THE INTERSTIMULUS INTERVAL IN CLASSICAL AUTONOMIC CONDITIONING IN YOUNG INFANTS

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ABSTRACT

THE INTERSTIMULUS INTERVAL IN CLASSICAL AUTONOMIC CONDITIONING IN YOUNG INFANTS

by

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Conditioned discrimination and extinction of the skin potential response was attempted in four-month-old infants. In addition to conditionability, a major focus of the study was to investigate the effects of four different interstimulus intervals on conditionability. Also of major importance was an attempt to investigate the extent to which individual differences in orienting response magnitude predict conditionability, and interact with the interstimulus interval. A delayed conditioning procedure was used in which CS onset preceded UCS onset by 1500, 3500, 5500, and 7500 msec.; UCS duration was 1000 msec.; CS and UCS terminated simultaneously. The CSs were 75 db 800 and 400 Hz square wave tones. The US was a 3.6 g/mm air puff to the infant's cheek. A control group was included. The results support the contention that conditioning of autonomic responses is possible during early infancy. Conditioning was very much a function of ISI, with 7500 msec. ISI group showing superior conditioning. Moreover, the results indicated a strong relationship between OR magnitude and conditionability, such that individuals manifesting large magnitude ORs also showed the greatest amount of conditioning regardless of ISI.

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INTRODUCTION

Fitzgerald and Porges (1971) refer to the 60's as "a decade of surging research interest in all aspects of infant behavior." Increased attention was then, and continues to be, devoted to factors involved in infant classical conditioning and learning. The focus of this research has been in two directions. The first of these was due to the consideration by several investigators of the conditions under which specific stimuli serve as effective elicitors of infant behavior (e.g., Brackbill & Fitzgerald, 1969; Kay, 1967). According to Soviet Physiologists, there is an immutable developmental order for conditional stimulus (CS) effectiveness in conditioning. The Soviets contend that the effectiveness of the sense modalities from the earliest to the last in effectiveness are in order: vestibular, auditory, tactile, olfactory, gustatory, and visual (Brackbill & Koltsova, 1967). Brackbill and Koltsova suggest that temporal stimuli be positioned at the low end with thermal stimuli positioned at the upper end of the continuum.

A second issue for infant conditioning research concerns the role of the CS. The Soviets contend that the CS is the most important component of those involved in classical conditioning for predicting the course of conditioning (see Brackbill & Fitzgerald, 1969).

Recent reviews of the literature on infant learning clearly show that human infants are conditionable (see Fitzgerald & Porges, 1971; Brackbill & Koltsova, 1967). However, the data on autonomically conditioned responses is meager in comparison with data on somatically mediated responses. Using the classical conditioning paradigm Kasatkin et al., (1953), Koch (1965), Kaye (1965), Lipsitt and Kaye (1964) and Lintz, Fitzgerald and Brackbill (1967) have obtained evidence demonstrating conditioning of somatically mediated responses such as the Babkin Reflex, sucking, eyeblinking, and head rotation.

The major extent of the conditioning of autonomically mediated responses in infants has been done by Brackbill, Fitzgerald and their associates (Brackbill & Fitzgerald, 1969; Brackbill, Fitzgerald, & Lintz, 1967; Brackbill, Lintz, & Fitzgerald, 1968; Fitzgerald, Lintz, Brackbill, & Adams, 1967; Fitzgerald & Brackbill, 1971; Forbes & Porges, 1972; Ingram & Fitzgerald, in press). These studies involve conditioning of pupillary reflex dilation and constriction, heart rate, and skin potential to auditory, tactile and temporal stimuli. Sometime ago, Jones (1930) reported conditioning of the GSR in nine-month old infants using auditory, tactile, and visual stimuli with electroshock as the US. Although the combined results of these studies are by no means conclusive, they certainly suggest that autonomic conditioning in infants is possible.

Temporal Factors in Infant Classical Conditioning

Attention toward the temporal factors involved in infant behavior has increased in the last few years, however, the focus of this research has generally been on the ontogeny of biological rhythmicity. This includes studies of endogenous biological rhythms such as body temperature, electrodermal phenomena, heart rate changes, and sleep wake cycles by Hellbrugge (1960). Other researchers have studied rhythms involved in infant sucking and crying behavior (Wolff, 1967); and REM-NREM cycles (Stern, Parmelee, Akiyama, Shultz, & Wenner, 1969).

A second aspect of temporal regularity is the organism's ability to perceive the quantitative difference between intervals of time and to respond on the basis of this perception. For example, Brackbill, Fitzgerald & Lintz (1967) and Brackbill & Fitzgerald (1969) have found temporal conditioning of autonomic responses in infants, and have used this successful demonstration of simple temporal conditioning as a means of studying the development of more complicated temporal behavior, i.e., the organism's ability to make complicated temporal pattern discriminations (Brackbill & Fitzgerald, 1972).

The Optimal Interstimulus Interval

One of the many conditions affecting the formation of conditioned reflexes is the interstimulus interval (ISI). The ISI refers to the amount of time elapsing between the onset of the conditioned stimulus (CS) and the onset of the unconditioned stimulus (US). The problem of the optimal ISI was first discussed by Hull (1943), who concluded that the optimal ISI is 500 milliseconds. Subsequently many researchers studied this phenomenon confirming Hull's conclusion (Spence, 1960).

Nevertheless, a number of recent studies point to areas of difficulty in establishing the optimal ISI in classical conditioning (Stewart, Stern Winokur & Fredman, 1961; Lockhart, 1966; Lockhart & Grings, 1963; Hartman & Grant, 1963; Kykman, 1967). These problems center around the various criteria used for the identification of the conditional responses (CR), the various methods for establishing a conditional response, the differences between species, and the differences between response systems.

The following briefly outlines some of the findings with regard to the optimal ISI in infrahuman and human adult Ss with respect to various response systems. In addition, two other areas are examined--autonomic conditioning and conditional discriminations.

