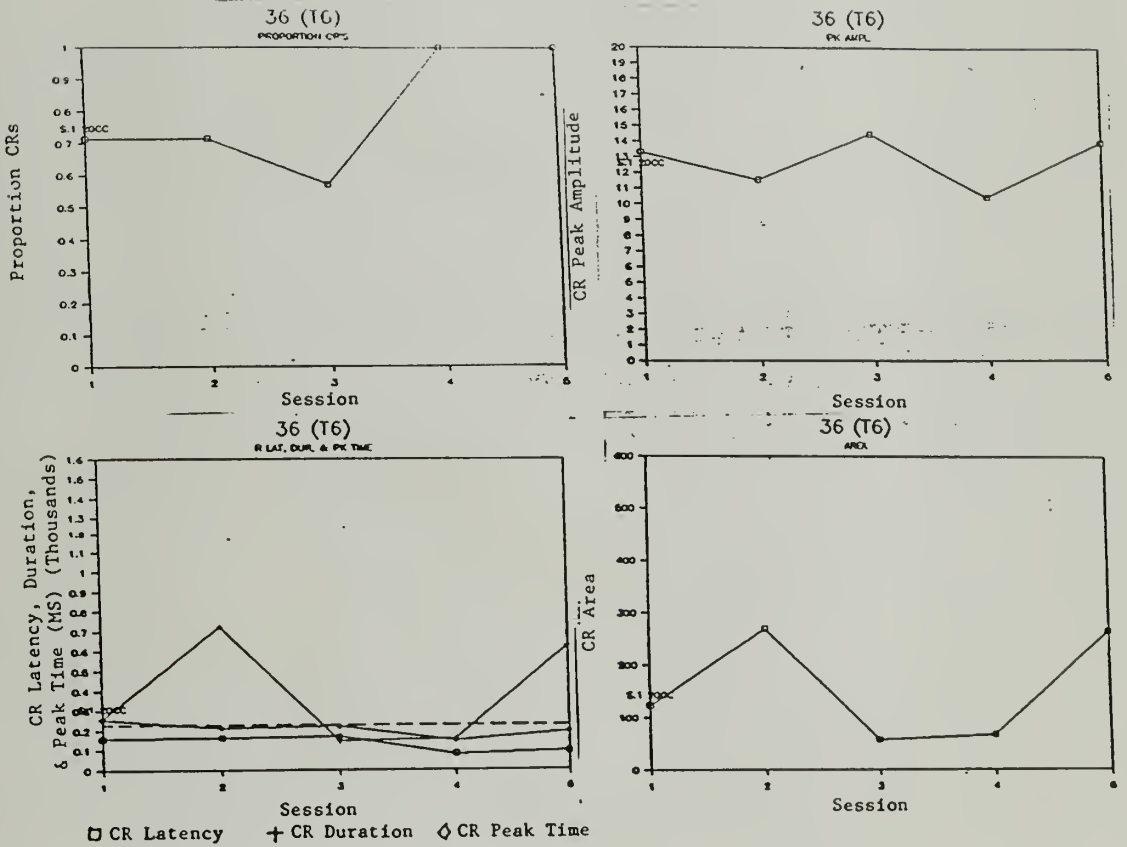


Figure 10. Mean proportion CRs, CR peak amplitude, area under the CR curve, CR latency, duration, and peak time during training of CON S 36. Dashed line indicates US onset time. Number in parentheses following subject number indicates transducer used.

