T H E   U N I V E R S I T Y   O F   H U L L

DISCRIMINATION OF CARDIAC ACTIVITY

BEING A THESIS SUBMITTED FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN THE UNIVERSITY OF HULL

BY

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JULY, 1987.

ACKNOWLEDGEMENTS

Firstly, I would like to gratefully acknowledge the British Council for providing the financial support without which this thesis would not have been possible.

My sincere thanks to Professor Jasper Brener. I couldn't have wished for a better supervisor.

I am also greatly indebted to my family, friends and colleagues who have given much help and encouragement throughout my postgraduate course and made my stay in Hull an enriching experience. Suzanne Mitchell deserves a special mention for typing the Bibliography.

Finally, many thanks to the volunteers who participated in these experiments.

ABSTRACT

This thesis is concerned with techniques for assessing the ability of individuals to detect internal sensations of heartbeats. In order to investigate this issue, a series of experiments was undertaken to examine certain procedural features of conventional heartbeat detection (HBD) tasks. This led to the development of an objective procedure for HBD assessment which was based on individual difference methodology. This procedure was employed to test several hypotheses about individual differences in heartbeat detection ability.

The first chapter presents a brief view of the nature and incidence of visceral sensation and introduces some research issues relevant to the study of visceral perception. In light of this, a critical account of the development of procedures employed to assess cardiac perception is presented in Chapter Two. After several unsuccessful attempts to quantify cardiac perceptual ability using paper-and-pencil tests, there was a move towards the development and use of objective techniques for measuring HBD.

A variety of new procedures were devised and employed primarily in the investigation of the role of individual differences in the ability to detect heartbeats. The wide variability among the techniques corresponded with an equivalent degree of variability in published results, hence, preventing clear inter-task comparisons. This problem of the lack of standardization of HBD procedures is raised in Chapter Three where it is argued that the role of individual

differences in heartbeat detection cannot be addressed until issues concerning the validity and reliability of HBD procedures are properly resolved.

The experimental work presented evaluates the essential features of the conventional HBD paradigm, beginning with tests using noncardiac stimuli of whether individuals are capable of making the temporal discriminations required in HBD procedures. The results provided evidence of very accurate temporal discrimination. However, this level of performance was not reflected in performance on a task involving the detection of internal cardiac stimuli. On the basis of the findings it was proposed that poor performance on the HBD tasks could be attributable to the practice in standard HBD procedures of using a single arbitrarily defined criterion for the occurrence of a heartbeat.

Hence, a HBD procedure was developed which did not impose *a priori* judgements of which events the individual will employ in detecting heartbeats. This procedure generated reliable and unambiguous evidence that individuals were detecting as heartbeats, events that occurred 200 to 300 milliseconds after the R-Wave of the cardiac cycle.

The procedure was considered a suitable basis for an unbiased test of heartbeat detection and was used to test the individual difference variables mentioned in Chapter Three. The results of those tests led to speculations about the possible sensory pathways mediating the perceptions of heartbeat sensations and are also discussed in relation to published findings from studies employing other HBD procedures.

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CHAPTER ONE

VISCERAL PERCEPTION

INTRODUCTION

This thesis is concerned with the assessment of visceral perception in individuals. Operationally defined, the term 'visceral perception' refers to the detection and labelling of sensory information generated by the viscera. This implies the the existence of a visceral afferent system comparable to the somatomotor afferent system. Experimental investigation of the visceral afferent system reveals the existence of a highly organized sensory system (Newman, 1974) functioning similarly in many ways to the somatomotor afferent system. Some direct evidence of visceral afferentation includes the elicitation of EEG changes in response to visceral stimulation (Bonvallet, Dell and Hiebel, 1954; Adam, 1967) and demonstrations of the classical conditioning of the viscera (Razran, 1961) using interoceptive conditioned stimuli (CS). That finding that the use of interoceptive CS supports differential classical conditioning is convincing proof that the viscera are capable of initiating afferent impulses.

However, although the existence of visceral innervation is necessary for the awareness of visceral functions, the apparent limitations of visceral perception suggests that the visceral afferent system is not sufficient to provide a visceral perceptual capacity equal to that of say, environmental or proprioceptive perception. Perceptual differences apparent between visceral and somatomotor states seem to be attributable mainly to differences in the physiological characteristics of the visceral and somatomotor afferent systems. In an attempt to explain the effects of those differences, some functions and manifestations of visceral perception in everyday life will be briefly examined as will two experimental contexts in which visceral perception research has been conducted.

1.1 Some Common Evidence of Visceral Perception

(i) Symptom Reporting

Individuals take medication and visit doctors based on their perceptions of changes in the state of their bodies. Where external stimuli such as lesions, discolorations or swellings are obvious to the individual, the correspondence between the source of aberration and symptom reports is very high compared to when the offending stimulus is internal. Perceptions of internal sensations may be compromised by physiological limitations placed on the specificity of interoception such as the relatively small area in the cortex that is made available for analyzing visceral information compared to that allocated for the processing of somatic information (Chernigovskiy, 1967). Chernigovskiy also adds that overlapping of visceral and somatic afferent pathways could contribute to the diffuse nature and poor localization of sensations from the viscera. The effects of these factors are illustrated in the incidence of visceral sensation and visceral pain.

Visceral pain is often characterised by a dull and aching sensation produced by the inflammation or injury of internal organs. In some cases, the location of reported pain symptoms can lead directly to the identification of the affected organ as when severe deep pain in the lower right hand side of the abdomen is associated with appendicitis. In other cases however, an irritation of a viscus produces pain which is not felt in the viscus but in some somatic structure located far from the source of sensation. Such pain is said to be referred to the somatic structure. A typical example of referred pain is 'angina pectoris' where cardiac ischaemia causes intense pain which is felt in the chest and along the inner left arm.

The mechanisms of referred pain are explained by various theorists and one explanation which has received substantial experimental support (Cervero, 1980; 1985) is the Convergence-Projection theory of Ruch (1946) based on hypotheses made by Head in 1893. This theory suggests that visceral afferent fibres converge with cutaneous pain afferents to end upon the same neurones in the sensory pathways. As somatic pain occurs more frequently than visceral pain, the resulting impulses on reaching the brain are interpreted as having come from the skin, (an interpretation which has been learned from previous experience in which the same pathways were stimulated by cutaneous afferent fibres) and the pain is referred to the skin. This view that visceral afferent fibres do not convey information to specific visceral sensory pathways but converge onto somatosensory pathways supports the evidence of interconnections between visceral and somatic afference mentioned earlier. Furthermore, visceral pain can be both local and referred with the pain radiating from the local site to the referred location. Also, reference sites are not always the same and unusual sites often occur. To summarize, the characteristics of dullness, referral and poor localization, typical of visceral pain, present an example of how the organization of the visceral sensory pathways may affect the accuracy of visceral perception.

(ii) Biological Sensations

Whenever individuals change their behaviour in response to variations in the body's internal environment, they exhibit evidence of visceral afferent processing. Sensations from visceral organs are regularly being elicited in the course of routine visceral activity and provide information upon which the brain can act by initiating appropriate behaviour. For example, information relayed from afferents in the lower urogenital and gastrointestinal tracts confers the ability to detect sensations related respectively to the fullness of the bladder and the bowel.

