RESPIRATORY AND HEART RATE COMPONENTS OF ATTENTION

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ABSTRACT

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The respiratory and heart rate (HR) components of attentive observation to external stimuli (60 db tone, dim flashing light) and to an internal stimulus (Ss' own HR) were investigated. 48 male college students were assigned to 4 groups: one group estimated their HR, a second group estimated the rate of a series of intermittent tones, a third group counted light flashes, and a fourth group watched a light flash. Ss received 10 trials of 26 sec. duration with random variable intertrial intervals. The results indicated that attentive observation produced significant increases in frequency and decreases in amplitude of respiration and decreases in HR variance. The HR response pattern during the first 10 sec. of the trial differentiated between the groups; HR accelerated for internal observation and decelerated for external observation. Ss who estimated the rate of a tone were significantly more accurate than Ss who estimated their own HR. HR, HR variance, and respiration amplitude decreased across trials, while respiration frequency remained constant. An interpretation of the results suggests that although concomitant, HR and respiratory responses from attending to neutral stimuli appear to be independent.

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TABLE OF CONTENTS

PAGE

ACKNOWLEDGMENTS ii

LIST OF TABLES iv

LIST OF FIGURES v

Chapter

I. INTRODUCTION 1

II. METHOD 5

III. RESULTS 9

IV. DISCUSSION 22

REFERENCES 26

LIST OF TABLES

Table		Page
1.	Analysis of Variance of Respiration Frequency as a Function of Groups for Periods over Trials	12
2.	Analysis of Variance of Respiration Amplitude as a Function of Groups for Periods over Trials	12
3.	Analysis of Variance of Heart Rate as Function of Groups for Periods across Trials over Seconds	15
4.	Analysis of Variance of Heart Rate Variance as a Function of Groups for Periods over Trials	20
5.	Analysis of Variance of Heart Rate as a Function of Groups over Trials for the Evoked Period	20

LIST OF FIGURES

Figure		Page
1.	Mean Respiration Frequency as a Function of Trials for Periods	10
2.	Mean Respiration Amplitude as a Function of Trials for Periods	11
3.	Mean Heart Rate as a Function of Trials for Periods	14
4.	Mean Heart Rate Variance as a Function of Trials	16
5.	Mean Heart Rate Variance as a Function of Periods for Groups	17
6.	Mean Heart Rate as a Function of Seconds for Groups during the Evoked Period	19

RESPIRATORY AND HEART RATE COMPONENTS OF ATTENTION

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In recent years there has been considerable interest in the physiological components of attention. The varied experimental reports have demonstrated that attentive observation results in different heart rate (HR) patterns; studies have found HR acceleration (Lynn, 1966; Sokolov, 1960, 1963), HR deceleration (Lacey, 1959; Wood & Obrist, 1964), and changes in HR variability (Hnatiow & Lang, 1965; Lang, Sroufe, & Hastings, 1967; Lacey, 1967).

Lacey (1967) has noted that attentive observation of the external environment produces cardiac stabilization. HR deceleration has been well substantiated in experimental situations requiring S to pay attention (Lacey, 1959; Notterman, 1953; Graham & Clifton, 1966; Chase, Graham, & Graham, 1968). However, inconsistencies have been found in the interpretation of the accelerative HR response. Lacey (1959) has maintained that cardiovascular responses such as increased HR may lead to inhibitory effects on environmental inputs and motor outputs, while the acceleratory HR response has been interpreted by Sokolov (1960, 1963) as a component of the orienting reflex (OR). The OR, which corresponds in part to the concept of attention, produces a heightened sensitivity to environmental stimulation. This inconsistency between Sokolov and Lacey, according to Graham and Clifton (1966),

may reflect two different aspects of a diphasic response, HR acceleration being the initial phasic reaction, and deceleration a later, more prolonged, tonic response.

Hnatiow and Lang (1965) have reported evidence that human Ss learned to reduce HR variability when attending to a visual display providing synchronous feedback of their own HR. The increased stability was not accompanied by significant changes in average HR, and was relatively unrelated to respiration changes. Brener and Hothersall (1966) have extended this finding with evidence that Ss who were provided with exteroceptive feedback of cardiac behavior were able to control their HR. During the periods in which Ss were instructed to increase their HR, it was reported that the respiratory patterns were more erratic than those recorded in the periods in which Ss were instructed to decrease their HR. In a later study, Brener and Hothersall (1967) confirmed their previous finding when Ss were provided with sensory feedback. They concluded that HR control may occur independently of changes in respiratory behavior. Engel and Chism (1967) have indicated that changes in respiration frequency do not affect average HR, but that increased respiration frequency may decrease the HR variability. Similarly, Wescott and Huttenlocher (1961) have noted that the amplitude of the HR arrhythmia is a direct function of respiration.

Three conflicting reports of the respiratory components of attention have been noted. Petelina (1965) found that the respiratory com-

ponent of the OR to a tone was characterized by pauses and diminished frequency and amplitude, while repetitive stimulation was characterized by increased respiratory frequency and amplitude. Polezhaev (1965) noted that during the presentation of a neutral stimulus, dogs strenuously listened and looked in the direction of the source of stimulation. Simultaneously, some distinct and characteristic changes consisting of rapid and shallow breathing occurred. In cases of intense stimuli, respiratory components of the OR according to Polezhaev have the same characteristics. Lynn (1966) stated that regardless of the intensity of the stimulus, the respiratory components of the OR were characterized by pauses in respiration followed by an increase in amplitude and a decrease in frequency.

The present study was designed with six objectives: 1) to determine the changes in respiration amplitude and frequency concomitant with attention, 2) to determine the effect of attention on mean HR and on HR variance, 3) to compare the HR pattern elicited by attentive observation of the external environment with the HR pattern elicited by attentive observation of an internal observation, 4) to determine the nature of across-trial changes in HR, HR variance, respiration frequency, and respiration amplitude, 5) to determine if there is a relationship between respiration changes and HR, and 6) to determine if Ss can perceive internal stimuli arising from their own cardiac activity with the same accuracy that they perceive external stimuli.