Research with Infrahuman Organisms

Attempts to determine the optimal ISI, in addition to having involved both animal and human Ss, have included infra-mammalian organisms as Ss. Recent studies of infra-mammalian species suggest that the optimal ISI is greater than one second: [Coppock & Bitterman (1955) using marine analids; Adams, Hardesty, & Noble (1960) using the earthworm; and Smith & Baker (1960) with the horseshoe crab].

Research with organisms higher on the phyletic scale also demonstrates an optimal ISI that is longer than one second (Noble & Adam, 1963; Noble, Gruender, & Meyer, 1959; Noble & Adams, 1963, 1963a and Noble & Harding, 1963). Caldwell & Werboff (1962) found that among young mammalian rats the optimal ISI was longer than for adult rats, thus suggesting an ontogenetic relationship between the ISI and conditioning.

Research with Human Adults: The Optimal ISI for Somatic and Autonomic Conditioning

The results of studies using human Ss are different from those employing animal Ss. The interval producing the greatest amount of conditioning in humans is 500 milliseconds for at least two response systems: the eyeblink and the finger withdrawal responses (Beecroft, 1966). However, for the conditioning of autonomic response systems the optimal ISI is longer than the optimal ISI for the classical conditioning of motor responses.

Reports of successful conditioning of the eyeblink response have demonstrated that superior eyeblink conditioning occurs at ISIs of 500 milliseconds (Reynolds, 1945; Kimble, 1947). Additional studies have found ISIs of 500 msec. to produce superior conditioning of the eyeblink response (Kimble, Mann, Dufort, 1955; Ebel & Prokasy, 1963). In addition Hansche & Grant (1960) studied the effects of 150 msec. to 1750 msec. ISIs for both CS onset and CS offset and found that a 500 msec. ISI provided superior performance.

Similar results have been reported for a second response system--the finger withdrawal response. Using a measure of percent responding several investigators found that superior finger withdrawal performance occurred with the use of the 500 msec. ISI (Wolf, 1930, 1932; Spooner & Kellogg, 1947; Fitzwater & Reisman, 1952; Fitzwater & Thrush, 1956).

The optimal ISI for classical autonomic conditioning is longer than for the conditioning of motor responses (Pavlov, 1927; Gerall & Woodward, 1958; Fitzgerald & Brackbill, 1968; Hilgard, Dutton, & Helmick, 1949; Kakigi, 1964). However, with respect to the conditioning of the GSR, research findings seem to fall into two categories, differing somewhat from findings for other autonomic systems. The first category involves studies reporting superior GSR conditioning with short ISIs; for example, from 450 to 500 msec. (White & Schlodberg, 1952; Moeller, 1954; Prokasy, Fawcett, & Hall, 1962). The second category includes those studies reporting superior conditioning with long ISIs--1000 to 3000 msec. (Bierbaum, 1959; Wickens & Cochran, 1960; Jones, 1962).

In attempting to explain these differences, Prescott (1965) suggests that the GSR has orienting and unconditional response tendencies to the onset of the CS, which have not been sufficiently controlled in most research. Stewart, Stern, Winokur, & Fredman (1961) also refer to the lack of appropriate controls. Stewart, et al., advocate the use of a long ISI which they feel would allow the "true CR" to develop. However, during long ISIs multiple responses are likely to occur (Lockhart, 1966) thereby confusing the situation as to which is a true CR. An orienting response or first interval response occurs shortly after CS onset (Leonard & Winokur, 1963; Lockhart & Grings, 1964). A response occurring just prior to the onset of the US or "pre-US" response is referred to by Stewart, et al., as the "true CR" in GSR conditioning. In this study these responses will be referred to as second interval R's. Stewart also considers the response occurring in the position of the UR when the US is absent such as on test trials as a CR.

However, Lockhart & Grings (1963) point out that the first interval or orienting response shows conditioning if a magnitude rather than a frequency criterion is used. Therefore conditioning can be demonstrated with either a frequency or a magnitude criterion when the long latency ISI is used.

A hypothesis has been proposed to explain the fact that autonomic responses generally have longer optimal ISIs than somatic responses (Jones, 1961). Jones suggested that the optimal ISI for conditioning depends on certain characteristics of the reflex being conditioned. For example, some reflexes have long latencies while others have short latencies, therefore, long latency responses would condition at longer ISIs than would short latency responses. Eccles (1964) provides some neurophysiological evidence confirming that autonomic response systems generally have longer latencies than some somatic responses.

The Optimal ISI and the Differential Conditioning Paradigm

Again regarding the eyeblink response, there is an additional factor exerting influence on the ISI; namely the differential conditioning paradigm. Recently investigators have begun to study the effect ISI on differential conditioning of the eyelid response. Hilgard, Campbell and Sears (1938) were the first to examine this relationship by conditioning the eyelid response using ISIs of 600 and 650 msec. The longer ISI was found to give better performance. This general finding is supported by Hartman and Grant (1962) with a similar study which indicated that conditioned discrimination increased as the ISI increased in length.

Differential conditioning of the GSR was found to increase with increasing ISIs (Kimmel & Pennypacker, 1963). However, this effect was attributed in part to reduced responding to the negative CS in the longer ISI conditions. The above authors accept an explanation similar to one offered by Hartman and Grant (1962) for similar differences found in differential eyelid conditioning. Hartman and Grant point to the possibility that inhibition of responding may require more time. Inhibition of the response is also seen to be the cause of the attenuation of the response magnitude peak such that the peak of GSR responding falls off after fewer numbers of reinforced trials. Therefore, the greater amount of time allowed for response inhibition to occur in the long ISI conditions would improve performance.

