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ABSTRACT

Twenty normal newborns, approximately 36 hours old, were tested using an auditory temporal conditioning paradigm which consisted of a slow rise, 75 db tone played for five seconds every 25 seconds, ten times. Responses to the tones were measured by instantaneous, beat-to-beat heartrate; and the test trial was designated as the 2 1/2-second period following the last stimulus when a tone would have been expected. Two learning groups were defined: those subjects who gave significant responses on the test trial, regardless of direction, and those who did not respond. A 2 x 11 x 3 x 3 analysis of variance was run on the heartrate data with the 2 learning groups, 11 trials, 3 conditions (anticipatory response, response to onset of tone, and response to offset of tone) x 3 heartbeats (the slope of the three heartbeats associated with the responses to the tone, summed across the three conditions). Although the groups main effect only approaches significance (p<.08), the trial x beats interaction (p<.04) shows that the first trial startle pattern is followed by decreases in trials 2-4 and habituation in trial 5. Findings show that it is possible to obtain HR decelerations in newborn babies to a temporal conditioning paradigm and that the HR curves for newborn learning behavior are similar to those found in older subjects. (Author)

AUDITORY TEMPORAL CONDITIONING IN NEONATES

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The purpose of this study is to examine temporal conditioning in the newborn baby. Although there has been some dispute as to whether newborn babies are capable of exhibiting learning behaviors (Sameroff, 1971 & 1972), a number of researchers have demonstrated that newborn babies will learn using a temporal conditioning paradigm (Clifton, 1971; Lipsitt & Ambrose, 1967; Stamps, 1974). These findings are in keeping with Brackbill and Koltsova's (1967) contention that temporal conditioning should be the earliest obtainable form of learning. This technique is particularly useful in conjunction with heart rate deceleration as a measure of orienting (Graham & Clifton, 1966), in the presence of which learning occurs. This study makes use of the habituation paradigm, which has been described by Charlesworth (1964) as "surprise" in the face of disconfirmed expectation which elicits attentional mechanisms.

Method

The learning task consisted of a temporal conditioning paradigm with a slow-rise, 75 db tone played for five seconds every 25 seconds, ten times. (See slide 1.) The test trial was defined as the 30-seconds following the last stimulus trial when the 11th stimulus would have been expected. Thus, the violation of expectancy, results in orienting, or heartrate deceleration. The particular tone was chosen because it was most apt to elicit heartrate decelerations in the newborn baby (Hatton, Berg & Graham, 1970; Jackson, Kantowitz & Graham, 1971). All sessions occurred approximately one hour to 30 minutes prior to the 10 p.m. feeding when the babies were in a quiet-awake state, as defined by Brackbill and Fitzgerald (1969). Heartrate data obtained prior to eating and when the child is in a quiet-awake state are more apt to produce heartrate decelerations (Kearsley, 1973; Pomerleau-Malcuit & Clifton, 1971). The electrocardiogram was transmitted using telemetry equipment. It was recorded for 20 seconds prior to the onset of the learning task, in order to measure pretrial, resting, heartrate variability. The learning session lasted for 5½ minutes, the maximum time that the majority of subjects could be expected to maintain an alert state as shown by Berg, Adkinson, and Strock (1973). Thus, every effort was made to facilitate the baby's ability to produce orienting responses to the stimuli.

Twenty three-day-old babies (ten boys and ten girls) were selected from the newborn nursery at West Virginia University Hospital. Only those infants were included who were normal, healthy and full-term. All testing was done on the third day after birth in a laboratory adjacent to the nursery.

All data were stored on magnetic tape and then fed into a PDP-11 computer, which accummulated elapsed time; computed the interval between two succeeding heart beat pulses in milliseconds (the beat-to-beat interval), and computed the reciprocol of each interval in units of heart beat per minute (instantaneous heart rate). This information was transferred onto IBM compatible digital tape for processing by the IBM 360 computer system. The Cardivar program for analysis of variance for cardiac data, as developed by Wilson (1974) and Wilson and Scott (1970) was modified for use with the SAS Program package.