Other internal sensations which individuals perceive and react to include hunger and thirst. Several theories have been proposed to explain the mechanisms underlying the experience of hunger. Some of those theories suggest that sensations of hunger are due to the production by 'hunger pangs' caused by strong contractions from an empty stomach (Cannon and Washburn, 1912; Carlson, 1912), changes in blood glucose levels (Mayer, 1955) and thermal changes in the hypothalamus (Brobeck, 1955). Noticeably, central to all these explanations is that the perceptions are elicited via interoceptive afference. This is also true for some of the hypotheses proposed to explain the subjective awareness of thirst. Sensations of thirst has been explained by the various mechanisms through which the body detects changes in the concentration of body fluids and cellular dehydration and initiates drinking behaviour to regulate the body's water balance. Those mechanisms can be the sensations of dryness derived from the dehydration of mucosal areas in the mouth and throat as a result of decreased salivary flow (Cannon, 1918) or from osmotic interoceptors Verney (1947) which detect changes in the salt concentration of blood.

In addition to the perception of such sensations are those which are correlated with the specific timing and nature of chemical and hormonal changes in the body which are manifested behaviourally and psychologically as the premenstrual syndrome thereby providing evidence of chemoreceptive perception in female humans (Little and Zahn, 1974).

This brief resume of some common evidence of visceral sensations demonstrates the frequency and intensity with which they occur in daily functioning. Although we are able to detect these sensations and exhibit the appropriate adaptive behaviour, we do not tend to attribute our actions to visceral perception. Brener (1977b) suggests that this unawareness of visceral perception is largely accounted for by our inability to express these sensations appropriately. When expressed verbally, visceral perceptions are usually referred to in terms of how they affect our consciousness and not in terms of the internal stimuli or interoceptors involved. For example, we usually talk of feeling hungry, restless or agitated without the awareness that these sensations have arisen from visceroceptors or are the effects of internal stimuli acting upon visceroceptors mainly because we have not learned to label internal stimuli or localize interoceptors.

1.2 Two Research areas in Visceral Perception

Training individuals to detect and label their visceral activity has been an expanding area of psychophysiological investigation for many years. Initially, this work was confined mainly to research relating to the psychology of emotions where procedures that manipulated the detection of physiological changes could be used to test the theories of emotion which emphasized the perception of these changes (James, 1890; Wenger, 1950). With the advent of biofeedback research, visceral perception and visceral control training processes were also employed as therapeutic strategies in the management of maladaptive behaviours such as stress (Goldfried, 1971) and alcoholism (Silverstein, Nathan and Taylor, 1974). Research relating to theories of emotion and the control of autonomic activity has generated and significantly influenced experimental work relating to the ability of individuals to perceive visceral activity. The following sections will examine a selection of those experimental studies which investigated the relationships between visceral perception and emotion and visceral perception and the control of cardiac events.

(i) Visceral perception and Emotion

Theoretical basis

In very simplified terms, James' theory of emotion (1884) proposed that the percption of visceral activity constituted the experience of emotion. According to this theory, when individuals perceived a particular combination of physiological changes (such as a drastic increase in heart rate and profuse sweating and body tremor) in response to a stimulating event, they labelled these changes as an emotion (in this case, Fear). Severe criticism of James' theory came from Cannon (1927) who amongst others objected to the idea that specific bodily changes correlated with specific emotions. These criticisms reduced the theory into relative insignificance until its revision by Schachter and Singer (1962) after a systematic examinination of the influence situational factors had on individuals' emotional experiences.

In one of a series of studies those workers injected naive subjects with adrenaline, an arousal-inducing hormone and introduced them into experimentally created emotive situations. Schachter and Singer found that the drugged subjects tended to react more emotionally in these situations than other subjects who had not been given the hormone and subjects who prior to the injection of adrenaline had been informed of the expected effects of the drug on their bodily reactions. The results from Schachter and Singer's studies provided evidence of the close link between visceral perception and emotion. However, the findings supported Cannon's critique that specific sets of autonomic responses could not be associated exclusively with distinct emotional experiences and also that identical patterns of physiological activity could be manifest in different emotions. They concluded that individuals on detecting variations in visceral states and activity, tend to label the experience as an emotion which is cognitively compatible with the social context within which the experience occurs.

The Experimental study of Visceral Perception and Emotion

Schachter and Singer's findings revived interest in further testing of Jamesian theories and much of the research examined the relationship between visceral sensitivity and the accuracy of subjective reports of emotional experience. The Autonomic Perception Questionnaire (APQ), developed by Mandler, Mandler and Uviller (1958) was one of the first tests employed to obtain a measure of individuals' reports of their emotional and anxiety states with reference to the perception of their internal bodily activity. The APQ is composed of 30 items divided into two sections dealing with the perception of bodily reactions during experiences of pleasure (9 items) and anxiety (21 items). The items also covered seven areas of bodily reactions, namely; heart rate, respiration, perspiration, body temperature changes, gastrointestinal disturbances, muscle tension and blood pressure. A measure of autonomic awareness involved scoring individuals' responses to items such as, "When you feel anxious, how often are you aware of any change in your heart action ?" on a 10-point interval scale from zero (low perceptivity) to 9 (high perceptivity).

Mandler and his colleagues submitted 19 high and 13 low scorers on the APQ anxiety items to three stressful tasks while monitoring their physiological reactions. Correlations between subjects' APQ scores and physiological measures led to two main conclusions. Firstly, that high scorers showed significantly greater autonomic activity than low scorers and secondly, high scorers tended to overestimate their autonomic responses while low scorers tended to underestimate theirs. These results suggest that in emotive situations individuals are aware of changes in their autonomic system to some extent but tend to report these changes inaccurately.

The suggestion that people who report more intense feelings of emotion on the APQ exhibit better visceral perception than those who report less emotional feelings was explored further by other researchers employing different measures of autonomic perception and different assessments of emotional experience. Schandry (1979; 1981), Hantas, Katkin and Blascovich (1982) and Montgomery and Jones (1984) tested the common hypothesis that subjects who reported experiencing high levels emotionality in emotion-inducing situations would also be more sensitive to their heartbeats than subjects who report feeling less emotion in the same situations.

Schandry (1981) tested subjects' accuracy at detecting and counting their heartbeats under three separate conditions of physical and psychological stress and recorded their reported emotional state and 'emotional lability' from the State-Trait Anxiety Inventory (Spielberger, Gorsuch and Lushene, 1970) and the Freiburger Personlichkeits Inventar (Fahrenberg, Selg and Hampel, 1978), respectively. The results showed that good heartbeat detectors exhibited significantly higher measures of state anxiety and emotional lability than poor heartbeat perceivers. There was no difference between the groups' physiological measures, thereby providing evidence that the group differences were not a consequence of physiological differences between the groups.

Hantas et al. (1982) reported similar findings from their study designed to demonstrate that subjects who differed in their accuracy at detecting heartbeats would also differ in their reports of subjective reactions to unpleasant stimuli. Measures of subjects' heartbeat perception were obtained from their performance on a 40-trial heartbeat detection task developed by Katkin, Blascovich and Goldband (1986). Subjects' physiological and subjective reactions to slides of mutilated car-crash victims were also recorded. Good heartbeat perceivers rated themselves as more upset by the slides than poor heartbeat perceivers although both groups showed similar physiological change during the showing of the slides.

Thus both studies from Hantas et. al (1982) and Schandry (1981) provided evidence that accurate heartbeat detectors tend to report significantly more intense subjective emotional responses to noxious stimuli and in stressful situations than less accurate heartbeat detectors even though both groups show similar variations physiological activity in those situations. These findings seem to give credence to aspects of Jamesian and neo-Jamesian theories of emotion which stress the importance of visceral perception as a determinant of subjective affect.