Optimal ISI Research with Infants

Research with animals and human adults on the question of an optimal ISI seems to indicate that the longer ISIs afford better conditioning performance when the response is an autonomic response, and discrimination conditioning rather than simple conditioning is attempted. However, most of the existing research up to this point has yielded little evidence for assuming that any specific ISI would give superior performance with infants (Brackbill, Fitzgerald, & Lintz, 1967; Lintz, Fitzgerald, & Brackbill, 1967; Morgan & Morgan, 1944; Natio & Lipsitt, 1960; Rendle-short, 1961; Wenger, 1936). However, a closer examination of some of the above studies seems to indicate that differential performance does occur to different ISIs. Natio & Lipsitt found that an ISI of 500 msec. produced a mean of 27 percent CRs in an eyeblink conditioning study. On the other hand Lintz, et al., in a similar study found that a 1000 msec. ISI produced responding at about the 90 percent level. Since these studies differed methodologically to some extent, the differences in the percent of responding may have been due to any of the methodological differences. However, recent research presenting a much clearer picture of the relationship of the ISI to conditioning in young infants and children suggests that the longer ISIs afford better conditioning (Ohlrich & Ross, 1968; Little, 1971). Even among the animal research there is evidence to suggest that younger animals require longer ISIs for optimal performance (Caldwell & Werboff, 1962).

Eyelid conditioning studies by Little (1971) involving ISIs of 500, 1000, 1500, and 2000 msec. suggest that the only appreciable increase in responding over trials occurred in the group conditioned at ISIs of 1500 and 2000 msec. Subjects conditioned at the ISI of 2000 msec. did not show as large an increase in responding as did Ss conditioned at an ISI of 1500 msec. In a second experiment performance was compared between ISIs of 500 and 1500 msec. Conditioning was found to be significantly superior for those Ss conditioned with the 1500 msec. ISI. These data tend to support the contention that infants tend to condition best at ISIs longer than 500 msec., at least with somatic responses.

Finally, Fitzgerald & Brackbill (1973) have concluded from their research with stereotype conditioning that simple associative connections are formed more rapidly and more uniformly than are complex associations such as those required in a discrimination task (also, Brackbill & Fitzgerald, 1972).

On the basis of the above, one can contend that the relationship between conditionability and the ISI is quite complicated and the formation of a developmental theory of conditionability specifying only a small portion of the components of the classical conditioning paradigm is questionable.

To summarize: in the area of infant research the laborious task of examining in detail the temporal relationships involved in infant learning is required in order to understand the nature of conditionak reflex formation. For example, conditionability has been found to be related to the magnitude of the orienting reflex (Ingram & Fitzgerald, in press; Aslin &

Fitzgerald, 1973) and to other factors such as the type of CS (Brackbill & Fitzgerald, 1969; Fitzgerald & Porges, 1971), and type of CR (somatic or autonomic) (Fitzgerald & Brackbill, 1971).

The present study was designed to extend the investigation of variables affecting conditionability in young infants. Specifically, the present study investigates the effect of ISI on conditionability of the skin potential response (SPR).

METHOD

Subjects

The *Ss* were 30 full-term, clinically normal human infants from the local area surrounding Michigan State University. Subjects were 85-120 days old (mean = 112 days); 18 were male and 12 were female. Permission for participation in the experiment was obtained in writing from the parents once a complete description and explanation of the experiment and procedure were given. Initially 33 *Ss* were contacted, 3 were dropped from the experiment because of excessive state changes (excessive crying).

Appaeatus

The apparatus consisted of a Grass model 7 polygraph for recording the SPR. The two stimuli used as CSs were 800 and 400 Hz tones. The tones were delivered to *S* through a speaker located in front of and about 60 cm. away from *S* with an intensity of 75db recorded at *S's* ears. The tones were produced by an Eico tone generator operating through a Sony amplifier.

A 3.6 gm/mm puff of air served as the US. The US was delivered to *S's* right cheek from a distance of 2.5 cm. The air pressure was regulated by a Hoke Regulator Valve, and delivery was controlled by a

Hunter Silent Solenoid.

Stimulus duration was regulated by Hunter Electronic Timers. UCS duration was 1000 msec. for each group. The CS durations were 2500, 4500, 6500, and 8500 msec. for groups 1 through 4 respectively. The CSs and US terminated simultaneously. Inter-trial intervals varied randomly among 10, 15, and 20 seconds. The SPR was recorded as a change in millivolts with Beckman Biopotential electrodes placed as follows: the active electrode was placed on the arch of the foot halfway between the ankle and the first phalange; the referent electrode was placed over the tibia, 1/8 of the way up on the shin between ankle and knee; the ground electrode was placed on the outside of S's upper thigh. The skin surface was cleaned with 70 percent ethanol, dried, and covered with an electrolyte paste for contact between the electrode and the skin (Ingram & Fitzgerald, in press).

Design and Procedure

Subjects were assigned to each group on the basis of the magnitude of the orienting reflex (OR). The OR was measured according to the magnitude of the first response during habituation (Ingram & Fitzgerald, in press). Assignment to groups on the basis of OR magnitude was made such that each group was composed of 3 individuals whose OR magnitude was greater than 3.0 Mv. and 3 individuals whose OR magnitude was less than 3.0 Mv. The basis for the apriori cutoff was that this was the median OR magnitude found by Ingram and Fitzgerald in previous research with infants of the same age level as those in the present study.

The 4 different ISIs (1500, 3500, 5500, 7500 msec.) determined the 4 experimental groups. A fifth group served as a pseudoconditioning control. Each group contained 6 Ss, with half of the Ss in each group receiving the 800 Hz tone as CS+, while the other half received the 400 Hz tone as CS+.

The experiment was divided into 5 sessions: one habituation, three conditioning sessions, and one extinction session. Table 1 shows the experimental design. To control for any confounding due to endogenous rhythmicity, sessions were given at the same time on consecutive days for each S for a total of 5 days.

During session 1 each S received 15 presentations of the 800 Hz tone, and 15 presentations of the 400 Hz tone in mixed order for a total of 30 presentations. The habituation ISI varied randomly among 15, and 10 seconds, with each stimulus duration being the same length as the CS duration for each respective experimental group, after the first habituation trial. On the first trial all Ss received the 800 Hz stimulus for a duration of 5000 msec., then all subsequent trials were as described above.