This experiment attempted to present a situation in which some basic problems could be answered. The Ss were divided into four groups. Each group was instructed to perform a different attentional task. To answer the question of whether Ss are able to perceive internal stimuli as accurately as they perceive external stimuli, one group was instructed to match the rate of a variable flashing light to the rate of an external stimulus consisting of a series of intermittent tones, and another group was instructed to match the rate of the flashing light to an internal stimulus, their own HR. A comparison of the accuracy of the two groups was made to answer the above question. A third group was instructed to count the number of flashes in each trial and to record this number following the termination of each trial, and the final group was instructed only to watch the light flash. The physiological components were compared to see if the different tasks resulted in different response patterns and if there were differences between the group instructed to attend internally and the other groups, which were instructed to attend externally. In the process of fulfilling the experiment's objectives this study attempted to characterize the physiology of attention in terms of respiratory and HR components.

Method

Subjects. -- Forty-eight volunteers from introductory psychology courses at Michigan State University received research credit for serving as Ss. As they appeared at the laboratory, they were assigned to experimental conditions according to a predetermined random schedule.

Apparatus. -- Stimuli were programmed by means of punched paper tape and were presented automatically using electronic timers. The tones were produced by an Eico model 377 audio generator from which a 1000 Hz tone was amplified by a Dynaco Mark IV amplifier and presented to S via Sharpe HA 10 headphones. The intensity of the tone was 60 db with a duration of 60 msec. The matching apparatus consisted of a flashing neon light from a modified Crystal Lab Metronoma mounted on a panel which was placed on a table in front of S. S could control the rate at which the light flashed by a knob mounted on the right armrest of a padded arm chair in which S was seated. Since the rate of flashing of the Metronoma could not be controlled by E, Ss who were not instructed to perform a matching task observed a small tungsten light with an adjustable diaphragm set at a light intensity equivalent to the neon light. The ambient noise level of the subject room was 34 db, and the temperature of the room was kept fairly constant at approximately 70° F.

The physiological responses and Ss' estimates of the rates were continuously recorded on a Beckman Type R Dynograph at a paper speed of 5mm/sec. All of the recording sites were cleaned

with 70% ethanol prior to the application of the electrodes. Zinc cup electrodes with a surface area of 3.14 sq. cm. and filled with Beckman electrode paste were used to record HR from EKG lead II. The HR was measured with a Beckman 9857 cardiotachometer. Respiration was monitored with a Parks Electronics 12 in. mercury strain gauge attached around the chest by a Velcro fastener. Changes in chest circumference were measured by a Beckman 9875 mercury strain gauge coupler. Ss' estimates were recorded by the voltage produced by the Metronoma which was proportionate to the rate of the flashing light. This voltage was measured by a Beckman AC/DC coupler and the deflection of the polygraph pen recorded the estimate.

Procedure. -- The Ss were randomly assigned to one of four groups. The heart rate estimation group (HRE) was instructed to match the rate of the flashing light with the rate at which they perceived their heart to be beating. The tone-light group (T-L) was instructed to match the rate of the flashing light to the rate at which the intermittent tones were presented. The light-count group (L-C) was instructed to count the number of flashes the light made during each trial. The light group (L) was instructed to watch the light flash.

The S was seated in a comfortable armchair in a sound-attenuated room. After the pickups were attached, E calibrated the recording equipment and then read the instructions which informed

S of his task. The headphones were placed on S and E entered the equipment room. The room was darkened and the stimuli were then presented by the automatic equipment. Ten trials were administered to each S. The four groups had the same intertrial interval schedule of random variable intervals of 40, 60, and 80 sec. and the same trial duration of 26 sec. Each trial began when the light started to flashThe HRE and T-L groups were instructed to control the rate of the flashing light by the knob mounted on the right arm rest. At the cessation of each trial the light stopped flashing and the Ss in the HRE and T-L groups were instructed to turn the knob to the extreme left to insure independent matches. The intermittent tones for the T-L group were presented at rates of 50, 70, or 90 per min. in random order across the 10 trials. The L-C group was instructed merely to watch the light. For the L-C and L groups the light was flashed at the same rates as the tone was presented for the T-L group.

Quantification of the data. -- The responses during each of the 10 trials were scored for HR and respiration. Each trial was divided into three periods, a pre period consisting of the 10 sec. prior to the trial onset, an evoked period consisting of the first 10 sec. of the trial, and a final period consisting of the final 10 sec. of the trial. Respiration was analyzed by counting the frequency of initiation and termination of inspirations, and by measuring the mean amplitude of complete inspirations in each period in mm. of pen deflection. HR in

beats per min. was scored for each sec. interval in each period. IF more than one beat occurred during the sec. interval only the final beat was scored. The HR response was evaluated by a comparison of variabilities in the three periods and by a sec.-by-sec. analysis of HR during the evoked period. The variability analysis used the HR variance of each period as a test statistic in an analysis of variance design. The estimates of the HR and the tone were quantified by using the last position of the pen at the end of the final period of each trial. The error of the HR estimate was calculated by subtracting the HR estimate from the actual mean HR of the final period. The error of the tone estimate was calculated by subtracting the estimate from the actual rate.

Results

Respiration measures. -- The mean respiration frequency as a function of trials is shown for the three periods in Figure 1. It can be seen that there was an increase in respiration frequency from the pre to evoked and from evoked to final periods. Figure 1 also illustrates the stability of the period differences over trials. An analysis of variance (AOV) revealed that there were significant differences between the periods, $F(2, 88) = 23.7$, $p < .001$, and a Newman-Keuls test showed that the respiration frequency differed significantly among all three periods, ($p < .01$). (The AOV summary table for respiration frequency is shown in Table 1).