Visceral Perception and the Control of Cardiac Events

Another application of Jamesian theory to the study of visceral perception was derived by Brener (1974) from James' ideo-motor theory of voluntary action (James, 1890). Brener's afferent process theory of biofeedback learning proposed that during biofeedback training, the primary function of external feedback is to identify and label sensory correlates of the target response. This function is known as 'calibration' and operates by forming a memory or response image of the target response which is then used as a template for the production of future responses. In other words, biofeedback enhances individuals' ability to discriminate visceral responses by identifying and labelling the sensory correlates of the visceral response. Two predictions arise from this theory: (1). Individuals who acquire the ability to control a response should also show a marked ability to discriminate that response and (2). Individuals who are trained to discriminate a response should show marked improvement in the ability to control that response.

This implies that the ability to discriminate the occurence of a visceral response is the necessary and sufficient condition for controlling that response. Numerous studies have been undertaken to test these predictions and the data have yielded equivocal results (see Brener, 1977a, 1980; Carroll, 1977 and Lacroix, 1981 for reviews). Such results could either suggest that Brener's theory is invalid or the presence of flaws, methodological or otherwise in the investigative studies. A brief summary of test results from some studies involving cardiac discrimination and control will be presented to evaluate the status of the research issue.

Obviously it is essential to consider how the two factors, cardiac (heart rate or heartbeat) discrimination and cardiac control (heart rate control) are defined and measured in those studies. The means available to assess cardiac discrimination are varied (they include paper-and-pencil tests, heartbeat tracking tasks and heart rate discrimination tasks) and there is some doubt of the extent to which all the methods examine the same capacity. The assessment of heart rate (HR) control is more standardized and is usually measured as the magnitude of change (ie. increase or decrease) individuals are able to effect on their heart rate upon instruction. This gross measure is interpreted as, the larger the change in heart rate magnitude in the required direction, the better the ability to voluntarily control heart rate. Heart rate control data from subjects tend to be similar across studies which suggests that procedural differences such as the number and duration of HR control trials do not affect performance appreciably. Heart rate increases are generally reported to be easier to effect than HR decreases with subjects managing on average to increase their heart rates by a magnitude thrice that effected for heart rate decreases.

Studies that have investigated the relationship between HR control ability in individuals and cardiac sensitivity to test Brener's predictions include those that employed self-report scales such as the APQ. Those studies have found a wide range of factors related to HR control. For example, Whitehead, Drescher and Blackwell (1975) reported correlations between scores on the APQ heart activity subscale and heart rate decrease but not with heart rate increases. Likewise, findings from a variety of more objective cardiac discrimination tasks such as heartbeat-tracking tasks (Donelson, 1966; McFarland, 1975), heartbeat discrimination tasks (Clemens 1976; Clemens and MacDonald, 1976) and heart rate discrimination tasks (Grigg and Ashton, 1984) all showed a positive correlation between cardiac discrimination and the ability to voluntarily increase heart rates but not with the ability to effect heart rate decreases. Whether those results can be accepted as support for Brener's predictions is unclear.

Other studies give much clearer results and contradict Brener's theory in no uncertain terms. Lacroix and Gowen (1981) tested the accuracy with which subjects could detect variations in their heart rates after nine daily sessions of heart rate control training and testing. They found that although subjects acquired the ability to raise their heart rates significantly better than the ability to lower their heart rates, acquisition of heart rate control was unrelated to the discrimination of heart rate changes. Whitehead et. al (1977) had reported earlier that heart rate control was unrelated to heartbeat perception after they discovered subjects were able to control their heart rates voluntarily irrespective of their accuracy on the Whitehead heartbeat discrimination task.

The nature of those results raise a number of interesting issues. Judging from those reports, it could be argued that the relationship between the two processes is not as simple and straightforward as proposed by Brener. Furthermore, the lack of consistency of the various task measures questions the validity of their use as tests of visceral perception and control.

The standard experimental approach to the investigation of the effects of cardiac discrimination training on heart rate control has usually involves initially training subjects to detect and label the occurrence of discrete cardiac-related events followed by a test of their ability to voluntarily produce heart rate changes. These studies have tended to yield evidence which does not support Brener's theory. However, there is no basis for the assumption that performance on those two different tasks are transferable and it is possible that the tasks tap different aspects of cardiac functioning which are unsuitable for examination within a transfer paradigm. An insight into the difficulties associated with such designs comes from Ross and Brener's (1981) investigation of HR control and heartbeat discrimination using the Brener and Jones (BJ) and Whitehead (WH) procedures. Twenty subjects were dichotomised into groups according to the order in which they were trained on the two tasks. Larger magnitudes of heart rate change were exhibited by the group that trained on the BJ task prior to training on the WH task (the BJ-WH group) than by the group trained on the WH procedure first (the WH-BJ group).

Post-hoc data analyses to determine the strategies subjects employed to solve the tasks revealed that success on the BJ task was correlated with the use of 'active' strategies while solution of the WH task correlated with the use of more 'passive' strategies. Active strategies were defined as the use of cues from cardiac related processes such as respiration and passive strategies involved the use of more cardio-specific sensations such as the detection of a peripheral pulse. The researchers also found that on the heart rate control task, subjects who had adopted active heartbeat discrimination strategies produced larger increases in heart rate on instruction than those who adopted a passive heartbeat discrimination strategy. It was tentatively indicated that the strategies adopted by subjects to solve the first task were more likely to be employed on the second task and also on the heart rate control task, which could explain why subjects in the BJ-WH group were better able to transfer their discriminative ability to the heart rate control task.

This suggestion was supported by results from a study of heart rate perception and control undertaken by Carroll and Whellock (1980). Subjects were required to hyperventilate, hypoventilate or breathe normally prior to performance on a heart rate perception task where they were required to adjust the frequency of a visual pulse to match their current heart rate. On subsequent heart rate control trials, subjects who had employed respiratory cues (ie. an active strategy) during the heart rate perception task showed significantly larger magnitudes of increases in heart rate compared to subjects who did not employ active strategies during the heart rate perception task.

These studies show that discriminative behaviour which confers a predisposition towards the voluntary control of a response emerges as the essential factor in the search for a correlation between heart rate control performance and cardiac discrimination. Heart rate control performance should be more positively correlated with performance on those cardiac discrimination tasks which require the detection of centrally-produced variations in cardiac activity (eg. heart rate tracking tasks) than with those which emphasise the detection of more cardiac-specific sensations (eg. the WH HBD task).

CHAPTER TWO

ASSESSMENT OF CARDIAC PERCEPTION

INTRODUCTION

Various techniques have been developed for the assessment of the discrimination of visceral sensations primarily to investigate the level of accuracy with which individuals can discriminate these sensations and also to determine individual differences in the perception and control of various autonomic activities. In this chapter, several of those techniques will be reviewed with particular attention to those measuring perception of cardiac sensations. The variety of experimental procedures which have been devised and employed to assess cardiac perception can be placed into three main categories: (1) questionnaire methods, (2) heartbeat tracking tasks and (3) heartbeat discrimination tasks.

2.1 Questionnaire Methods

The Autonomic Perception Questionnaire (APQ), a subjective self-report inventory developed by Mandler, Mandler and Uviller (1958) is the best known paper-and-pencil measure of autonomic perception. The 30-item questionnaire inquired about both the frequency and intensity of internal sensations individuals were aware of during experiences of pleasure and anxiety. On administration of the inventory to subjects, Mandler et. al (1958) reported that subjects who scored high marks on the APQ showed significantly greater autonomic activity than those who achieved low scores. The APQ was also adopted by other researchers to investigate the relationship between the perception of cardiac activity and the ability to voluntarily control cardiac activity with unclear results. For example, neither Blankstein (1975) nor McFarland (1975) found any relationship between autonomic awareness and control. And whereas Blanchard, Young and McLeod (1972) reported that only low awareness subjects were able to control their heart rates, Bergman and Johnson (1971) reported that those subjects who scored in the middle range of the APQ (as compared with high and low scorers) were most proficient at heart rate control performance. While those results may question the validity of the APQ as a measure of cardiac perception, it may be argued that such findings are characteristic of those testing Brener's hypothesis.