During sessions 2, 3, and 4 all experimental Ss received 15 CS+ and 15 CS- trials for a total of 30 trials. Three of the 15 CS+ trials given per session were test trials (non-reinforced trials), for a ratio of 4:1 reinforced to non-reinforced trials. The test trials occurred on presentations 4, 8, and 12 of the CS+ stimulus in each conditioning session. The CS- trial occurring prior to, but not necessarily adjacent to each

TABLE 1

EXPERIMENTAL DESIGN

Experimental Sessions			
1 Habituation		2 3 4 Conditioning	5 Extinction
N = 3	800Hz & 400Hz (mixed)	CS+ = 800Hz CS- = 400Hz	800Hz & 400Hz
All ISI Groups N = 3	800Hz & 400Hz (mixed)	CS+ = 400Hz CS- = 800Hz	800Hz & 400Hz
	30 trials total	30 trials daily consisting of: 15 CS+ 15 CS-. (Of the 15 CS+ trials, 12 are reinforced and 3 (test trials) are not.	30 trials 15 800Hz 15 400Hz
Control Group			
	800Hz & 400Hz (mixed)	Random presentations of the 800 and 400Hz tones	
N = 6	30 trials total	30 trials daily 15 800Hz 15 400Hz	30 trials 15 800Hz 15 400Hz

test trials served as the control trial. Thus, there were 3 CS- control trials per conditioning session. The only difference between CS- control trials and the additional 12 CS- trials occurring in each conditioning session was that the control trials served as comparison trials for the CS+ test trials.

Extinction took place during session 5. All Ss (both experimental and control) were presented 15 trials of the CS+ unpaired with the US, and 15 trials of the CS-. The presentation schedule was the same for extinction as during conditioning. Therefore, extinction differed from conditioning in regard to stimulus presentations only with respect to the absence of the US.

The pseudoconditioning control Ss differed from the experimental Ss only during sessions 2, 3, and 4. The control Ss received the same stimuli and schedule of presentation in session 1 (habituation) and 5 (extinction) as did the experimental Ss. During sessions 2, 3, and 4, the control Ss received a total of 30 presentations per session of the 800 Hz and 400 Hz stimuli presented in random fashion. The basic difference between experimental and control Ss was that the US was omitted for the controls. The interval between stimuli varied randomly between 10, 15, and 20 seconds.

Each S appeared in the laboratory accompanied by at least one parent, to whom a complete description and explanation of the experiment was given, and from whom final permission for the infant's participation was obtained in writing. Care was taken to assure that permission was granted only after the parents clearly understood the exact nature of the experiment.

The infant was then placed into an infant seat. The seat was located inside a sound attenuated booth (ambient noise level = 50db). The electrodes were then placed as described above.

RESULTS

Habituation

In order to demonstrate a conditional discrimination, it is necessary to demonstrate that the response magnitude to the CS+ either remains constant, or increases, while the response magnitude to the CS- shows a decrement, or no increase over trials. Analysis of the mean response magnitudes to both stimuli during habituation indicated that there was no significant difference between the two stimuli in response magnitude (related measures $t = .097$, $df = 29$). Since the two stimuli elicited response magnitudes of basically the same level, any difference occurring during the subsequent course of conditioning should be due to the experimental manipulations.

Each S's response during the habituation session was analyzed by dividing the habituation trials into three blocks of 10 trials each. Each block of trials consisted of 5 presentations of one stimulus and 5 presentations of the other. The mean response magnitude for the first block of trials was compared with the mean response magnitude of the last block of trials. A related measures t-test (across all Ss on the first block, and across all Ss on the last block of trials) indicated a significant difference between means ($t = 3.210$, $df = 29$, $p < .01$). Therefore, across all Ss the mean response magnitude to the first block of trials was significantly greater than the last block of trials, indicating that response decrement had occurred (see Figure 1).

Conditional Discrimination

Overall effects. Analysis of variance showed that the main effects of ISI, OR magnitude and Trials were significant, as was the Trials X OR magnitude interaction. The analysis is summarized in Table 2. Since there were 5 different ISI groups it is not obvious from the analysis of variance which groups were different. The differences among the ISI groups were analyzed by Duncan's Multiple-Range Test. The test indicates that the 1500 msec. ISI was least effective in producing conditioning, followed by the control group, the 3500 msec. ISI group, and the 5500 msec. and 7500 msec. ISI groups as the most effective groups. The analysis is shown in Table 3. In all of the above analyses the mean difference score (the mean of the difference between the response magnitude to CS+ and the response magnitude to CS-) was used as a measure of responding. Therefore, according to the Duncan Multiple Range statistic, differential responding to the CS+ increased as the ISI increased in length.

In addition, the significance of the overall analysis on OR magnitude, Trials and the Trials X OR magnitude interaction indicates that differential responding to CS+ was also influenced by OR magnitude. The significant Trials effect indicates that Ss increased responding as a