The mean respiration amplitude as a function of trials is shown for the three periods in Figure 2. This shows a decrease in respiration amplitude from the pre to the evoked periods but virtually no difference between the evoked and final periods. This was substantiated by a significant period difference, $F(2, 88) = 15.1$, $p < .001$ (see Table 2). A Newman-Keuls test showed that the respiration amplitude was significantly greater in the pre period than during the evoked or final periods, ($p < .01$). The average respiration amplitude in all periods decreased over trials. The differences between trials was significant, $F(9, 396) = 7.6$, $p < .001$. The groups were compared in terms of the respiration amplitude response evoked by the onset of the trial. There was a significant difference in the number of Ss in each group whose mean respiration amplitude for the evoked period

Figure 1 - Mean Respiration Frequency as a Function of Trials for Periods

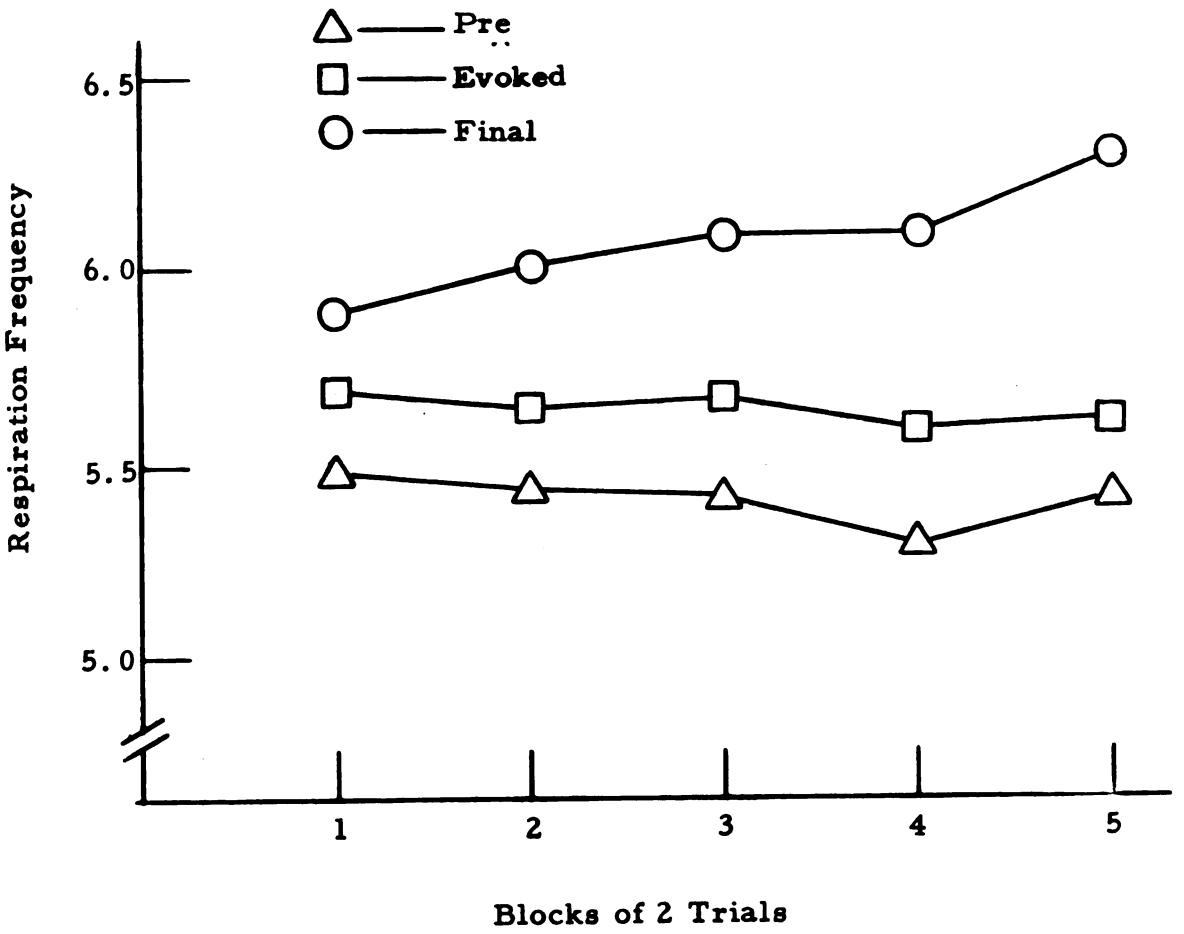


Figure 2 - Mean Respiration Amplitude as a Function of Trials for Periods

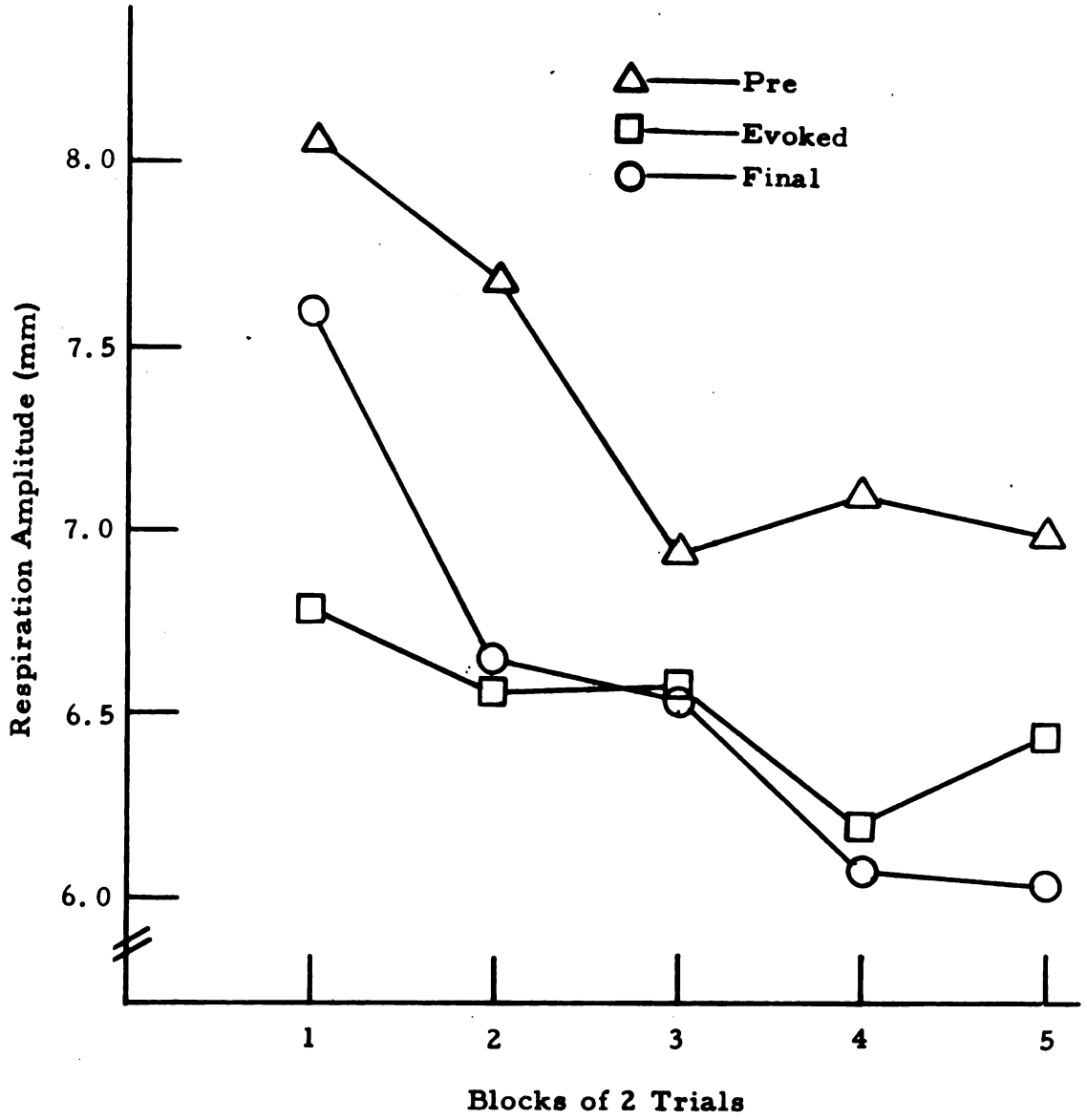


Table 1. - Analysis of Variance of Respiration Frequency as a Function of Groups for Periods over Trials

Source	SS	df	MS	F
Groups (G)	33.75	3	11.25	<1.00
Error (between)	982.96	44	22.34	
Trials (T)	5.56	9	.62	<1.00
Periods (P)	101.63	2	50.81	23.70***
T X P	18.50	18	1.03	1.15
G X T	30.23	27	1.12	<1.00
G X P	11.08	6	1.85	<1.00
G X T X P	47.64	54	.88	<1.00
Error (T)	486.15	396	1.23	
Error (P)	186.96	88	2.12	
Error (T X P)	703.43	792	.89	
Total	2607.98	1440		

*** p .001

Table 2. - Analysis of Variance of Respiration Amplitude as a Function of Groups for Periods over Trials

Source	SS	df	MS	F
Groups (G)	55.33	3	18.44	<1.00
Error (between)	8696.46	44	197.65	
Trials (T)	253.94	9	28.21	7.60***
Periods (P)	224.19	2	112.10	15.10***