The heart rate data were analyzed using three periods of time associated with each trial: (See slide 2.) the anticipatory response period (2½ seconds prior to onset of the sound stimulus), the response to onset (2½ seconds following onset of the sound stimulus), the response to offset (2½ seconds following offset of the sound stimulus). The test trial was analyzed using mean heartrate change between anticipatory and onset periods.

Results

Graham and Clifton (1966) have established that heart rate decelerations are a measure of orienting in older subjects. However, Graham and Jackson

(1970) have suggested that heart rate decelerations do not have the same psychological significance in infants as they do in the older sumjects. For this reason, the analysis of variance was run twice. A median split was done using the directional test trial response. Thus, two groups were compared: those who responded on the test trial with HR accelerations and those who responded with HR decelerations. The second analysis formed the two groups on the basis of magnitude only with directional signs removed. Two 4-way analysis of variance programs were run with 2 groups, 10 trials, 3 conditions (anticipatory, onset and offset periods), and 3 beats (the 3 heart beats associated with each condition, measured across conditions). The main effect of group, in the analysis based on the directional test trial responses, was not significant. However, in the analysis of groups based on the magnitude of the test trial response, the group effect approached significance ($p < .08$). The over-all mean heart rate for responders was 128 bpm, while for non-responders, it was 141 bpm. Thus, those infants who responded to the test trial had an overall lower heart rate across the conditioning session then those who did not respond. All of the subsequent discussion will be based on this analysis of variance program using response magnitude.

Although the group x trial interaction only approached significance ($p < .09$) its graph is worth investigating. (See slide 3.) If we assume that the subjects who responded on the test trial learned the temporal pattern, the learning presumably occurred in conjunction with the heartrate decrease, the orienting response. The learners' curve is similar to those observed in older subjects during problem solving tasks (Lacey, Kagán, Lacey & Mass, 1962; Lewis & Wilson, 1970). Lewis and Wilson (1970) observed a significant HR deceleration during a perceptual discrimination problem in four-year-olds. The HR rapidly returned to the resting rate after the problem was solved. It is tempting, in looking at the learners' curve, to designate the decreasing slope of trials 2 - 5 as the learning phase, with trial 5 as the trial on which the temporal pattern was learned, since it is followed by a HR increase in trials 6 and 7.

Unfortunately, we have no direct behavioral evidence for the moment at which the newborn baby acquires knowledge about the temporal pattern. However, we have available, some indirect evidence from the habituation literature. Habituation can be used to pinpoint the moment of learning, since presumably the organism ceases responding because knowledge has been acquired (Petrinovich, 1973; Worden, 1973). Using heart rate data (Graham, 1973), this point is marked by the point at which orienting (HR decelerations) give way to blocking (HR accelerations). (See slide 4.) The trial x beats interaction (which is significant) shows this pattern clearly. The beats shown here have been summed across conditions for each trial. Trial 1 shows a clear startle pattern. Trials 2, 3, and 4 show, predominantly, the orienting response. Trial 5, which is located at the lowest HR point, is the first pattern since Trial 1, that is predominatly accelerating, while Trials 6 and 7 are clearly accelerating. This pattern is what one would expect in order to argue that the newborn HR responses in a learning situation are similar to those found in older subjects. Evidence that this comparison can be made comes from the symposium: Classical Conditioning and Cognitive Processes, where both Lockhart (1973) and Epstein (1973) emphasize the importance of cognitive processes in the expectancy of the temporal pattern. Thus, I would argue that when the conditions for conditioning are properly controlled for newborn babies, these young subjects can demonstrate learning patterns similar to those of older subjects.

It should be pointed out that the groups x trial x beat interaction was not significant ($p < .11$). We have no direct support that this learning pattern differentiates responders from non-responders on our learning task. However, the learning pattern for the responders is very similar to the over-all pattern we see here; whereas, the pattern for non-responders was quite different and impossible to interpret using habituation mechanisms.

Another interesting point is the spontaneous reinstatement of the orienting response, once again, at a low point in over-all heart rate. Petrinovich (1973) has pointed out that spontaneous reinstatement of responding, after habituation, often occurs in the natural environment, particularly if the stimulus is important to the subject. It is clear from this data that orienting during learning, is associated with a lowering of the heart rate.