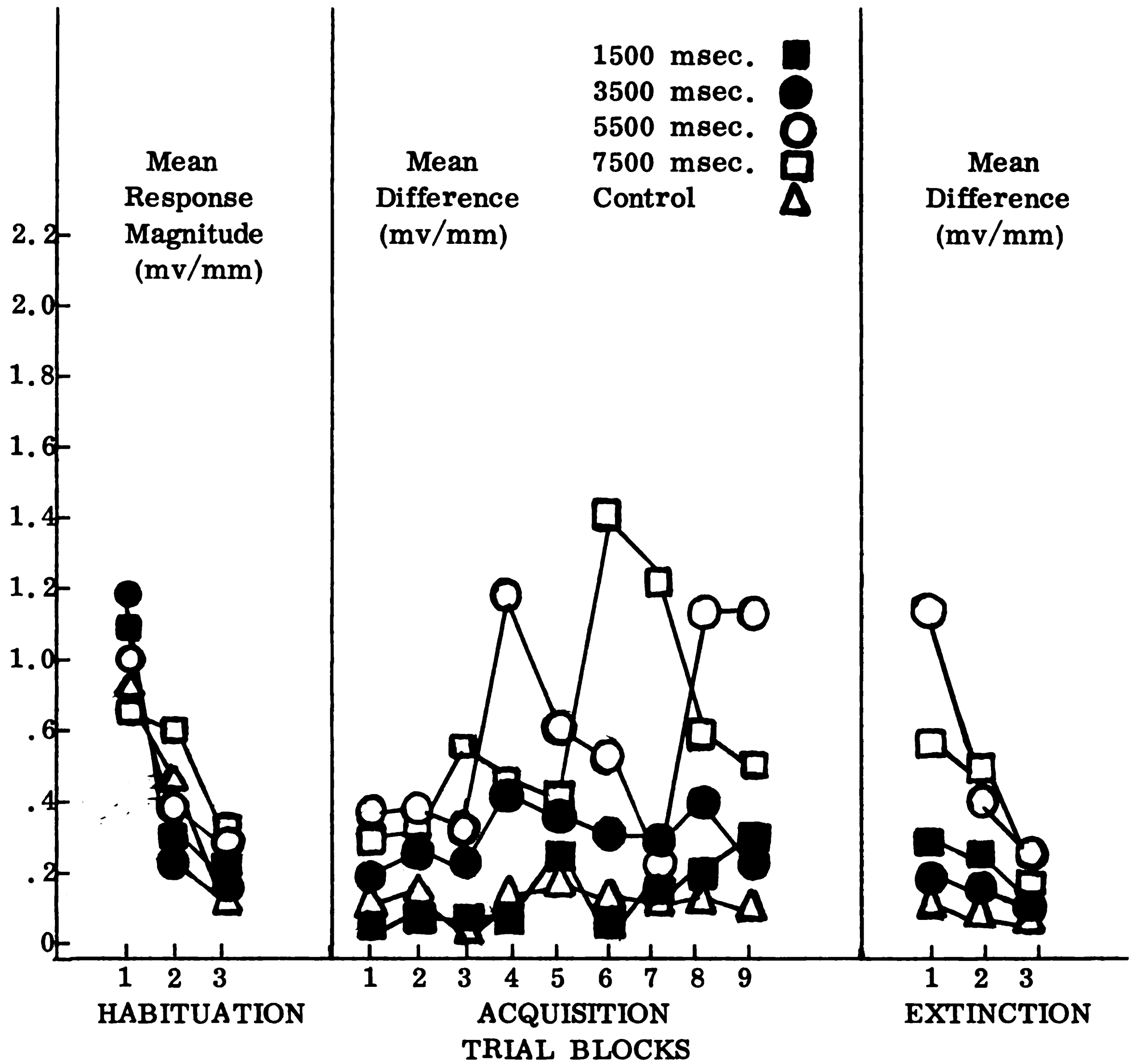

Figure 1. The Mean Response Magnitude for all Ss during habituation and the Mean Difference Score for all ISI Groups during acquisition and extinction.

TABLE 2

ANALYSIS OF VARIANCE OF THE MEAN DIFFERENCE SCORE FOR THE FIRST INTERVAL SPR

Source	Ss	df	MS	F
Total	289.18	269	--	--
Between Ss	141.65	29	--	--
ISI	65.28	4	16.32	5.49*
OR	31.10	1	31.10	10.47*
ISI x OR	14.15	4	1	--
Error (Between)	59.43	20	2.97	--
Within Ss	147.54	240	--	--
Trials	60.44	8	7.56	9.34**
Trials x ISI	33.713	32	1	--
Trials x OR	103.55	8	12.94	15.99**
Trials x ISI x OR	112.151	32	1	--
Error (Within)	129.41	160	--	--

*$p < .005$
**$p < .001$

TABLE 3

SUMMARY OF DUNCAN'S MULTIPLE-RANGE TEST
ANALYSIS OF THE EFFECTS OF ISI ON CONDITIONABILITY

	$\bar{X}$ 1500	$\bar{X}$ Control	$\bar{X}$ 3500	$\bar{X}$ 5500	$\bar{X}$ 7500
$\bar{X}$1500 = 1.25 Mv.	--	.02	1.22	4.63*	5.75*
$\bar{X}$Control = 1.27 Mv.		--	1.20	4.61*	5.53*
$\bar{X}$3500 = 2.47 Mv.			--	2.50*	3.62*
$\bar{X}$5500 = 5.88 Mv.				--	1.12
$\bar{X}$7500 = 7.00 Mv.					--

*$p < .05$

The overall mean difference score for each group. The figures on the right in the table refer to the difference between comparison means (Mv/mm).

function of practice. As shown by the significant Trials X OR magnitude interaction the rate of increased responding to the CS+ is related to OR magnitude.

Figure 1 shows the acquisition curves for all groups (1500, 3500, 5500, 7500 msec. and control groups). Generally all groups show an initial rise in the difference score between trial blocks 2 and 5, however, after this initial increase all groups show a decrease in the difference score, followed by a gradual rise in most cases. Specifically each group shows an initial sudden increase, with the 7500 msec. ISI group showing the increase first, followed by the 3500 and 5500 msec. ISI group, with the 1500 msec. ISI demonstrating the phenomenon last. Following the sudden rise all groups show a sudden decline with the exception of the control group which shows a gradual increase followed by a decline. The 5500 and 7500 msec. groups show a sharp rise in difference score. For the 7500 msec. group this increase is greater than the initial increase. The 5500 msec. group shows an additional increase following the second rise, which does not later decrease. In the case of the 7500 msec. group, the final increase drops off to stabilize at a lower point.

Individual differences. For each S, all trials from sessions 2, 3, and 4 were combined and divided into blocks of 10 trials. Each block of 10 trials contained 5 CS+ (including test trials) and 5 CS- trials. The mean response magnitudes of the CS+ trials were compared with their counterpart on CS- trials, and a difference score computed (a minus sign was assigned to all CS- responses, and the algebraic difference was used as the difference score for each trial). As can be seen in Table 4, seven of the 30 infants demonstrated a significant level of differential responding to the CS+. Of these seven infants, 4 were in the 7500 msec. group, and the remaining 3 Ss were in the 5500 msec. group. This distribution of Ss showing superior performance at longer ISIs supports the group finding of better conditioning at longer ISIs.