T X P	98.04	18	5.45	1.27
G X P	41.45	6	6.91	<1.00
G X T	89.96	27	3.33	<1.00
G X T X P	222.17	54	4.11	<1.00
Error (T)	1475.94	396	3.73	
Error (P)	647.33	88	7.36	
Error (T X P)	3367.10	792	4.25	
Total	15171.90	1440		

*** p .001

was greater than that of the pre period, $\chi^2(3) = 8.6$, $p < .05$. An inspection of these data revealed that 12 Ss in the L-C group, 11 Ss in the T-L group, 8 Ss in the HRE group and 7 Ss in the L group exhibited amplitude decreases from the pre to the evoked period.

Heart Rate Measures. -- The mean HR changes as a function of trials are shown for the three periods in Figure 3. This shows the decrease in HR over trials and the decrease in period differences over trials. The difference between trials was significant, $F(9, 396) = 11.0$, $p < .001$, (see Table 3). The decreases in period and group differences over trials is substantiated by two significant interactions, Trials X Periods, $F(18, 792) = 2.5$, $p < .001$, and Group X Trials X Periods, $F(54, 792) = 1.89$, $p < .001$.

The mean HR variance as a function of trials is shown in Figure 4. Across trials there was significant decrease in mean HR variance, $F(9, 396) = 2.15$, $p < .05$. In Figure 5 the mean HR variance is shown as a function of periods for the different groups. There appeared to be a general decrease in HR variance across the three periods in all the groups except L group. The data revealed that this was a significant decrease in HR variance over the three periods, $F(2, 88) = 8.19$, $p < .001$. A Newman-Keuls test showed that the HR variance during the final period was significantly less than during the pre and evoked periods, ($p < .01$). The groups exhibited a large HR variance decreases during different periods. The HRE and L-C groups had the greatest decrease in HR variance from the evoked to the final period.