However, when the APQ was compared with other tests of cardiac perception, the APQ did not fare very well. Whitehead et al (1976), compared subjects' scores of autonomic perception from the complete APQ to d' indices of cardiac perception obtained from performance on a heartbeat discrimination task where subjects were required to discriminate between trains of light flashes which had different temporal relationships with the occurence of their ongoing heartbeats (R-Waves). Spearman's correlation index, rho calculated between APQ scores and d' indices was weak, negative, ($r=-.26$) and not significant where a strong and positive correlation was expected as both methods claimed to be indicators of subjects' autonomic perception. Furthermore, the five cardiac activity-related items of the APQ were shown to be negatively correlated with the d' indices of heartbeat detection ($r=-.16$).

Similar results were also reported by McFarland

(1975) from the comparison of subjects' scores on the five heart activity-related items of the APQ and their performance scores on a heartbeat tracking task where subjects were required to press a button for short periods to the rhythm of their perceived heartbeats. The absolute difference between the number of button presses and the actual number of heartbeats occuring during the test period was taken as the heart activity perception (HAP) score which was representative of heartbeat detection accuracy. Following performance on both cardiac discrimination procedures, the subjects were engaged in a heart rate control task. Data analysis showed a positive correlation of .50 between subjects' ability to increase their heart rates and their HAP scores but there was no significant correlation between APQ scores and heart rate increase or decrease scores. A rank order correlation index computed between HAP and APQ scores was only 0.13. The low correlation coefficient prompted McFarland's claim that the APQ was a poor predictor of heartbeat awareness compared to the heartbeat tracking task. He considered the APQ to be the less satisfactory measure of cardiac perception because unlike the tracking task, the APQ did not correlate with control of heart rate increases.

Similarly, Blankstein (1975) found that scores from both the complete APQ and its various subscales were uncorrelated with heart rate increases or decreases. Only two pleasure-related APQ items were found to be correlated to heart rate increases. In view of this evidence, it is doubtful if the APQ can provide a valid means of predicting and assessing autonomic perception. It would appear that the APQ scores are best interpreted as an indication the degree of concern individuals have about their internal processes, a view which is consistent with the positive correlation of Ø.5 Mandler et al. (1958) report between the APQ and Taylor's Manifest Anxiety Scale (Taylor, 1953).

Another type of questionnaire which has been used in the study of autonomic perception and HR control is the Locus of Control (LOC) Scale (Rotter,1966) which is a self-report scale measuring individuals' affective state. Locus of control (LOC) is a personality construct developed from social learning theory which refers to the degree of control individuals think they have over their environment or life situation. From a 29-item inventory, the degree of a person's perceived control can be measured on a scale ranging from extreme external LOC to extreme internal LOC. People with a high degree of external LOC would regard their life and life events as totally due to chance while people with high internal LOC would feel they were in complete control of their life and destiny. Although Rotter's scale does not claim to measure visceral perception, the LOC index could be applied to measure the control individuals believe they have over their internal environment. Hence, it would be expected that people reporting high internal LOC will be more sensitive to internal events than people who report high external LOC.

Ray (1974; Ray and Lamb, 1974) administered the LOC scale to subjects and grouped them as either Externals (high external LOC) or Internals (high internal LOC) according to their LOC scores. On the first session, half the subjects in each group underwent cardiac awareness training which entailed them attending to a light stimulus flashing on every heartbeat for 200 heartbeats. The subjects were instructed to associate the visual stimuli with internal sensations. Subjects who were not given any cardiac awareness training were instructed to relax for the time it took for 200 heartbeats to occur. Following the completion of the first session all subjects were instructed to control their heart rates bi-directionally during a two-phase experimental session. Knowledge of results on their IBI variation was presented during one phase only.

Ray (1974) found that subjects' performance at the heart rate control task improved significantly when feedback was presented and cardiac awareness training did not have any significant effect on the ability to control heart rate. These data are consistent with those presented by some other workers (eg. Whitehead et al, 1977; Lacroix and Gowen, 1981) examining the cardiac perception and control relationship. Data analysis yielded a significant interaction between HR control and group performance, which indicated that the Externals were better at decreasing their heart rates than the Internals. The Internals in turn, were better at increasing their heart rates from baseline levels than the Externals. A similar finding had been previously reported by Fotopolous (1970).

Despite obtaining results comparable to those from visceral perception studies, further inspection of the self-report data concerning the behaviour subjects engaged in during the HR control trials calls for some caution in the interpretation of the results. Externals reported having "looked at objects in the room" significantly more often than

Internals during HR control trials and this action correlated positively with heart rate deceleration and negatively with heart rate acceleration. This significant interaction with the environment has been linked to some theories of information processing (Lacey and Lacey, 1974). Those theories have suggested that heart rate decelerations are elicited by tasks that require attention to the environment (ie. executing responses to external signals) whereas heart rate accelerations occur during tasks that demand minimal attention to the environment and increased attention to processing of internal information (Lacey, Kagan, Lacey and Moss, 1963; Porges and Raskin, 1969). On this basis it may be reasoned that the strategies used by the subjects in controlling their heart rates were not attributable to any perception of internal activity.

From the foregoing, cardiac awareness determination procedures which rely exclusively on subjects' subjective reports of perceived internal activity have been shown to produce measures whose validity is at best questionable. The development of more objective procedures for examining the ability of individuals to discriminate cardiac activity has been welcomed as an improvement in this area of research.

2.2 Heartbeat Tracking Procedures

One of the earliest attempts at recording an individual's responses to heart rate changes was by Mandler and Kahn (1960). A subject was instructed to say "Slow" or "Fast" whenever he felt his heart rate was increasing or decreasing. Heart rate was monitored continously enabling the presentation of KOR on correct responses (if there was a 2-bpm variation in the appropriate direction). After 600 trials on the first day performance was at chance level but improved on the second day with the subject achieving 80% correct responses after a session of 600 trials. On the third day the subject made his responses only on direction from the experimenter who asked him to respond each time his heart rate showed a 2 bpm change. The subject was given KOR on correct responses on this procedure and achieved 100% correct responses in the last block of 60 trials. KOR was withdrawn on the fourth day during free responding and responding-on-instruction sessions and this resulted in a decline in performance. The data seemed to indicate that the ability to detect heartbeats could be improved with the presentation of KOR. However, when the subject was interviewed about the bodily cues he had employed during the task, he claimed to have based his responses on variations in his respiratory activity and not on cardiac activity. The results from Mandler and Kahn's study of heartbeat detection illustrates the necessity of cardiac perception procedures designed to prevent the use of inappropriate behaviours which would invalidate the relevant measures.

In a second study, Mandler and Kahn (1960) examined the relevance of instructional set in a heart rate detection paradigm. In this setup a subject was asked to simply guess which of two lights would be illuminated on each ensuing trial. The order of light illumination on each trial was random and unknown to the subject, the right-placed light was always contingent on occurrences of heart rate increases while the left-placed one lighted up only on heart rate decreases. The operation of the procedure can be illustrated thus: If the random sequence called for the right-placed light to come on, the experimenter inspected the subject's heart rate recording and prompted the subject to make a guess during a period of heart rate acceleration. After the subject's response was made, the right-placed light was illuminated and KOR was thus provided about the correctness of the response. After 4675 trials the subject's performance was still no better than chance level. However, the results are not suprising as it is doubtful that the information given to the subject about the task was sufficient to effect the requisite connection between the visual stimuli presentation and visceral activity.