Analysis of OR Magnitude and Conditionability

Figure 2 shows the performance of the high and low OR Ss collapsed across ISI groups. Both curves show an initial gradual increase reaching a peak in responding, which is then followed by a decrease. For the high OR group, the decrease following the peak in responding is gradual ending on the 7th trial block, with an increase extending through the 9th trial block. On the other hand, the decrease following the peak of responding for the low OR group continues to zero at the 9th trial block with only a small increase occurring between the 7th and 8th trial blocks. The performance of the High OR Ss can be seen to be superior to the performance of the low OR Ss. Also as seen in Table 2 the OR effect was significant ($F\ (1,20) = 10.471,\ p < .005$).

Figure 2 also shows that there were no significant differences between high and low OR Ss on rate of habituation and rate of extinction. However, there was a significant difference between the high and low OR Ss on the mean difference magnitude during the extinction session ($t =$

TABLE 4

MEANS RESPONSE MAGNITUDE FOR EACH S TO THE CS+ AND CS- DURING DISCRIMINATION CONDITIONING

Subject: mean response magnitudes (mv/mm)

S	ISI GROUP	CS+	CS-	df	t*
1	1500 msec.	.155	.177	8	.181
2		.268	.233	8	.238
3		.204	.231	8	.221
4		.304	.113	8	1.156
5		.088	.031	8	1.240
6		.922	.588	8	.998
7	3500 msec.	1.502	1.073	8	.813
8		.340	.380	8	.175
9		1.270	.720	8	1.863
10		1.000	.444	8	1.932
11		.913	.457	8	1.682
12		.702	.488	8	1.034
13	5500 msec.	.973	.429	8	1.854
14		.830	.344	8	1.227
15		1.306	.511	8	1.475
16		2.325	1.003	8	2.357*
17		1.733	.833	8	2.868*
18	7500 msec.	1.942	.831	8	3.215**
19		.950	1.210	8	.670
20		1.758	.787	8	2.932**
21		2.168	1.131	8	2.336*
22		.996	.386	8	2.803*
23		1.133	.433	8	3.670***
24	Control	.263	.277	8	.235
25		1.710	1.653	8	.342
26		.478	.499	8	.229
27		.086	.053	8	.618
28		.880	.753	8	.392
29		.923	1.235	8	.571

+related measures t; *$p < .05$; **$p < .02$; ***$p < .01$.

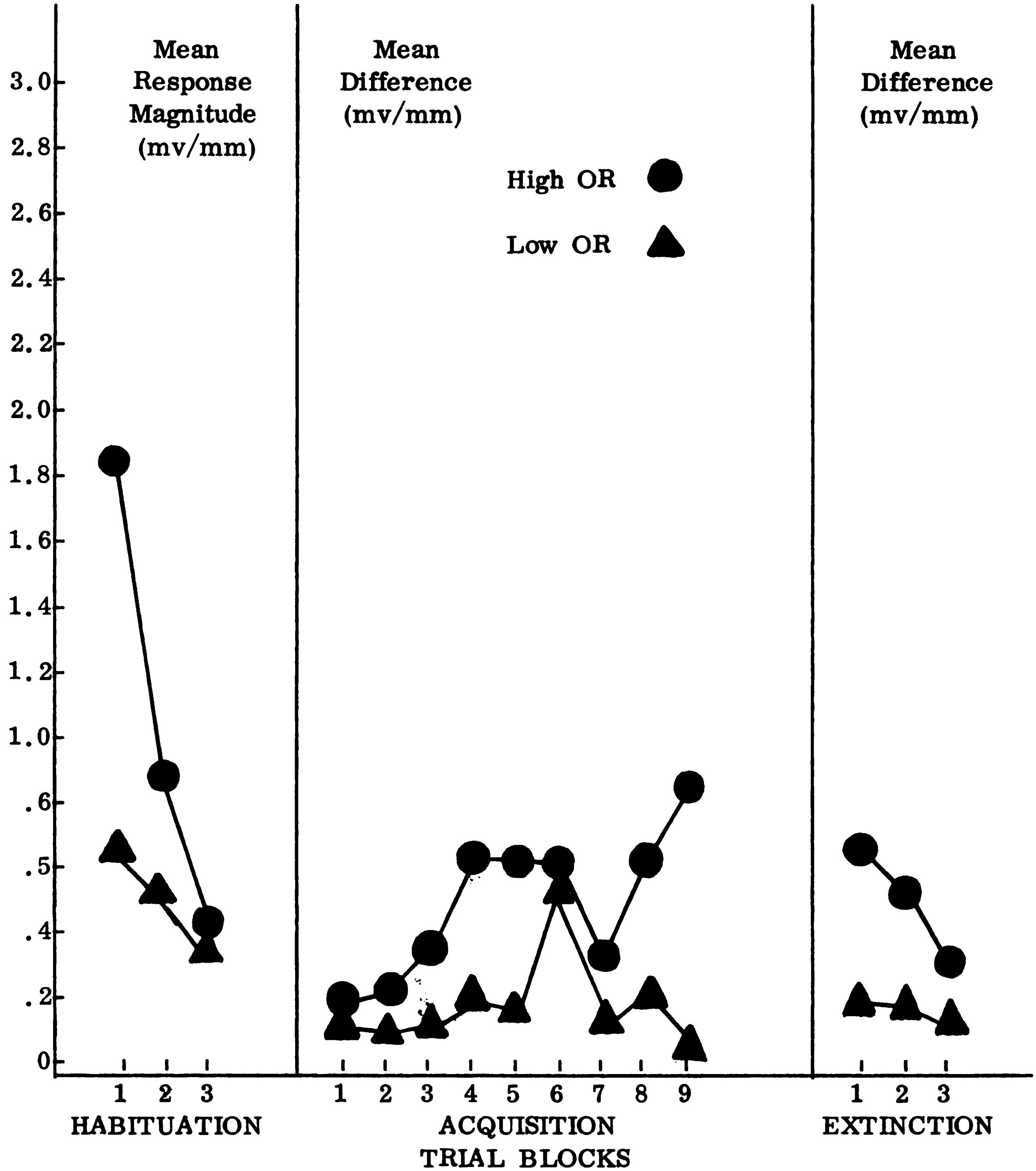

Figure 2. The mean response magnitude for high and low OR Ss during habituation and the mean difference score for high and low OR Ss during acquisition and extinction.