In the second analysis, a median split was run on the pretrial, resting, heart rate variability, and these groups were substituted for the response groups in the group x trial x condition x beats analysis of variance. In this analysis, the main effect of group is not significant. The HR variability x beats interaction is significant. (See slide 5.) As you can see, the infants with high HR variability have over-all lower heart rates, and these have the tendency to decelerate. The group x condition x beats interaction only approaches significance; but it shows, in more detail, the differences between low and high HR variability subjects. (See slide 6.) Those infants with high HR variability show orienting patterns to the onset response while the infants with low HR variability show orienting responses to the anticipatory condition, and, to some extent, in the offset condition. Thus, these groups seem to be differentiated by the conditions under which orienting responses will occur. Possibly, for the low HR variability subjects, the tone is noxious and tends to be blocked out; while for the high HR variability subjects, the tone is sufficiently stimulating to elicit responding.

Porges and his colleagues (Porges, Arnold, and Forbes, 1973; Porges, Stamps, & Walter, 1974) have found that a higher, resting, pre-trial, HR variability was associated with more mature response patterns. This was supported by the developmental findings of Lewis, Wilson, Ban & Baumel (1970), who found that increased HR variability and lower heart rate were found in the more mature newborn infants. Thus, this study supports other findings that high HR variability is related to the ability of the infant to respond to stimuli, and therefore, to learn.

Discussion

It should be noted that, although magnitude was the most useful for differentiating our subjects, this study is not able to assess the importance of the directional HR response. Our groups of subjects responding with accelerations and decelerations included all those subjects, whose directional change was not a significant one; that is, the groups included those subjects who did not give a significant response. Ideally, we should have divided our group of responders (based on magnitude only) by direction. This would give us subjects who responded with a significant directional response only. However, we did not have a large enough number of subjects in each group to run such an analysis. Thus, this study cannot resolve the issue of directional responding in newborn babies. To do so would require a larger subject population.

This study does show that it is possible to obtain HR decelerations in newborn babies to a temporal conditioning paradigm. In addition, it suggests that the HR curves for newborn learning behavior are similar to those found in older subjects. The trends in the data suggest that those who learn have higher resting, pretrial, HR variability and lower, over-all rate then those subjects who do not learn a temporal pattern..

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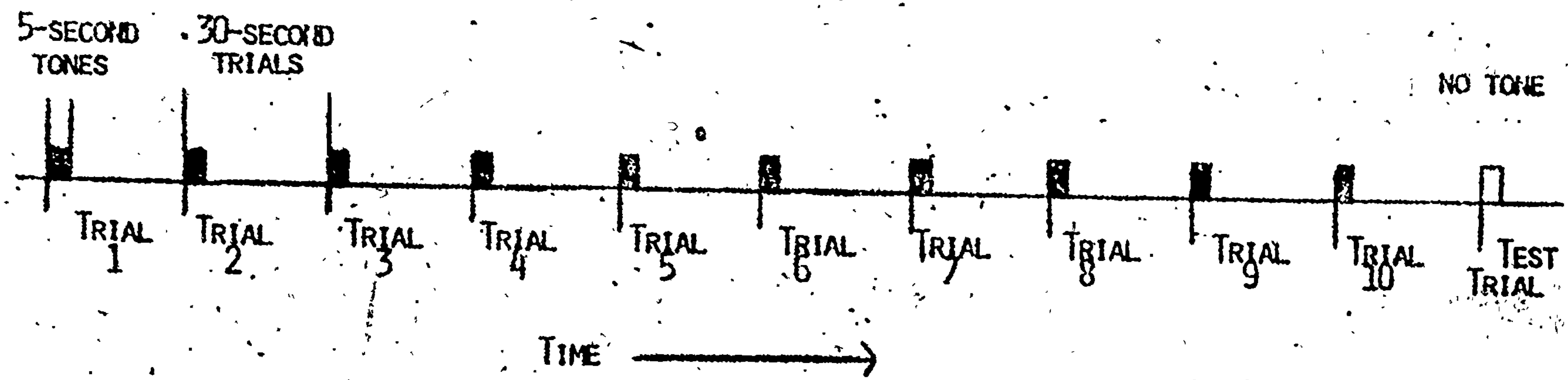
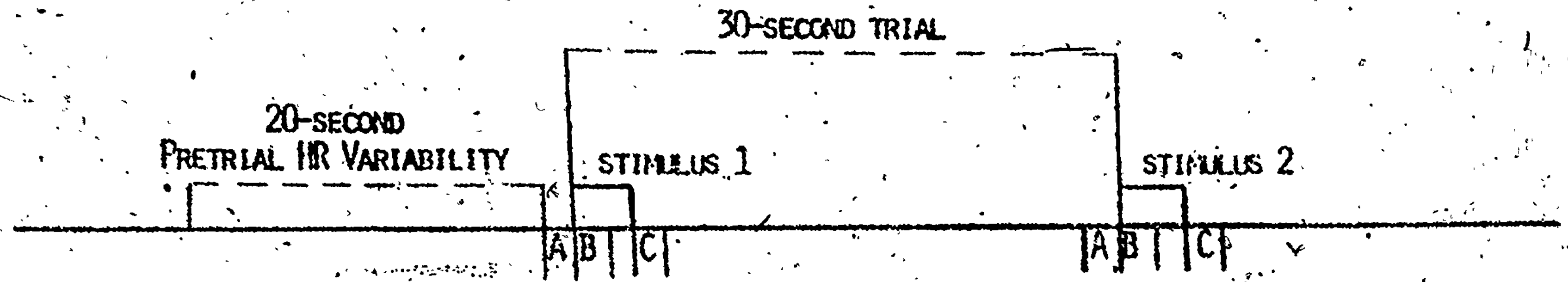
SLIDE 1