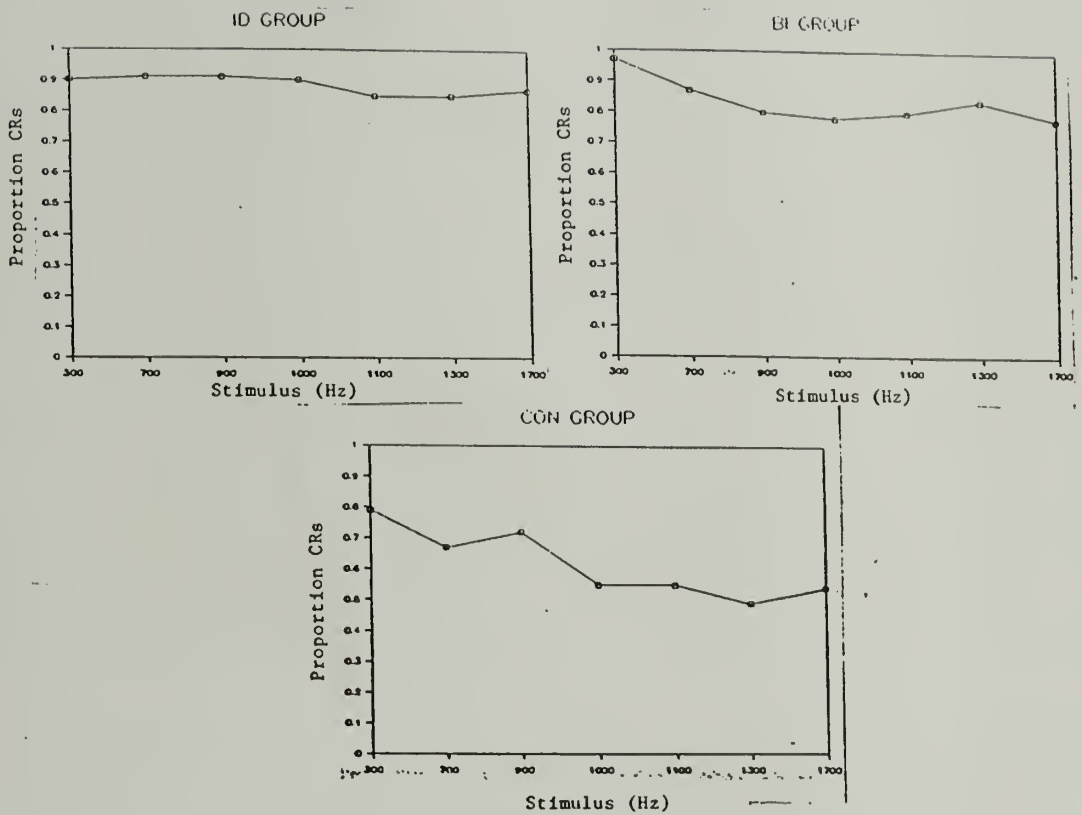


Figure 11. Mean proportion CRs of intradimensional (ID), interdimensional (BI), and control (CON) groups at each auditory frequency used during testing.