The effectiveness of KOR was investigated further by Epstein and Stein (1974) in a heart rate detection procedure where subjects made button press responses to indicate their perceptions of heart rate fluctuations. Each subject underwent two experimental conditions where the discriminative stimulus was a change (an increase or decrease) in mean heart rate. Each condition consisted of four ten-minute Phases; an initial Adaptation Phase to determine the baseline heart rate and a Phase of discriminative responding with feedback, sandwiched between two Phases of discriminative responding without feedback. This provided detection measures both prior to and after the provision of feedback. Respiration rate was monitored and on examination, the researchers claimed that subjects did not manipulate respiratory activity as cues for heart rate detection. Subjects' accuracy of heart rate change detection was measured by calculating a Change score derived from subtracting the expected percentage of random responding from the actual percentage of discriminative responses. Change scores submitted to a Condition x Phase x Subjects ANOVA yielded only a significant Phase effect and no significant Condition or Phase x Condition effects. Comparison of Phase means showed that heart rate detection was more accurate during feedback Phases than during pre- and post-feedback Phases. Performance only reaching chance level during the pre-feedback Phase, improved significantly during the feedback Phase and declined with withdrawal of feedback during the post-feedback Phase. Thus, those results showed that discrimination training significantly improved individuals' ability to accurately detect heart rate changes.

A heartbeat-tracking procedure for the detection of discrete heartbeats instead of gross heart rate changes was employed by Schandry and Specht (1981). Subjects were instructed to attend to and count their heartbeats during five time periods (three rest periods and two periods of psychological and physical stress situations) of different durations (average duration, 33 minutes). To prevent subjects calculating a heartbeat count inferred from knowledge of the temporal features of cardiac activity, no information was given about the durations of the time periods. From the subjects' verbal heartbeat counts and their actual recorded heartbeats for each time period, an error score was computed to represent the accuracy of heartbeat detection. The difference between the number of button presses and the number of heartbeats emitted by the subject was divided by the number of heartbeats to produce the heartbeat perception score. Schandry and Specht reported significant differences in error scores between the rest periods and the two experimental periods with some subjects exhibiting very accurate heartbeat detection of near perfect scores on some occasions. However, this measure of heartbeat detection is inherently unreliable as most naive people can give an accurate estimate of their heart rates without any internal perception (Ross, 1980). As the authors do not present any data showing evidence that subjects actually employed cardiac sensations during the experiment, the heartbeat detection index calculated could well be an index of subjects' accuracy at guessing heartbeat frequencies on non-cardiac basis rather than being a measure of cardiac perception.

In McFarland's (1975) heartbeat tracking task subjects were required to make a motor response in synchrony with perceived heartbeat sensations. Prior to the test session subects were engaged in a short training session where they pressed a button in synchrony with movements of a voltmeter needle which deflected on each heartbeat. During the heartbeat detection task subjects had to make button presses corresponding to their perceived heartbeat sensations for a period of time with no provision of external feedback. The absolute difference between the number of button presses and the number of heartbeats produced by the subject was divided by the number of heartbeats. This value was subtracted from one to generate the Heart Activity Perception (HAP) score. A high HAP score represented accurate heartbeat perception and scores ranged from 0.48 to 0.98 (Mean=0.85). However, as in Schandry and Specht's study (1981) high HAP scores could be achieved without the involvement of visceral cues. By merely producing button presses at the same rate as the feedback stimuli presented during the heartbeat training session, subjects could appear to attain accurate heartbeat perception.

This artefact was controlled for to some extent by Kleinman and Brener (1970) by the introduction of a measure that took into account a latency criterion between the occurrence of a heartbeat and the subsequent button press. A heartbeat detection response was registered only if the button press occurred within 180 milliseconds after a heartbeat. During a training session, subjects were presented with light flashes which occurred coincidentally on their heartbeats. On the test session following this training procedure, the light flashes were withdrawn and subjects were required to make button presses which coincided with internal sensations of heartbeats. The heartbeat perception measure employed was whether subjects showed a mode in their heartbeat-to-button press latency distributions. However, despite this procedural criterion, this heartbeat tracking task does not completely dispel the possibility of subjects' responses being reproductions from memory of feedback-motor relationships acquired during training trials. The application of a latency criterion in order to validate the heartbeat perception index can only be accepted cautiously because interbeat intervals exhibit variations within and between subjects and it is difficult to accurately establish an *a priori* criterion of responses at any given range of interbeat intervals.

Donelson (1966) reports a study that controls for the possibility of improved performance on a visceral awareness task resulting from noninteroceptive strategies transferred from training sessions. She presented subjects with visual tracings of their ongoing cardiac activity displayed on an oscilloscope during training trials and on test trials they were instructed to adjust the frequency of the oscilloscope tracing to match their current heart rates. To rule out the possibility of the subjects' performance being due to their memory of the visual display of heartbeats, Donelson instructed half of the subjects to hyperventilate for 15 seconds prior to test trials and the other half to hyperventilate for 15 seconds prior to training trials. Consequently, their heart rates were different on test and training trials. On this procedure, heart rate discrimination was indexed by the difference between subjects' estimated heart rates and their actual heart rates. The results showed that subjects who had hyperventilated prior to training trials acquired the highest indices of heart rate discrimination. Donelson suggested that the increased cardiovascular activity produced by hyperventilation augmented feedback on training trials thereby making cardiac sensations more obvious to those subjects.

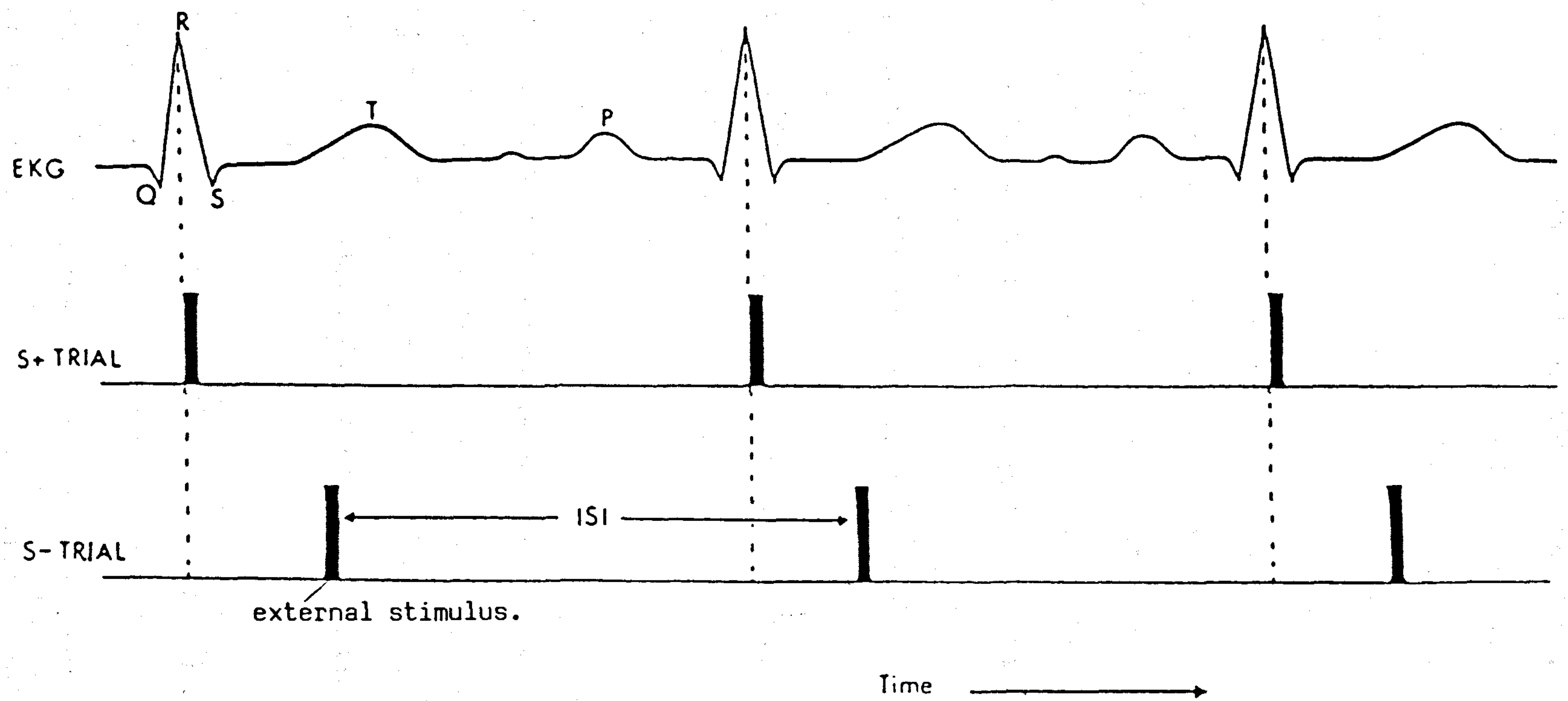
In summary, although heartbeat tracking procedures have been characterised by sophisticated procedural features and measures of assessing cardiac perception, most of the measures are fundamentally unreliable because the procedures seem unable to control for the use of non-cardiac cues during task performance. Moreover, interoceptive discrimination suggests an atmosphere of subtle but considerable inward attention on the part of an individual and a heartbeat discrimination task that requires subjects to perform a motor act on each discrete heartbeat can only prove a distraction and an interference in itself. Preferably, a heartbeat discrimination task should be designed such that its performance does not confound the effects it sets out to measure.