Figure 3 - Mean Heart Rate as a Function of Trials for Periods

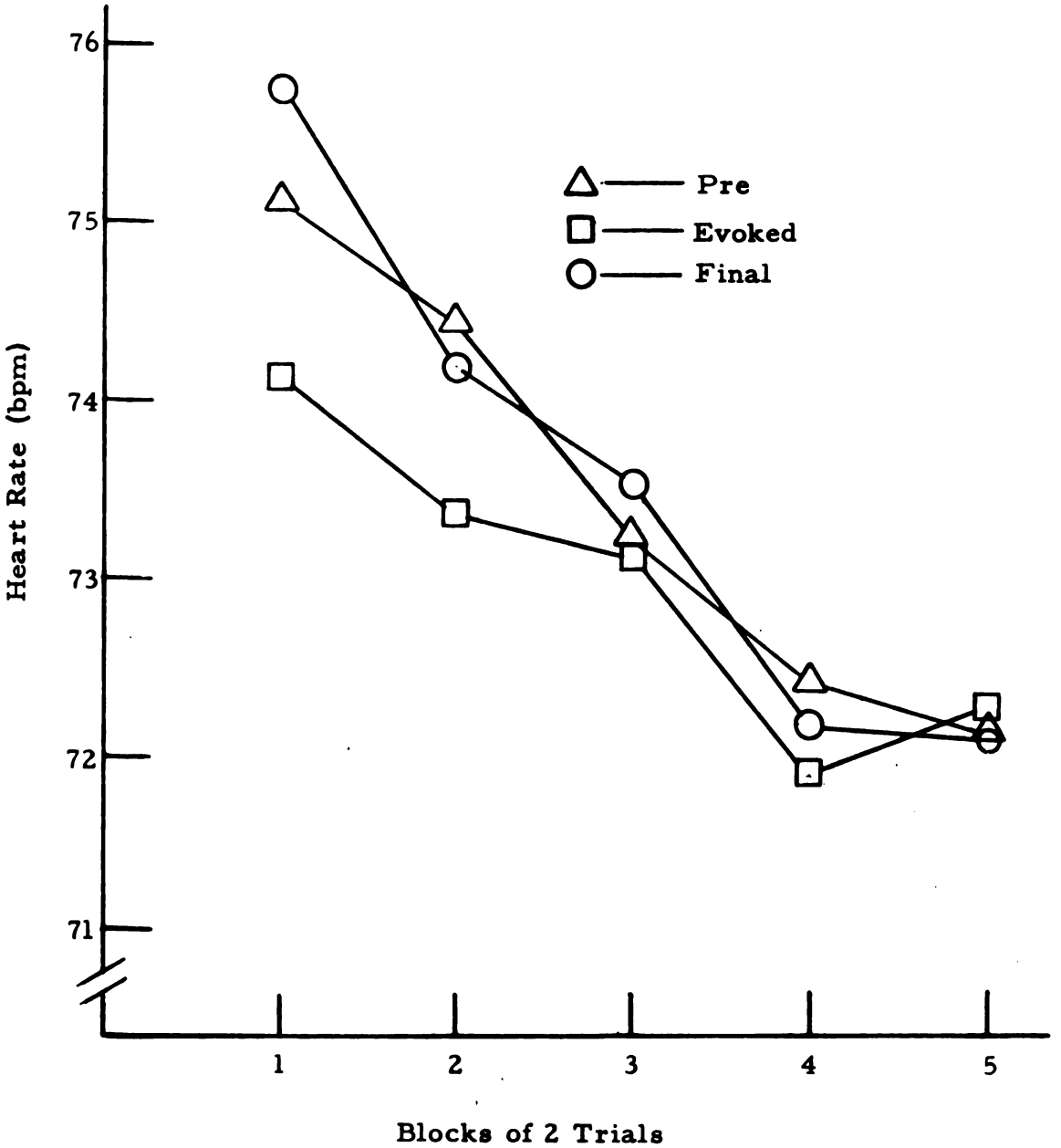


Table 3. - Analysis of Variance of Heart Rate as Function of Groups for Periods across Trials over Seconds

Source	SS	df	MS	F
Groups (G)	103036.22	3	34345.41	<1.00
Error (between)	1961070.74	44	44569.79	
Trials (T)	19836.89	9	2204.10	11.00***
Periods (P)	1112.95	2	556.48	3.04
Seconds (S)	250.21	9	27.80	<1.00
T X P	2967.27	18	164.85	2.50***
T X S	1618.43	81	19.98	<1.00
P X S	1240.61	18	68.92	2.52***
T X P X S	5640.02	162	34.81	1.51***
G X T	7548.61	27	279.58	1.39
G X P	937.02	6	156.17	<1.00
G X S	927.12	27	34.34	<1.00
G X T X P	6745.67	54	124.92	1.89***
G X T X S	5529.89	243	22.76	1.01
G X P X S	2412.63	54	44.68	1.64**
G X P X P X S	9986.63	486	20.55	<1.00
Error (T)	79341.04	396	200.36	
Error (P)	16114.23	88	183.12	
Error (S)	14308.03	396	36.13	
Error (T X P)	52372.82	792	66.13	
Error (T X S)	79421.72	3564	22.28	
Error (P X S)	21594.24	792	27.27	
Error (T X P X S)	165365.99	7128	23.20	
Total	2559378.97	14400		