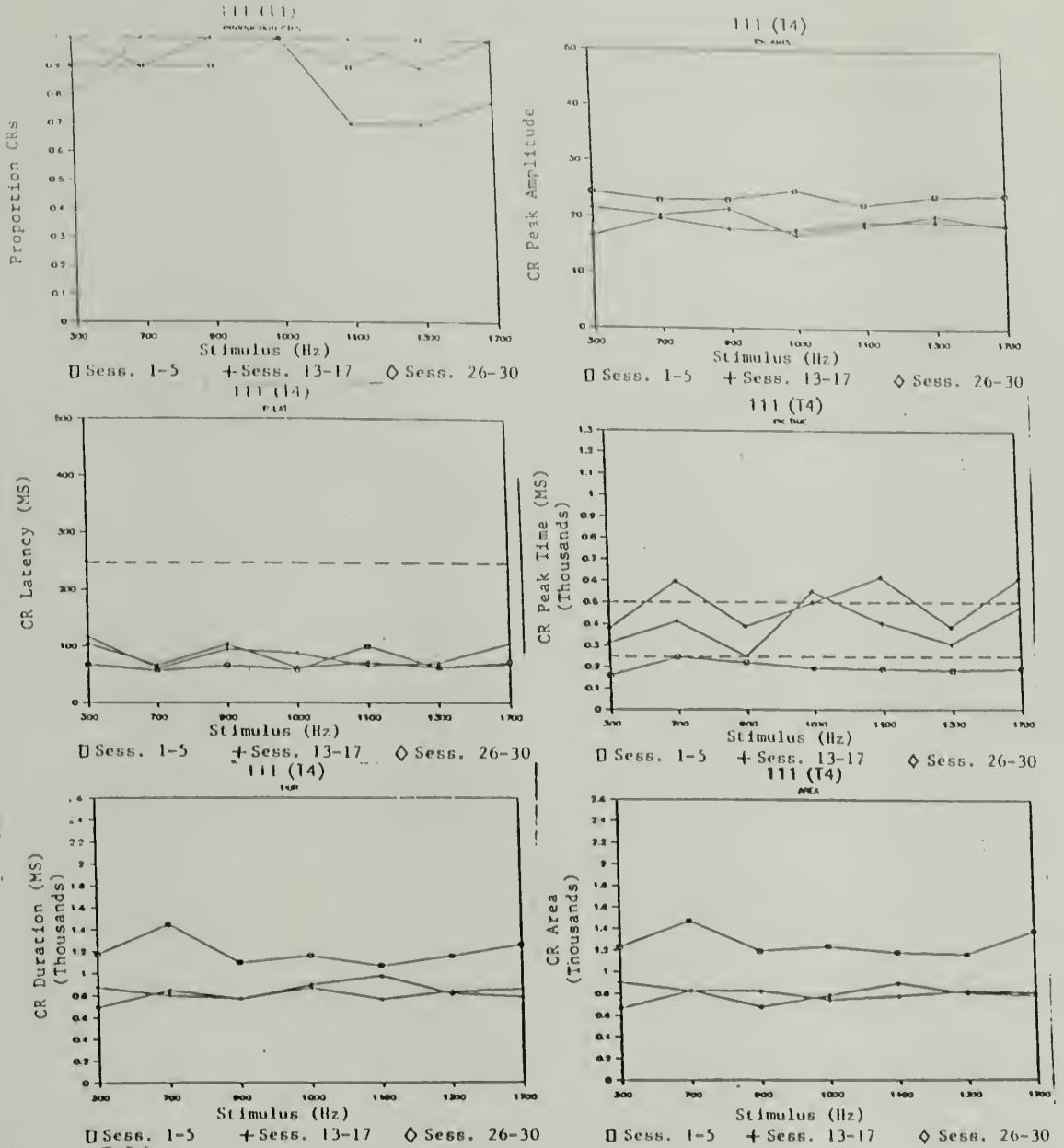


Figure 12. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency at each auditory frequency used during testing of ID S 111. Dashed lines indicate US onset times during training. Number in parentheses following subject number indicates transducer used.