2.3 Heartbeat Discrimination Tasks

The final group of tasks to be examined has been devised to counteract the shortcomings of those procedures already reviewed. Subjects are required to distinguish between external stimuli that bear different temporal relationships to their ongoing cardiac activity. No physical manoeuvres are expected of the subjects and relatively more refined methods of data analysis are employed in determining cardiac perception.

The Brener and Jones (BJ) procedure was the first reported heartbeat discrimination task developed within this framework (Brener and Jones, 1974). The task involved the discrimination of heartbeat-contingent trains of external stimuli from trains of external stimuli that were not contingent on heartbeats. On S+ trials the external stimuli were triggered by the subjects' EKG R-Waves and on S- trials the stimuli were generated by a pulse generator at the subjects' mean heart rate and therefore unrelated to ongoing cardiac activity on a beat-by-beat basis. A schematic diagram of the procedure is shown in Figure 2.1.

Brener and Jones (1974) carried out a study to determine the efficacy of their heartbeat discrimination procedure by testing three different groups of subjects. On training trials the Experimental group (Exp. group) were given KOR on correct discriminative responses. Subjects in the first Control group (KOR Control group) underwent the BJ task without KOR. The S+



ISI (Interstimulus interval)=constant

<u>Figure 2.1</u> Schematic diagram of the Brener and Jones Heartbeat Discrimination Procedure

and S- stimuli presented to the second Control group (Periodicity Control group) were generated from pre-recorded EKGs and the subjects were given KOR on the basis of whether the stimuli were correctly identified as contingent or not on the pre-recorded EKGs. This Periodicity Control group served as a check on the use of periodicities of the feedback stimuli as discriminative cues instead of internal cardiac sensations. That check was neccesary because on S+ trials, the external stimuli have the periodic variations of heart rate activity whereas on S- trials, the stimuli are presented at an invariant frequency and there is the possibility of differentiating between the two stimuli train types on that basis. It was reasoned that if subjects can discriminate between S+ and S- trials solely on the basis of the different periodicities between stimuli trains, then all subjects should be equally successful at solving the task. However, if subjects solved the task by using sensations of their heartbeats then the second Control group should fare poorly at the task. The heartbeat perception measure was generated from the number of correct discriminative responses made on each session. During the training session, discrimination trials were presented until the subject achieved a criterion level of successful discrimination performance of 80% correct discriminations over twenty consecutive trials.

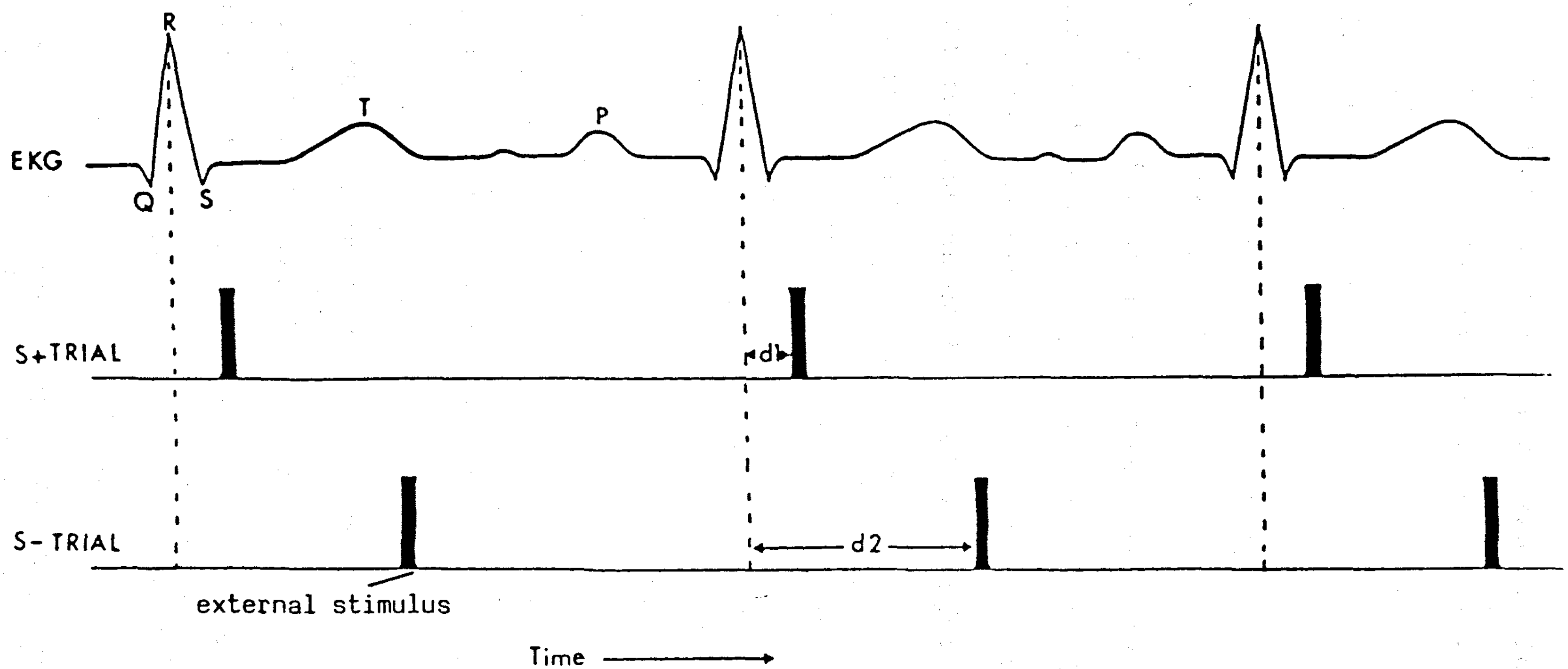
Results of from the groups' discrimination performance showed that only the Experimental group exhibited any improvement in heartbeat perception from the pre-training block to the post-training block. That group also required significantly fewer training trials to reach the criterion of task solution. The two Control groups performed similarly and at chance level, leading to the conclusion that discrimination could not be effected by employing cues from the differences in the periodicities of the S+ and S- trial types and also that KOR improved heartbeat discrimination performance.