*** p .001
** p .01

Figure 4 - Mean Heart Rate Variance as a Function of Trials

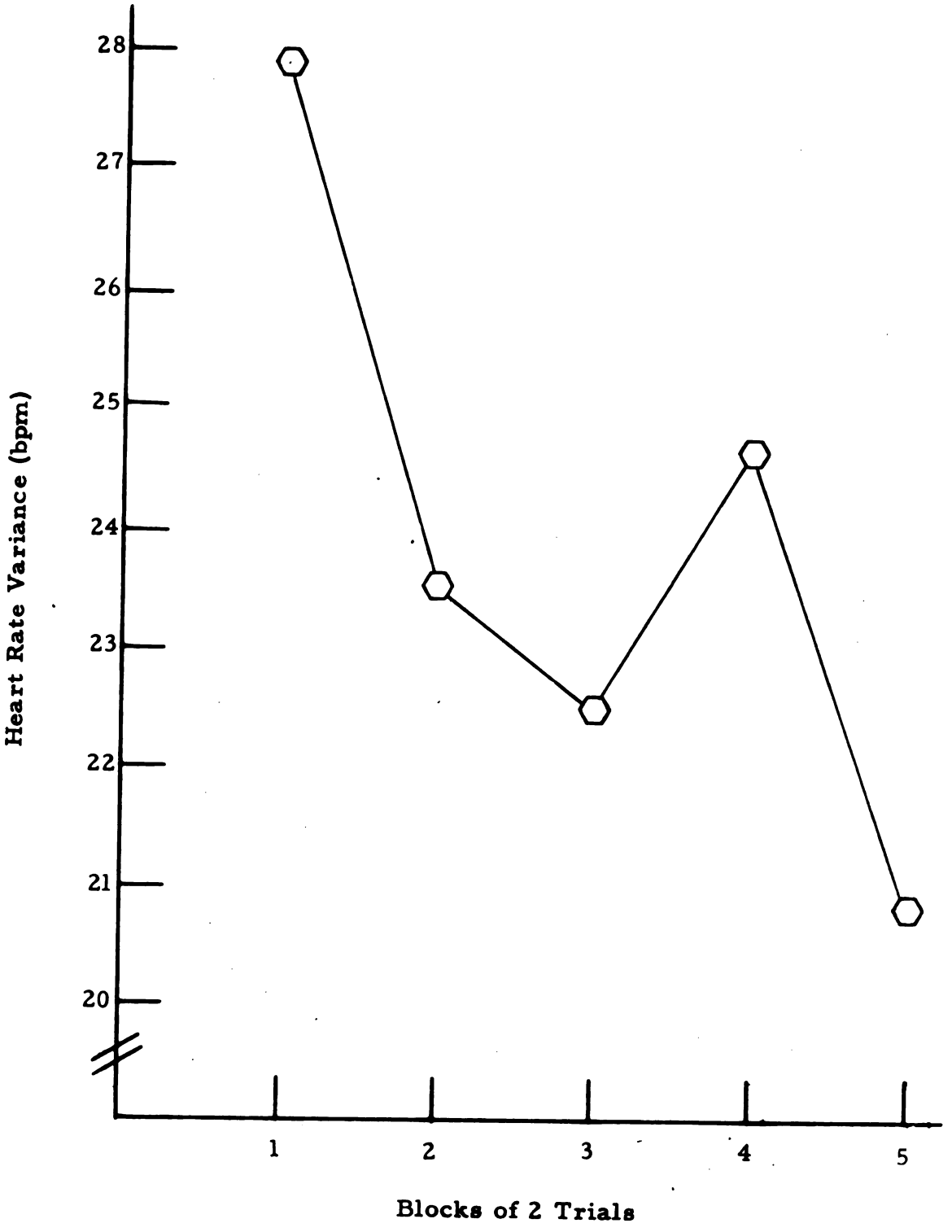
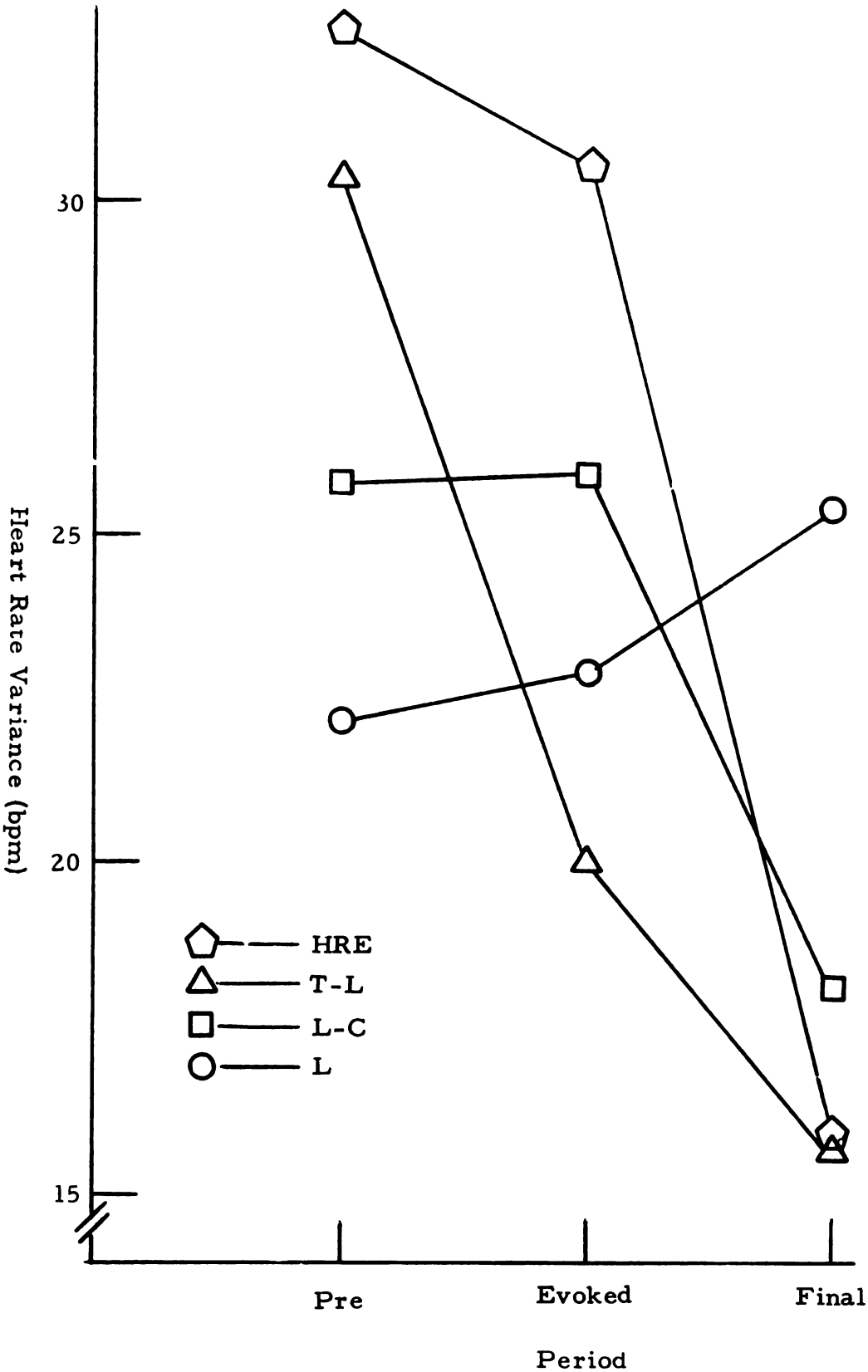


Figure 5 - Mean Heart Rate Variance as a Function of Periods for Groups



The T-L group had the greatest decrease from the pre to the evoked period, while the L group had only a slight variance change in an increasing direction. These group differences were revealed in a significant Groups X Periods interaction, $\underline{F}(6, 88) = 2.60$, $\underline{p} < .025$ (see Table 4).