EXPERIMENTAL DESIGN FOR TEMPORAL CONDITIONING



SLIDE 2

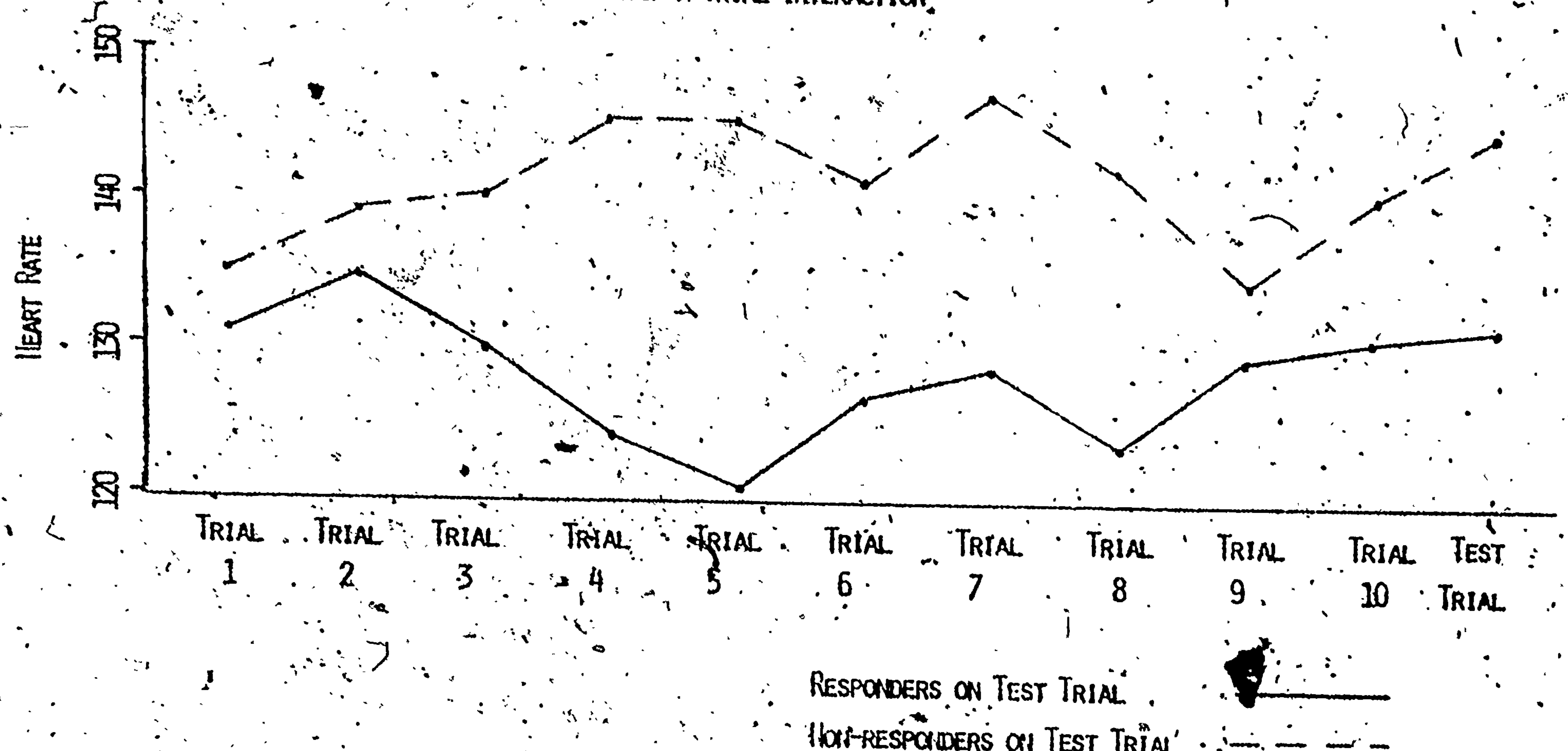
DATA ANALYSIS - RESPONSE TIME PERIODS



A - ANTICIPATORY RESPONSE TIME PERIOD