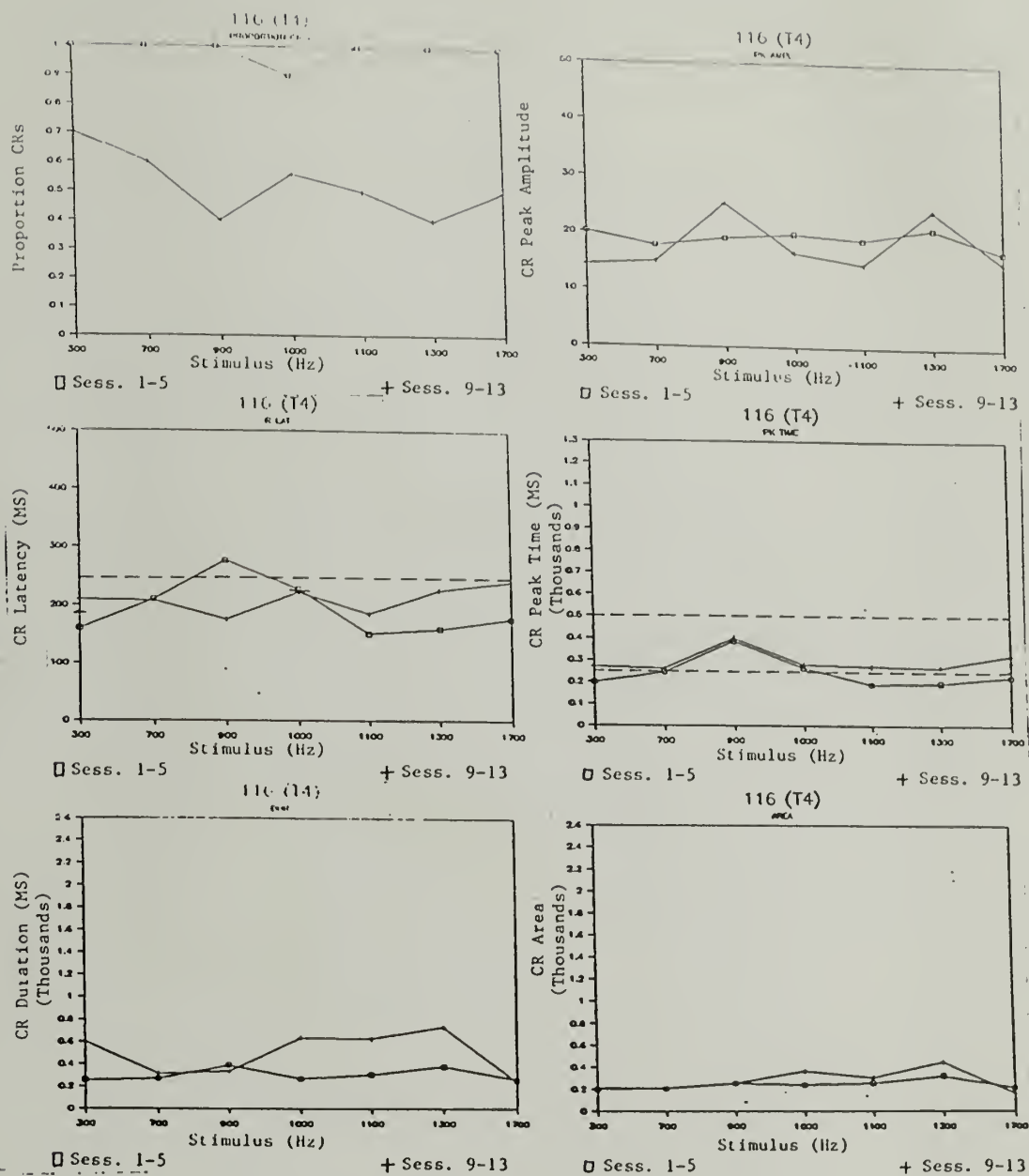


Figure 13. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency at each auditory frequency used during testing of ID S 116. Dashed lines indicate US onset times during training. Number in parentheses following subject number indicates transducer used.

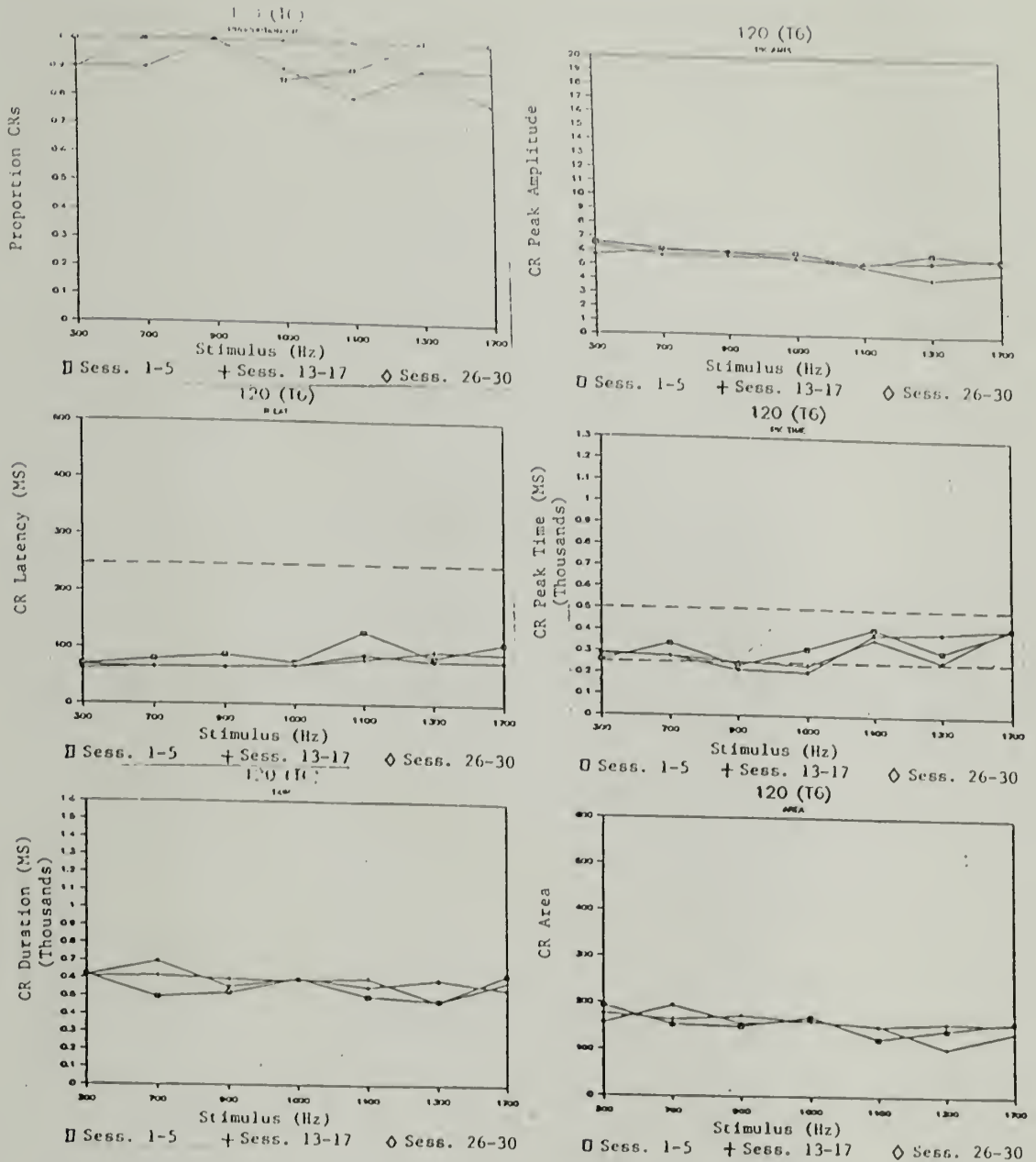


Figure 14. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency at each auditory frequency used during testing of ID S 120. Dashed lines indicate US onset times during training. Number in parentheses following subject number indicates transducer used.