2.237, df = 14, $p < .05$). Table 5 summarizes the analysis of response frequency to CS+ and CS- by high and low OR _Ss_, and for each ISI group.

Extinction

Figure 1 shows the extinction performance of all _Ss_. As seen in Figure 1 there is a significant decrement in responding from the last block of extinction trials collapsed across all _Ss_, i.e., means for _Ss_ on the last block of conditioning were compared with the means for all _Ss_ on the last block of extinction trials (_t_ = 2.791, df = 29, $p < .02$). However, when the above comparison was made within each group no significant differences were found, i.e., the amount of decrement from the last conditioning trials block and the last extinction trial block was analyzed separately for each group (see Table 6).

Figure 2 shows the extinction performance of both high and low OR _Ss_. A comparison of the means for the last block of conditioning trials and the last block of extinction trials showed that a significant difference in magnitude of responding existed, which indicates the decrement occurring over extinction trials was significant (_t_ = 2.791, df = 29, $p < .02$) (see above) (the same comparison). Also, a comparison was made between high and low OR _Ss_ on overall magnitude of the difference score across extinction trials. There is a significant difference between these two groups (t = 2.237, df = 14, $p < .05$) which is probably accounted for by the large magnitude difference on the first block of trials.

TABLE 5

RESPONSE FREQUENCY TO CS+ AND CS- FOR HIGH AND LOW OR Ss AND FOR ALL Ss

	N	CS+	CS-	df	t
High OR	15	.52	.24	14	2.360*
Low OR	15	.32	.52	14	.852
All Ss	30	.84	.76	29	1.537

*$p < .05$.

TABLE 6

THE MEAN MAGNITUDE OF THE MEAN DIFFERENCE ON THE LAST BLOCK OF CONDITIONING TRIALS AND THE LAST BLOCK OF EXTINCTION TRIALS
(THE 9th AND 3rd BLOCK RESPECTIVELY)

GROUP	9th Block of Conditioning Trials (Mv/mm)	3rd Block of Conditioning Trials (Mv/mm)	df	t
1500	.34	.10	5	1.201*
3500	.24	.02	5	.668*
5500	1.60	.29	5	1.873*
7500	.87	-.01	5	1.805*+
Control Ss	.42	.31	5	.043*

*Not significant

+The lack of significance in a comparison that appears as though it should show significance may be explained by the extremely small number of degrees of freedom available.

Second Interval Response

The second interval response terminology refers to the response occurring in an interval beginning 1000 msec. after UCS onset and ending 5000 msec. later only on those trials when the UCS is omitted (test trial). The response was compared with a control to produce an algebraic difference score. The control was the first CS- trial occurring prior to the test trial. Table 7 summarizes the performance of all Ss except the 1500 msec. ISI group when the test trial response is used. The reason for excluding the 1500 msec. group is that the ISI is too short for solely a response to the UCS to occur, thus the response to the CS would overlap the response to the UCS. Therefore, in terms of the second interval response, a comparison between long and short ISI may be meaningless due to the lack of a comparable response.

As seen in Table 7 only 1 S shows a significant level of differential responding; this S is in the 7500 msec. group. In addition, the data indicates that the mean difference score increases as the length of the ISI increases.

In Table 8 the Pearson r shows significant correlations between the second interval response mean difference score (algebraic difference between test and control of response magnitude) and trial blocks required for conditioning to take place. Also a significant correlation occurred between the second interval response mean difference score and the response frequency score (the percentage difference between the percent of respond-

TABLE 7

THE MEAN RESPONSE MAGNITUDE TO TEST AND CONTROL STIMULI FOR THE SECOND INTERVAL RESPONSE DURING DISCRIMINATION CONDITIONING[1]

Subject: mean response magnitude (mv/mm)					
S	ISI GROUP	Test	Control	df	t
1		.3766	.440	2	.278
2		.386	0.00	2	1.000
3	1500 msec.	.886	.440	2	.909
4		*	*		
5		.200	.093	2	1.163
6		*	*		
7		2.886	.553	2	1.401
8		*	*		
9	3500 msec.	*	*		
10		2.720	.110	2	1.447
11		1.163	.110	2	1.305
12		.663	.496	2	.318
13		*	*		
14		*	*		
15	5500 msec.	*	*		
16		.703	.303	2	1.397
17		2.606	.276	2	2.206
18		1.850	.333	2	1.710
19		1.163	.386	2	1.950
20		1.930	.683	2	1.772
21	7500 msec.				
22		1.340	.166	2	1.944
23		.996	.386	2	1.571
24		.606	.076	2	3.826**
25		*	*	2	
26		*	*	2	
27	Control	1.740	1.523	2	.305
28		*	*	2	
29		.530	.672	2	.221
30		*	*		

Table 7 (continued)

*Subject did not respond to either the test or control trial
**p . 05.

1. The data from a response in the position of the second interval response was recorded for the 1500 msec. group for possible comparison.

TABLE 8

INTERCORRELATIONS, PEARSON r

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.00											
2	.00	1.00										
3	-.08	.02	1.00									
4	.09	-.34	-.01	1.00								
5	-.08	-.21	-.01	.17	1.00							
6	.15	1.44*	.02	.22	.22	1.00						
7	-.14	-.32	.00	.32	.39*	.57*	1.00					
8	-.17	.50*	.02	-.31	-.15	-.79*	-.42*	1.00				
9	-.15	-.46*	.31	.43*	.04	.69*	.40*	-.67*	1.00			
10	.24	-.20	-.05	.00	.13	.19	.06	-.31	.05	1.00		
11	.13	-.21	-.19	.24	-.01	.22	.16	-.12	.04	-.18	1.00	
12	.00	.06	-.12	-.06	-.08	-.07	.02	.16	-.06	.06	-.03	1.00

*p .05

1. ISI
2. OR
3. Habituation (number of trials)
4. State
5. Extinction (number of trials)
6. Mean difference score
7. Mean difference score for test trial
8. Trial blocks to condition
9. Frequency difference score
10. Sex
11. Age
12. CS type (400 or 800Hz)

ing to CS+ and percent of responding to CS-). The latter correlation suggest a positive relationship between the amount of responding to CS+ and CS- to the magnitude of the second interval response mean difference score (the larger the magnitude of the mean difference score, the greater the response to test trials over the response to the CS- control trials). There was no significant relationship between the second interval response and the magnitude of the OR.