B - ONSET RESPONSE TIME PERIOD
C - OFFSET RESPONSE TIME PERIOD

SLIDE 3

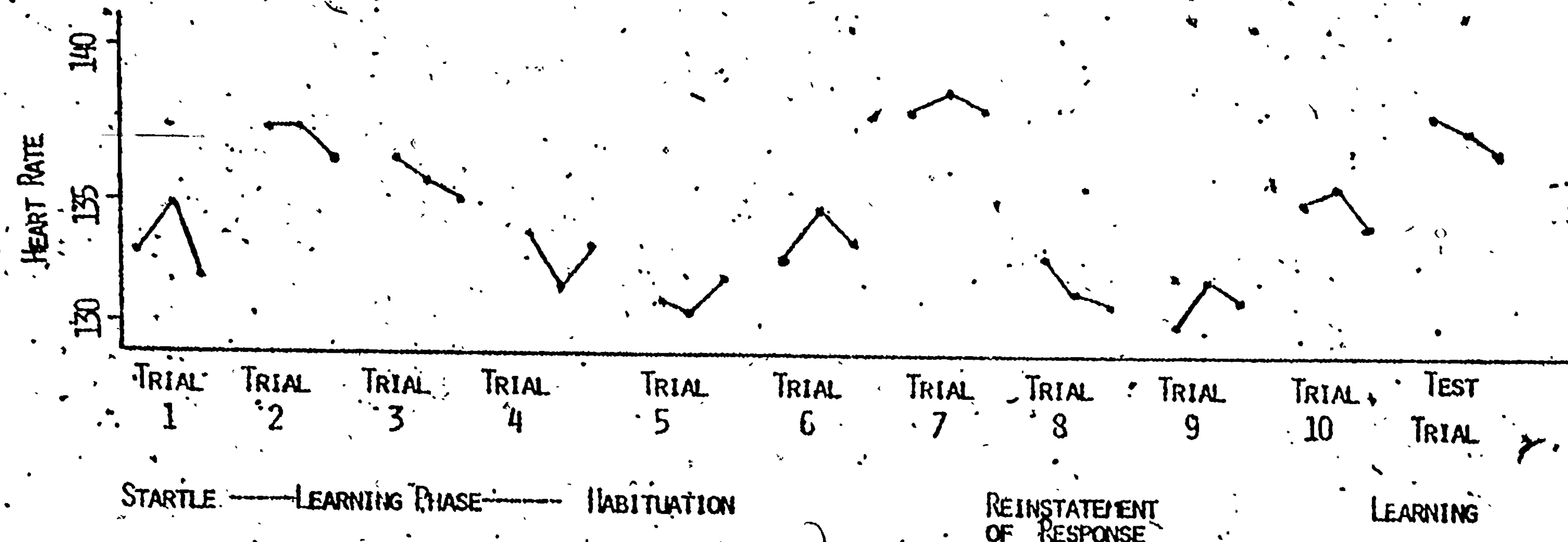
GROUP x TRIAL INTERACTION



$p < .09$