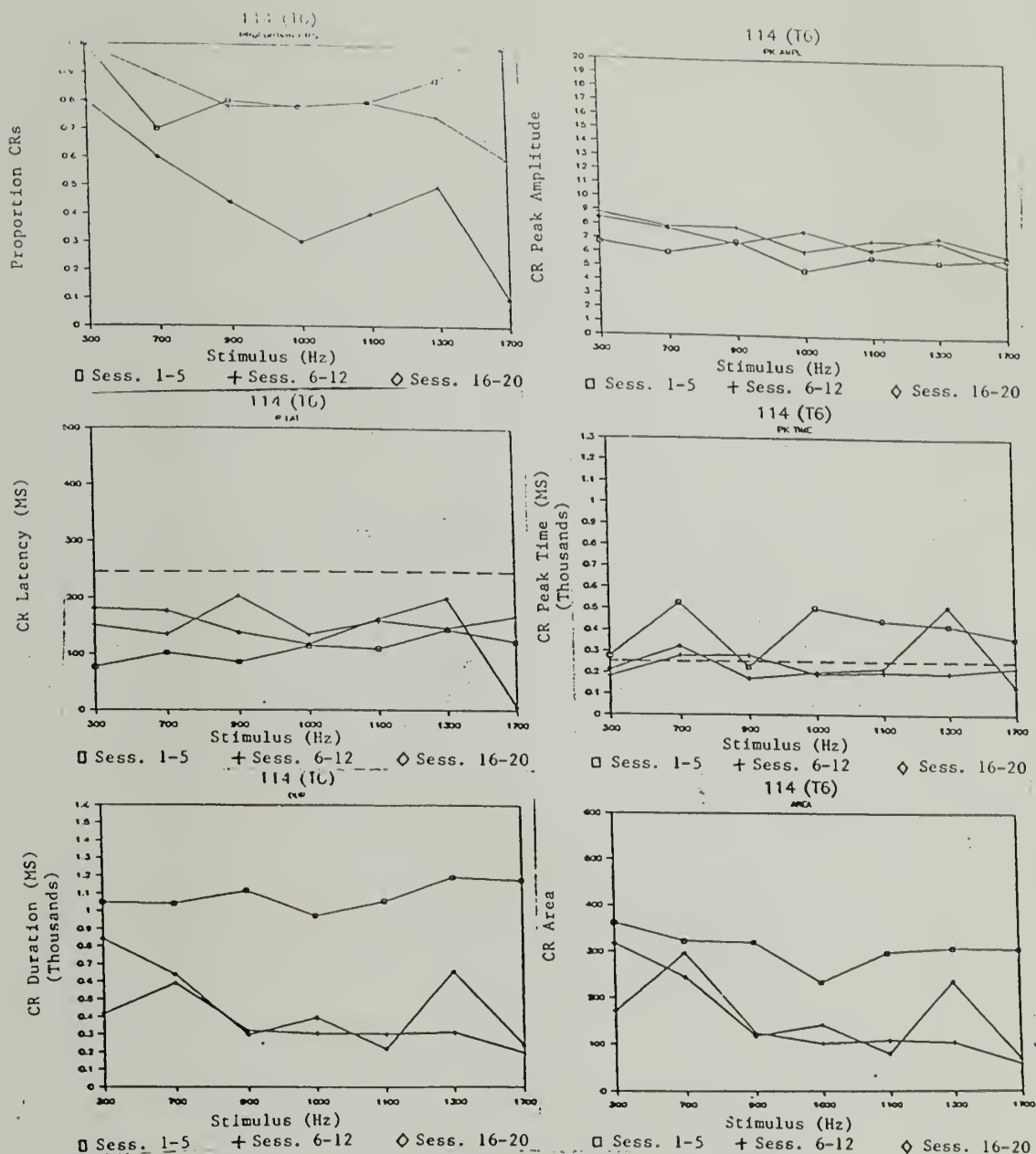


Figure 15. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency at each auditory frequency used during testing of BI S 114. Dashed lines indicate US onset time during training. Number in parentheses following subject number indicates transducer used.