However, on retrospection the researchers admitted that subjects could register correct responses by employing non-cardiac information to solve the BJ task. Since production of S+ stimuli was triggered by cardiac activity while S- stimuli occured at a constant rate, muscular activity or respiratory manoeuvres during a trial would produce a noticeable effect on the stimulus periodicities on S+ trials but leave S- trials unaffected. Brener and Jones argue that discriminations achieved this way should be considered valid as internal events or stimuli associated with cardiac activity were employed to distinguish S+ trials from S- trials. Where possible however, heartbeat discrimination tasks should aim to tap finer modes of cardiac perception that rely more on cardiospecific cues.

Clemens and MacDonald (1976) modified the BJ procedure by triggering S- stimuli from subjects' pre-recorded EKG so that stimuli production rate and variability were similar to that of the S+ stimuli. Other changes involved substituting light flashes for vibratory external stimuli and the employment of a more advanced method of heartbeat discrimination assessment. Brener and Jones had calculated heartbeat perception from the percentage of correct discriminative responses made by subjects per session whereas Clemens and MacDonald employed a measure derived from d' (McNicol, 1972) which was computed from the rates of Hit and False alarm responses. However, these workers did not control for the possibility of task solution on the basis of variations in stimuli periodicities, produced by respiratory or somatic activity. Since the S+ and S- stimuli trains in this procedure remain differentially correlated with the subject's ongoing cardiac activity, these modifications do not prevent subjects employing non-cardiac interoception to solve the task.

Whitehead, Drescher, Heiman and Blackwell (1977), reported a heartbeat discrimination procedure (WH procedure) which appears to overcome the problems inherent in the BJ task and Clemens procedures. On S+ trials of the WH task, subjects were presented with trains of external stimuli which occured 128 milliseconds after each R-Wave and on S- trials these stimuli occurred 384 milliseconds after each R-Wave (see Figure 2.2). Subjects were required after each trial to register by a button press if they perceived the light flashes as occuring 'immediately' on or 'delayed' after their heartbeats. As all the feedback stimuli were triggered by the subjects' ongoing EKG, making the stimuli presented on both S+ and S- trials correlated with cardiac activity, any respiratory or motor manipulation undertaken by subjects would affect stimuli presented on both trials equally. The researchers presented subjects with 200 ten-second discrimination trials and the ability to accurately detect heartbeat was measured using the d' index of perceptual sensitivity.

Computed d' values ranging from 0.05 (no discrimination) to 1.56 (high discrimination) were reported in this study. Unlike other studies where subjects were given feedback or KOR



d1=128 milliseconds
d2=384 milliseconds

Figure 2.2 Schematic diagram of the Whitehead Heartbeat Discrimination Procedure.

after each response, Whitehead et. al. (1977) gave subjects monetary rewards on correct discriminations only after completion of all the experimental sessions. This action might be responsible for the low heartbeat perception performance, compared with reports from studies where perception was enhanced by immediate feedback.

This chapter illustrates the assortment of procedures and measures of cardiac perception employed in this area and the wide variety of results obtained from them. This diversity in reports points to two main requirements. Firstly, there is the issue of the standardization of cardiac discrimination procedures. At the moment each task is characterized by its own unique measures and procedural methods, a situation which renders inter-test comparisons very difficult. A case in point is the establishment of a criterion for successful cardiac discrimination. In some studies this is defined statistically as performance which differs significantly from chance over a session while in others success is the attainment of a predetermined level of performance within a session. Related to this point are the issues of the validity and reliability of tasks. Most of these tasks are operationally valid but one questions the extent to which they examine the same capacity. The solution has been to examine how performance on different cardiac discrimination tasks correlate with each other (Ross and Brener, 1981; Jones, O'Leary and Pipkin, 1984). The results from both these studies indicate no correlation between the tasks, thus implying that they do not tap the same abilities. Test reliabilities have fared no better under examination (Clemens, 1976), revealing poor intra-subject across and within task sessions.

The second factor relating to the differing and often conflicting reports of cardiac discrimination task performance stems from wide inter-subject differences in cardiac discrimination ability which have been largely unexplored in this area of research. However, some investigators have extensively examined and reviewed the influence of individual differences on cardiac perception (eg. Katkin, Morrell, Goldband, Bernstein, 1982) and the control of cardiac activity (McCanne and Sandman, 1976; Williamson and Blanchard, 1979; Carroll, 1979; Levenson and Ditto, 1981). Those workers present evidence that suggest that some individual differences in cardiac perception ability can be attributed to inherent individual variables such as gender or to the physical and psychological states of the individuals. Although in most cases these variables are reliable predictors of performance, the reasons for some of these individual differences remain unknown.

The issues raised in this chapter will be elaborated upon in Chapter Three which will examine in more detail the influence of task differences and individual differences on cardiac discrimination.

CHAPTER THREE

ISSUES IN CARDIAC PERCEPTION

3.1 Standardization of Heartbeat Discrimination Procedures

The standardization of techniques for assessing cardiac awareness is an important issue that has been sadly neglected. Task standardization would involve a reasonable assessment of the reliability and validity of the many objective tasks developed to measure cardiac discrimination ability in humans. Whether the ability to discriminate cardiac activity is a stable process and whether the performance scores generated by different procedures for assessing cardiac discrimination ability give consistent and valid measures are questions which have not yet been adequately researched. Clemens (1979), Grigg and Ashton (1982), and Wildman and Jones (1982) are the only workers to date who have published reports of studies investigating the stability of cardiac discrimination performance.

Investigating the test-retest reliability of a modified version of the BJ heartbeat detection (HBD) procedure, Clemens (1979) ran subjects for five consecutive days on the task, presenting all subjects with knowledge of results (KOR) on correct responses only on Day 3. On computing the day-to-day correlations among subjects' heartbeat discriminative scores obtained over the five sessions, Clemens found that day to day consistency was "distressingly unreliable" (page 336) prior to KOR training. However, after the brief session of HBD training there was a tendency to more stable and consistent HBD performance particularly in subjects who had learned the task. Similar results were reported by Grigg and Ashton (1982) in a couple of studies undertaken to examine the consistency of discrimination performance on the Ashton, White and Hodgson (1979) heart rate detection procedure. On this task subjects were required to indicate after presentation of two consecutive 4-second intervals, in which interval their peak heart rate occurred. In the first of two studies, subjects participated on the task for four consecutive days and performed the BJ task on the fifth day. Grigg and Ashton found no significant day-to-day correlations between performance on the five days of testing. The findings from both studies suggest that there is poor discrimination consistency but that discrimination training might improve both the accuracy and stability of cardiac discrimination performance.

The stability of discrimination performance on the Whitehead (WH) HBD procedure was examined by Wildman and Jones (1982). Subjects were presented with 240 trials divided into five trial blocks and the experiment was conducted over a single session lasting for two and a half hours. Half of the subjects received KOR on correct reponses for 80 trials throughout the third trial block. Computations of correlation coefficients between performance scores of trial blocks were very low. Wildman and Jones claimed that those results raised doubts concerning the validity of the WH task in the measurement of HBD and concluded that the WH task was an unreliable indicator of HBD. However unlike the other test reliability studies, this experiment was conducted over a single session and its findings cannot provide a plausible basis for predicting the long term stability of the WH procedure. Performance could have been adversely affected by fatigue or boredom setting in over the lengthy experimental session. As Jones, O'Leary and Pipkin (1984) have pointed out, the WH task becomes rather monotonous for many subjects after more than 80-100 trials.