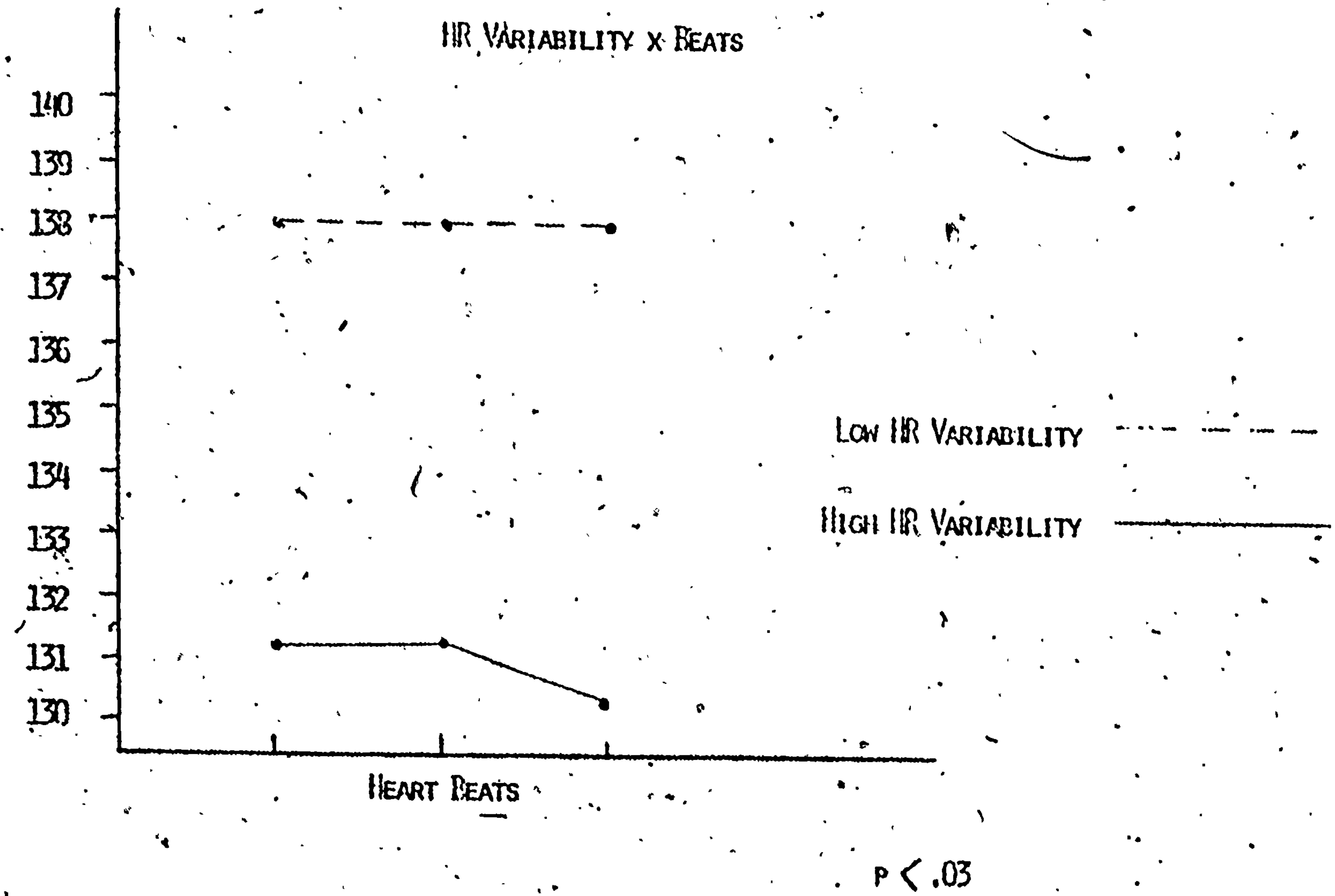
Slide 4

Trial x Beats Interaction



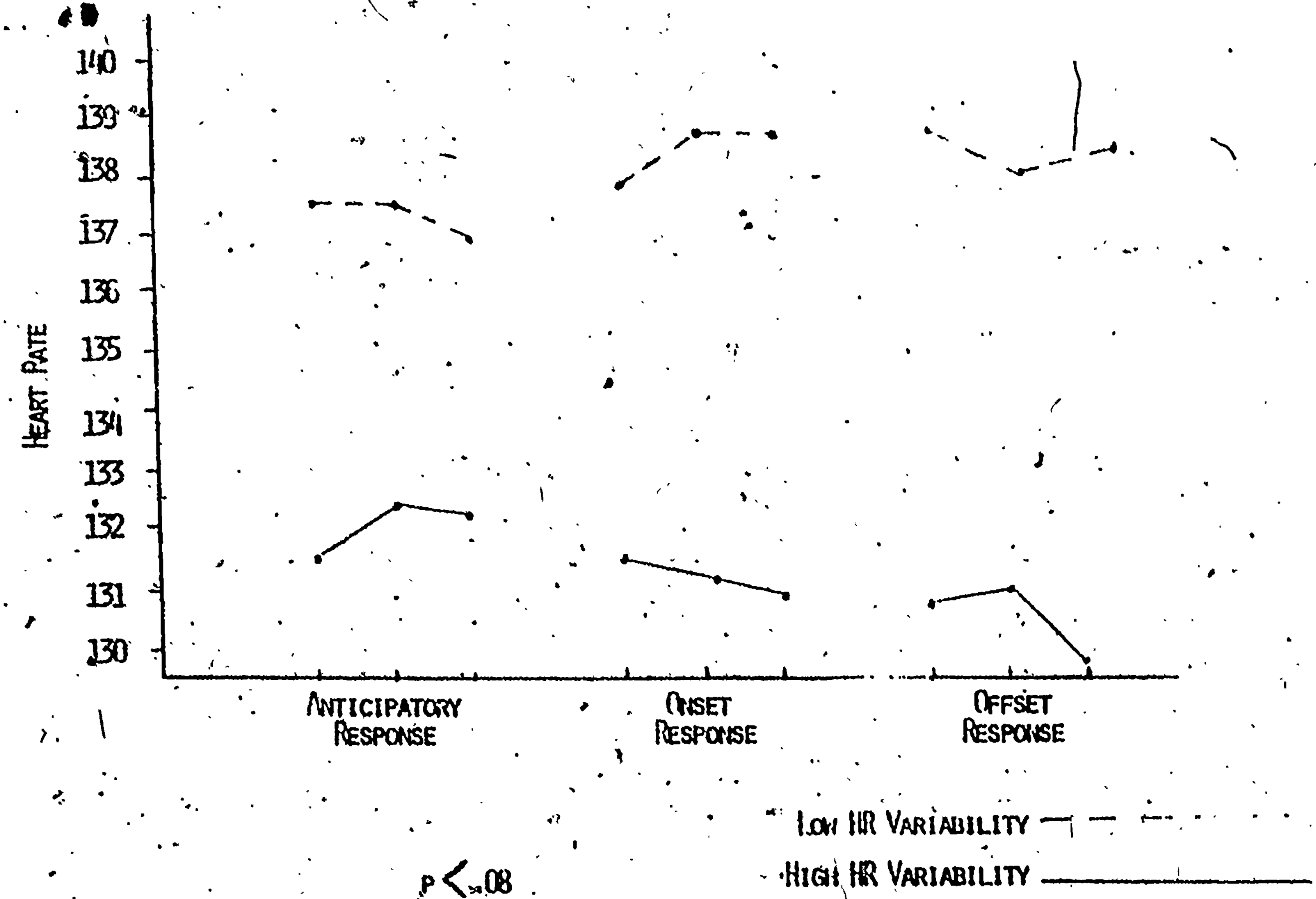
$p < .04$

SLIDE 5


HR VARIABILITY x BEATS
HEART RATE
140
139
138
137
136
135
134
133
132
131
130
HEART BEATS
LOW HR VARIABILITY
HIGH HR VARIABILITY
P < .03

SLIDE 6

HR VARIABILITY X CONDITION X BEATS



$p < .08$