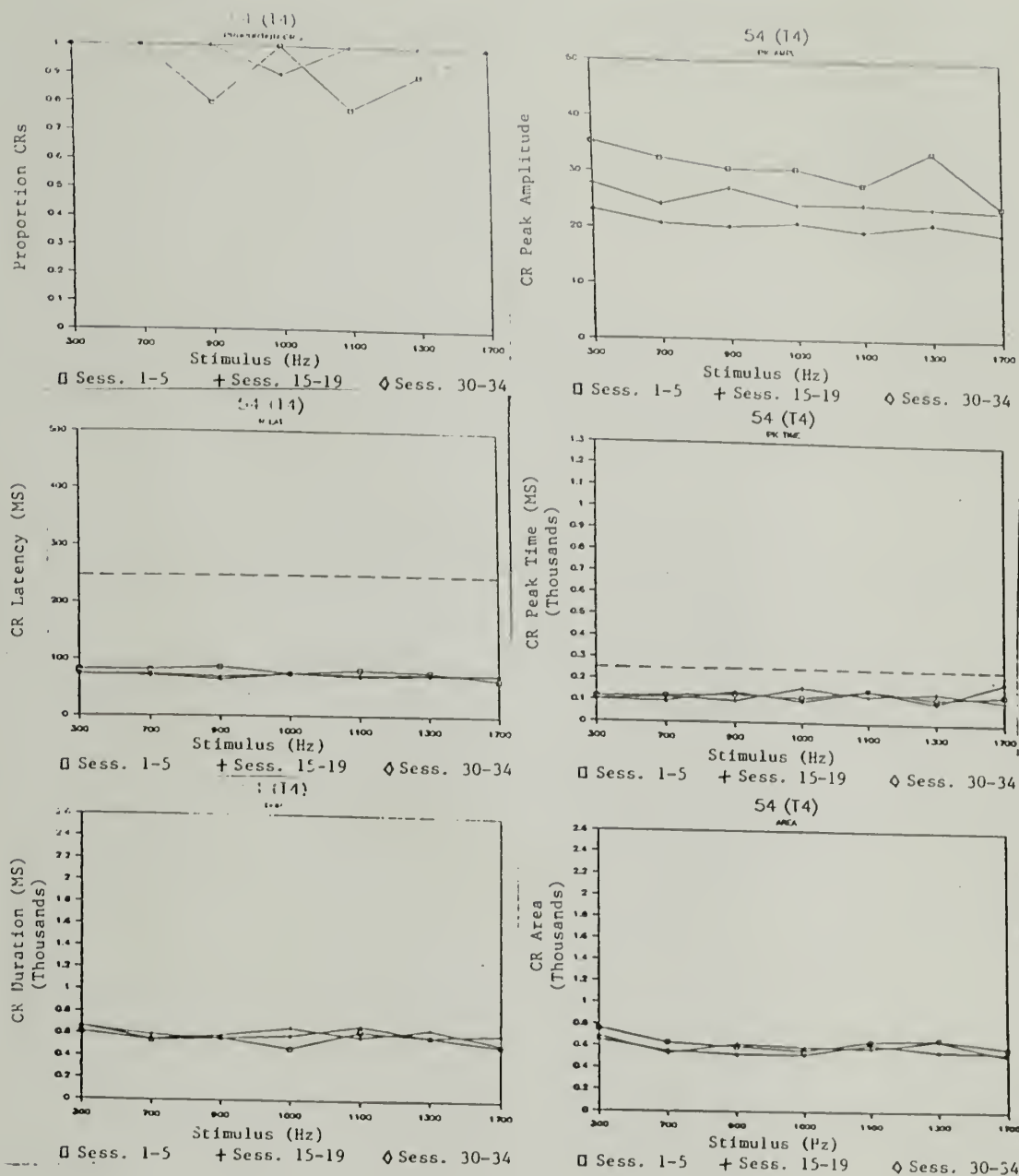


Figure 16. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency at each auditory frequency used during testing of BI S 54. Dashed lines indicate US onset time during training. Number in parentheses following subject number indicates transducer used.