The sec.-by-sec. HR measures during the first 10 sec. following the onset of each trial were averaged over the 10 trials and the AOV summary for the HR during the evoked period is shown in Table 5. The dominant feature of the evoked HR response was a pronounced deceleration during the first three sec. of the period followed by a return to pre-stimulus level and then a slight deceleration during the last five sec. The reliability of this pattern was supported by a significant difference among the seconds, $\underline{F}(9, 396) = 2.1$, $\underline{p} < .05$. Figure 6 presents the evoked HR response average over the 10 trials for each group as a function of seconds. The HR values were expressed as changes from the last sec. of the pre period. The evoked HR response for all groups except the HRE group was a pronounced deceleration as indicated by a significant Groups X Seconds interaction, $\underline{F}(27, 396) = 1.51$, $\underline{p} < .05$. The shape of the evoked responses appeared to be different. The T-L and L-C groups had similar shapes, with maximum deceleration during the second and third sec., followed by a slight acceleration over the pre-stimulus level on the fifth sec. and a subsequent deceleration below pre-stimulus level during the last five sec. of the period. The HR responses for HRE and L groups were mirror images. The HRE group reached maximum HR during the

Figure 6 - Mean Heart Rate as a Function of Seconds for Groups during the Evoked Period

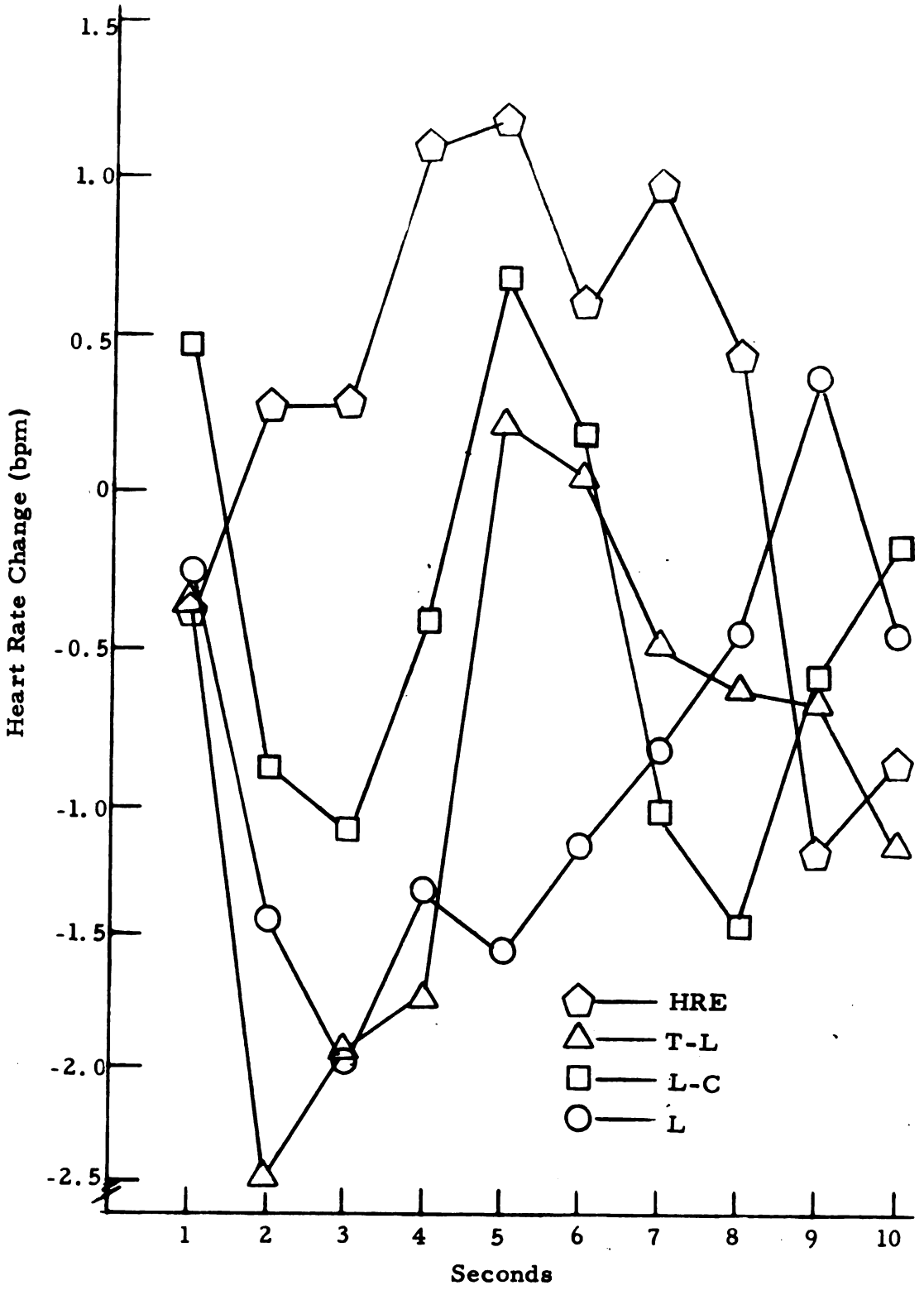


Table 4. - Analysis of Variance of Heart Rate Variance as a Function of Groups for Periods over Trials

Source	SS	df	MS	F
Groups (G)	3698.11	3	1232.70	<1.00
Error (between)	437655.11	44	9946.71	
Trials (T)	21847.38	9	2427.49	2.15*
Periods (P)	19676.27	2	9838.13	8.19***
T X P	17991.04	18	999.50	1.04
G X T	19408.12	27	718.82	<1.00
G X P	18804.36	6	3134.06	2.60*
G X T X P	56090.30	54	1038.71	1.12
Error (T)	444710.04	396	1123.01	
Error (P)	105659.80	88	1200.68	
Error (T X P)	788286.28	792	995.31	
Total	1933826.72	1440		