DISCUSSION

The results of the present study may be summarized as follows: First, young infants (3-4 months old) are capable of learning a conditioned discrimination, as indicated by the autonomically mediated SPR. This finding strengthens previous assertions that autonomic conditioning is possible in infants (Fitzgerald & Brackbill, 1973). Second, the interstimulus interval has a definite influence on conditionability, such that conditionability increases as the length of ISI increases. Third, there are individual differences in OR magnitude. Fourth, these individual differences in OR magnitude are related to conditionability, where conditionability in this study refers to the rapidity with which conditioning occurs as well as to the attainment of set criteria (a significant level of differential responding) concerning response magnitude.

The question arises as to whether or not any difference between the response magnitudes to CS+ and CS- can be considered sufficient to denote a conditional discrimination. The answer to this question is apparently yes. The general superiority of the experimental Ss over the control Ss indicates a trend toward conditioning for all except one group, the 1500 msec. ISI group. In addition, the overall significant decrement during extinction indicates that discrimination conditioning took place. The significant decrement shows that a shift took place from greater magnitude responding to the CS+ over the CS- to equivalent responding to both CSs. However, the failure of some individual Ss to reach the criterion set for conditioning (a significant level of differential responding) indicates differences in the degree of conditioning or conditionability among Ss.

The overall analysis of the data showing a significant effect of ISI on conditioning, and the ranking of the ISIs from least significant to most significant tends to suggest a trend similar to ISI research with human adults; that is superior autonomic conditioning is attained by using longer ISIs. All experimental groups with the exception of the 1500 msec. ISI group show an increase in the differential responding to CS+ over CS-.

The obvious speculation from these data is that some minimal time is needed for young infants to process the stimulus input before an effective discrimination can be made. A similar interpretation of differential eyelid conditioning is offered by Hartman and Grant (1962) who, upon finding that the optimal ISI is longer for differential eyelid conditioning than for simple conditioning, interpreted this to suggest that the longer ISI permits a more complete "perceptual" response to the nature of the CS. Either way a longer optimal ISI for differential conditioning implies that operations involved in responding to stimuli differentially are occurring during the ISI, and have definite temporal requirements.

With respect to the temporal requirements for perceptual assimilation, the superior performance by the high OR Ss, suggest that individually unique levels of responding are related to differences in the degree that an individual can utilize the amount of time available for performing the operations involved in differential responding. The high OR S, regardless of the ISI, may demonstrate a more stable system of responding, which is reflected by the probability of an individual's ability to produce and inhibit responses at given instances of stimulation. In other words, the high OR individual receives stimulation and performs whatever perceptual operations are necessitated by the nature of the stimulus, producing or inhibiting a response as required, in a shorter amount of time. However, for all individuals, the probability of a response decreases as the amount of time required for that response to occur decreases. In terms of the present data this can be seen in the superior performance of the high OR Ss at ISIs of less than the optimal, where the probability of a response is not yet high enough to reach significance, but still higher than the low OR S's response probability. In addition, the significant Trials X OR magnitude interaction indicates that the mean level of differential responding to CS+ increases over trials. These data also suggest that the likelihood of responding appropriately, also increases over trials.

Specifically the response probability interpretation suggests that the difference between the high and low OR Ss on the mean difference score reflects a separation of the two groups on the probability of the CS- eliciting a response of equal strength as the CS+. Recall from Table 5 that the frequency of response to the CS- is higher for Low OR Ss than it is for High OR Ss.

Zeiner and Schell (1971) offer a similar interpretation of thier results obtained with human adults. They found that low OR Ss had as many as 4-7 times as many non-responses to the CS+ as did high OR Ss.

There are at least three theories which try to account for the fact that some Ss condition better than others. First, Spence (1954) suggested differences in drive level, with manifest anxiety as an indirect measure of drive. Second, Eysenck (1957, 1972) argued that introverts (from the introvert-extrovert dimension of the MPI) have less cortical inhibition, therefore, condition more rapidly. Third, Maltzman and his associates (Maltzman & Raskin, 1965; Maltzman & Mandell, 1968) relate conditionability to differences in attention, with the magnitude of the OR as the index of attention. Moreover, Sokolov (1963) suggest that OR elicitation facilitates conditioning.

The second interval response, the response occurring when the US is omitted, is probably the most difficult of all the responses to interpret. For example, Grings, Lockhart, and Dameron (1962) found that in mentally subnormal boys the earliest evidence of conditioning occurred with the second interval response.

However, one problem occurs with the second interval response when one attempts to compare very short (under 3000 msec. ISIs) and long ISIs (over 4000 msec.) using an autonomic response such as the GSR, and

SPR. The problem is with latency and time course, which are in the area of from 1000 to 5000 msec. This long time course and latency would produce overlapping responses, thus, making a comparison with long ISI situations difficult to interpret meaningfully. The long ISI would allow the response to return to base level, thus subsequent responses would more likely be completely new responses rather than a summation of two responses.

In the long ISI situations the second interval response has been considered a disparity response, that is, a response to the perceived absence of the US. It has also been considered to be a temporal conditioned response to the length of the ISI. A third possibility is that the response may be a conditioned OR to the offset of the CS when the CS terminates at the same time as the US. Regardless of the nature of this response it shows characteristics of conditioning, i.e., Ss demonstrate differential levels of responding to differentially reinforced stimuli. Despite that many Ss did not respond on test trials, a sufficient number did to indicate that this response has some significance in conditioning. What this significance is can be determined only through further research into classical conditioning and ISI effects on the formation of conditioned reflexes.

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