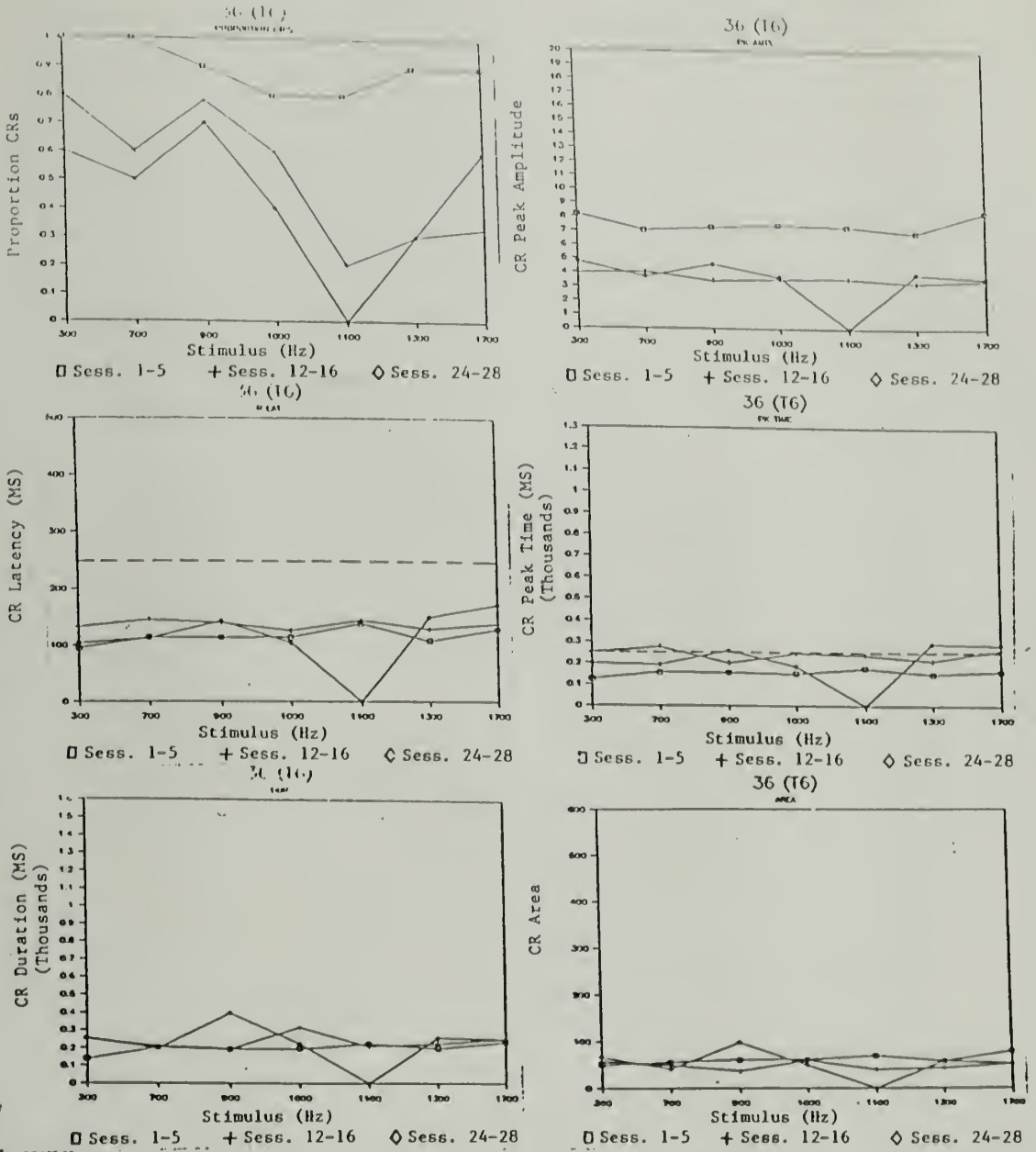


Figure 18. Mean proportion CRs, CR peak amplitude, peak time, area under the CR curve, CR duration, and CR latency at each auditory frequency used during testing of CON S 36. Dashed lines indicate US onset time during training. Number in parentheses following subject number indicates transducer used.

## CHAPTER 4

### SUMMARY AND CONCLUSIONS

#### Training

General analyses of proportion CRs before and during training suggested the following conclusions:

1. Spontaneous responding was reasonably low before training.
2. Conditioning to S+ developed to a high level in all groups.
3. Responding to S- was significantly lower in the BI group than in the ID group.
4. The ID group showed essentially no discrimination between S+ and S-.

Detailed analyses of the training data (CR frequencies of individual Ss and CR topography data) indicated the following:

1. Proportion CRs is as informative as the topography measures for indicating levels of conditioning and discrimination.
2. Each of the four procedural changes made during training of the ID group had an apparent effect on conditioning or discrimination.
3. Generalization from S+ is the most plausible explanation for the lack of discrimination in the ID group.
4. CR duration and area under the CR curve are highly correlated.