*** p .001
* p .05

Table 5. - Analysis of Variance of Heart Rate as a Function of Groups over Trials for the Evoked Period

Source	SS	df	MS	F
Groups (G)	950.72	3	316.91	<1.00
Error (between)	31970.12	44	726.59	
Trials (T)	2115.04	9	235.00	<1.00
Seconds (S)	800.62	9	88.96	2.10*
T X S	1759.63	81	21.72	<1.00
G X T	9684.48	27	358.68	1.25
G X T X S	4640.42	243	19.10	<1.00
G X S	1733.86	27	64.22	1.51*
Error (T)	113530.17	396	286.69	<1.00
Error (S)	16780.89	396	42.38	
Error (T X S)	81770.33	3564	22.94	
Total	265736.28	4800		

* p .05

the fifth sec. and a minimum HR on the ninth sec. The L group reached minimum HR during the second sec. and maximum HR on the ninth sec.

Estimate measures. -- The mean HR of the Ss in the HRE group was correlated with the Ss' mean absolute error of the estimate. A Spearman r = .75, between the ranks of the error and the ranks of the actual HR indicated a strong positive relationship between HR and magnitude of error. The rates of the intermittent tones presented to the Ss in the T-L group were correlated with the mean absolute deviation of the estimate from the actual rate. A Spearman r = .86, between the ranks of error and the ranks of rates at which the tones were presented also indicated a strong positive relationship between the rate of the tone and the magnitude of the error of the estimate. Both groups maintained approximately constant percents of error regardless of the rate of the stimuli to which the Ss attended, 8% for the T-L group and 37% for the HRE group, the difference between the two groups was significant, $t_{22} = 5.3$, $p < .001$. The percent of trials in which Ss underestimated was different between the two groups, 93% of the trials in the HRE group were estimates lower than the actual HR while only 62% of the trials in the T-L group were estimates lower than the actual rate of the tone.

The results of the number of flashes each S in the L-C group recorded were not analyzed although the instructions implied that the S's ability to accurately record the number of flashes was being measured.

Discussion

Although the respiration measurements failed to differentiate between the groups, there were significant period differences. All of the groups exhibited increases in respiration frequency as a function of periods and decreases in respiration amplitude following the onset of a trial. This finding is not in accord with the results reported by Lynn (1966) who stated that regardless of the intensity of the stimulus, the respiratory components of the OR were associated with a pause, followed by increases in amplitude and decreases in frequency. However, Polezhaev (1965) reported increased respiration frequency and decreased amplitude in an experiment presenting neutral stimuli to dogs. Although their results differed, Lynn and Polezhaev state that regardless of the intensity of the stimulus the OR has the same respiratory components. These differences may be based upon the experiments they used to support their hypotheses. Lynn (1966) based his statement upon Davis et al. (1955) who employed high intensity stimuli, while Polezhaev (1965) based his statement upon a study by Balakin who employed neutral stimuli. From the comparison of these two studies it appears that stimulus intensity might affect the respiratory components of the OR. The present study using neutral stimuli found respiration frequency increases and amplitude decreases similar to Polezhaev's conclusion.

There were no mean HR differences between the groups or

between the periods. This may indicate that the period differences found in respiration amplitude and frequency did not affect mean HR. HR variance was found to decrease as a function of trials. This result is consistent with the findings of Davis et al. (1955) and Meyers and Gullickson (1967), and it is not in accord with the results obtained by Lang and Hnatiow (1962). Lang and Hnatiow concluded that the peak-to-trough index, a variability measure, was resistant to response decrement. In the present study the HR variance decreased as a function of trials, and decreased across the three periods of the trial. This finding supports Lacey's (1967) observation that increased cardiac stability occurred during attention. All of the groups except the L group exhibited a large decrease in HR variance from the pre to the final period. This might indicate that there is a relationship between HR variance and the degree of subject involvement while attending.

The decelerative component of the evoked HR response in the T-L, L-C, and L groups in the initial seconds of the trial is consistent with the findings of other investigators (Lacey, 1959; Graham & Clifton, 1966; Chase & Graham, 1967). The evoked acceleration of the HRE group may be interpreted as confirmation of Lacey's (1959) hypothesis that HR acceleration leads to inhibitory effects on environmental inputs. Contradicting the Johnson and Campos (1967) hypothesis that conditions requiring rejection of the environment are not associated with specific physiological changes, but that the changes

attributable to a verbalization requirement of the tasks, this study demonstrated that HR acceleration occurred during the process of internal observation in which neither overt or covert verbalization is required. The Ss instructed to attend internally to perceive their own HR presumably blocked the external environment. According to Lacey this rejection of the external environment is concomitant with cardiac acceleration.

The respiratory and HR components of attentive observation to external, neutral stimuli found in this study may be summarized as increased frequency and decreased amplitude of respiration, decreased HR variability, and an evoked decelerative HR. Repeated stimulation did not effect the respiratory component but did decrease the mean HR and HR variance. Attentive observation of internal stimuli produced effects on respiration and HR variance which were similar to those produced by attentive observation of external stimuli. However, the average evoked HR response to the first 10 sec. of the task of HR estimation was accelerative.

A comparison of the accuracy of the estimates of the intermittent tones (an external stimulus) with Ss' estimates of their own heart rates (an internal stimulus) indicated that external stimuli were estimated more accurately. Interestingly, both groups maintained a constant percent of error regardless of the actual rate of the tone or the actual heart rates. There was a very high correlation between the rate of the stimulus to which the S was attending and the magnitude of

S's error.

One of the objectives of this study was to investigate the relationship between respiration and HR. From the data presented in this study it appears that HR changes may occur independently of respiration changes. When neutral stimuli were used in this study independent HR and respiration changes occurred in the HRE group in which increases in respiration frequency and decreases in respiration amplitude and HR variance decreases were similar to the other groups, but unlike the other groups the evoked HR response in the HRE group was distinctively accelerative.

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