### Testing

General analyses of proportion CRs from generalization testing indicated the following:

1. There was no evidence of peaked gradients.
2. CR frequency in the CON group was lower across all frequencies than in the ID or BI groups.

Detailed analyses of the testing data (CR frequencies of individual Ss and CR topography data) indicated the following:

1. CR frequency decreased substantially in four of the seven Ss.
2. Alpha conditioning had probably occurred during training in those Ss in which responding did not extinguish.
3. Tone frequencies lower than the S+ tended to produce higher CR frequencies than tone frequencies greater than the S+.
4. Two of the three Ss in which responding was most resistant to extinction as measured by CR frequency nevertheless demonstrated substantial decreases in CR magnitude.
5. During extinction, decreases in CR magnitude precede those of CR frequency.
6. As in training, CR duration and area under the CR curve were highly correlated.

An appeal to both alpha conditioning and generalization from S+ now seems necessary to account for both training and testing results. The resistance to

extinction and short latencies of Ss 111, 120, and 54 during testing indicate alpha conditioning developed to S+ in these Ss during training. Alpha conditioning through sensitization by the US can develop to S- as well, also indicated by a high frequency of short-latency CRs. The two ID Ss whose responding showed resistance to extinction (111 & 120) also showed evidence during training of alpha conditioning to S-. The BI S (54) whose responding showed resistance to extinction did not show evidence of alpha conditioning to S-. The remaining ID S (116), whose responding did extinguish during testing, also showed a high frequency of S- CRs during training, but the latencies of these CRs remained within the "true CR" range. These findings suggest that during training:

1. Pairing with the strong US caused alpha conditioning to S+ in Ss 111, 120, and 54.
2. Alpha conditioning generalized to S- in ID Ss 111 and 120, but not in BI S 54.
3. "True" conditioning generalized to S- in ID S 116.

During testing none of the Ss showed clear discrimination between tones. For Ss 111, 120, and 54, this was probably due to generalization of alpha conditioning from S+ to the other tone frequencies. As for the Ss that demonstrated both "true" conditioning and "true" extinction (ID S 116, BI S 114, and CON S 119) but failed to discriminate to a reasonable degree between frequencies during testing, it may have been that the range

of testing frequencies was too limited, and "true" conditioning generalized to the other test stimuli. Although similar test ranges were used by Moore (1972) to detect peak shifts, it would be more appropriate for an initial study of generalization to use a wider range of stimuli with greater steps between them; for example, a range from 400 Hz to 4000 Hz in steps of 600 Hz (Moore, 1972).

It would also be appropriate to begin training, particularly of the ID group, using conditions more conducive to producing discrimination. The ID group of this study was informative to the extent that the procedural changes made during training did produce at least transient changes in the expected directions. It is likely, then, that another ID group trained with the following conditions would demonstrate good discrimination:

1. Higher ratio of S-/S+ trials -- 2:1.
2. Greater S+/S- difference -- 1400 Hz (Chisholm, Hupka, & Moore, 1969).
3. Longer ISI -- 500 ms (Chisholm, Hupka, & Moore, 1969).

To avoid alpha conditioning in those Ss that do not require an increase in US intensity, a better strategy than increasing US intensity would be to discontinue the Ss showing a need for a more intense US, or perhaps even tailoring US intensity to particular Ss. The interpretative problems created by the latter option would

not be difficult if it could be shown that Ss for which comparable URs were evoked conditioned at approximately the same rate and discriminated to about the same degree. Differences between groups would then most likely be due to differences in other characteristics of the training conditions.

In conclusion, enough useful information was produced by this study to render it a worthy endeavor:

1. The CR topography measures were not more informative than the frequency measure for degree of discrimination or generalization, but proved invaluable for assessing changes in training procedures, for evaluating the probable causes for the absence or presence of discrimination, and for indicating the degree of extinction during testing.

2. The high correlations between CR area and duration indicated a degree of redundancy between these measures. However, in this laboratory analyzing area in addition to duration or vice versa is of little cost, since both measures are already included in the software that analyzes the transducer voltages. In addition, it would be helpful to measure both of these CR characteristics when evaluating situations in which changes in area might be expected without corresponding changes in duration (e.g., changes in US intensity).

This study does fulfill the objectives of broadening the base of NMR data and of expanding upon the initial study of the pigeon NMR preparation by Stickney, Donahoe,

and Carlson (1981), and will certainly serve as a basis for further study of this preparation.



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