The issue of whether the WH procedure and other procedures assessing cardiac perception are valid tests of what they claim to measure remains unresolved because there have been very few inter-task comparisons. Ross and Brener (1981) employed a transfer of training design to examine HBD performance on the WH and the BJ task. Using KOR for correct responses, these investigators trained 20 subjects on the WH and BJ procedures until they reached a high level of heartbeat discrimination performance on both tasks. Although a strong and positive correlation was expected between performance on the WH and BJ tasks as they both claim to measure the same perceptual ability, the data yielded none.

Jones et al (1984) also reported a lack of correlation between the BJ and WH tasks after testing 24 subjects on both WH and BJ tasks. After a session of 50 trials on each task without KOR, 13 subjects were able to perform at better than chance level (greater than or equal to 64% correct discrimination responses) on at least one task. Of those subjects, eight were able to solve only the WH task and four were successful only on the BJ task. Only one subject achieved performance that was better than chance level on both tasks. Correlational analyses between performance scores on the WH and

BJ tasks yielded a coefficient -0.11. In conjunction with the results reported by Ross and Brener, this could be viewed as an indication of low validity of either the WH or BJ task.

Alternatively, the failure to find relationships between those tasks could be attributed to the possibility that they do not assess equivalent aspects of cardiac sensitivity and hence skill transfer between the tasks is improbable. Correlations are more likely to emerge between tasks that require the same or similar solution strategies. Solution of the WH task appears to involve the use of relatively cardiospecific cues whereas solution of the BJ task can be based on information from non-cardiac sources that are correlated with heart rate variation. The same sort of information may presumably be used in the solution of Ashton, White and Hodgson's (1979) heart rate detection procedure. In this procedure subjects are requested to report on each trial whether their peak heart rate occurred in the first or second of two successive four-second intervals. Grigg and Ashton (1982) found that subjects trained with KOR on that procedure transferred their cardiac discrimination to the BJ task, implying that similar discriminative skills may have been required on both HBD tasks.

The evidence presented does not give an impressive account of the reliability and validity of cardiac discrimination measures as examined by traditional standardization methods. However, those examinations raise some noteworthy issues. Task validity as assessed by the correlation between cardiac discrimination performance on different HBD tasks appears to exist only when the tasks concerned train subjects to focus on the same aspects of cardiac functioning. This specificity in inter-task relationships suggests that cardiac perception might be a multi-dimensional phenomenon whose different facets cannot be adequately represented by a measure from one HBD procedure. Therefore the continued refinement of all operationally valid HBD procedures should add to the knowledge of the different components and processes involved in cardiac perception.

In summary, we find that central to all the reports examining the consistency and reliability of HBD performance scores is the observation that subjects unexposed to HBD training tend to exhibit changeable and poor levels of HBD performance. Also, participation in a brief session of HBD training seems to result in more consistent and stable performance. These findings portray cardiac perception as an inherently unstable process, susceptible to modification by various factors such as HBD training. It is anticipated that identification of the mechanisms which mediate underlying the perceptual process can be understood by examining the role of individual differences in HBD performance.

3.2 Individual Differences in Heartbeat Discrimination

The first question to be asked in the the examination of individual differences in HBD is whether all subjects can reliably discriminate their cardiac activity. It is realistic to believe that individuals can detect their heartbeat sensations with varying degrees of accuracy. Such differences in perceptual sensitivity provide reasons for more detailed examination. Data from several studies indicate that very few subjects are capable of perceiving sensations of their heartbeats without training (Whitehead et al, 1977; Jones et al, 1984) and most experiments report that individuals' ability to detect their heartbeats is improved with training (Brener and Jones, 1974; Ross and Brener, 1981) as is the detection of heart rate changes (Ashton, White and Hodgson, 1979).

Brener and Jones (1974) assessed HBD performance in three groups of subjects (Experimental, KOR Control and Periodicity Control) on the BJ task. Each group was comprised of ten subjects. The Periodicity Control group's performance will not be considered here as they were run on an experimental procedure which was very different from the other groups. The other two groups were received twenty Pre-training and Post-training trials without the provision of KOR. The two groups differed with respect to the treatment given during the Training phase of the experiment. Subjects in the Experimental group were given HBD with KOR on each correct response while the Controls did not receive any information about the correctness of their responses during that period. Comparison of the percentage correct discriminative responses for both the groups on the two No-KOR sessions revealed that the Experimental group displayed a significant improvement in HBD from the Pre-training phase to the Post-training phase whereas the Controls did not. Furthermore, more Experimentals than Controls solved the BJ task with nine out of ten subjects from the Experimental group being able to solve the task compared to four out of ten subjects from the KOR Control group.

In an experiment described earlier in this work, Ross and Brener (1981) presented 21 subjects with KOR on each correct discriminative response during their performance on both WH and

BJ tasks. All the subjects were trained in this manner for a maximum of 100 trials each session until they achieved the performance criterion for successful solution which was was set at 16 correct responses during 20 successive HBD training trials. Ross and Brener found that only one subject out of 21 was unable to solve the WH task after undergoing this extensive training regime. All the other subjects were successful at solving both tasks, with eight of them achieving success after presentations of as few as twenty HBD training trials.

The extent of change in HBD performance with training differs substantially from study to study, producing results which are often not as spectacular as those reported in the Ross and Brener study. When Clemens (1976) submitted subjects to a modification of the BJ HBD procedure with the provision of KOR on correct and incorrect discriminations, only sixty percent of the subjects could solve the task although the criterion for solution of the HBD task was set at eight correct discriminations during a block of ten training trials, a level far less stringent than that employed by Ross and Brener. More recently, Davis, Langer, Sutterer, Gelling and Marlin (1986) compared the performance of three different HBD procedures. They submitted three groups of 36 subjects each to the WH (Whitehead et al, 1977), Katkin (Katkin, Blascovich and Goldband, 1981) and Constant Initial Delay (Davis et al, 1986) tasks. The WH task required subjects to discriminate stimuli that were presented a short interval after their heartbeats (S+) from those that were delayed for a longer time interval after their heartbeats (S-). The Katkin and Constant Initial Delay (CID) procedures involved the discrimination of stimuli that followed the heartbeats at a constant interval of 100 ms (S+) from stimuli that followed heartbeats at a delay which increased on successive heatbeats within a trial (S-) and in the case of the Katkin task, also varied from trial block to trial block. The investigators reported that when all three groups were provided with KOR on correct and incorrect responses for 25 training trials, only subjects in the CID group exhibited significant improvement in heartbeat discrimination performance.

The superior HBD performance exhibited by subjects in the Ross and Brener study compared to those in the Clemens and Davis studies could be explained by two procedural differences between those studies. Firstly, subjects in Clemens' study were submitted to S+ and S- trains of visual heartbeat-contingent external stimuli whereas Ross and Brener employed trains of auditory stimuli. On the basis of subjects' verbal comments during pilot studies in this laboratory, presentations of visual stimuli are distracting during visceral discrimination tasks compared to auditory or vibratory stimuli. It is reasonable to assume that behavioural quiescence is effective in heightening visceral perception during cardiac discrimination trials and subjects frequently report that closing their eyes during trials is an effective practice which accentuates the perception of internal sensations. Such behaviour would be impossible where they are required to keep a constant watch on visual stimuli. In the Davis et al (1986) study, subjects were presented with concurrent visual and auditory external stimuli and hence in that study were not restricted in their choice of discriminative behaviour.

However, those subjects were trained only for a brief period of 25 HBD trials with KOR. The duration of the training session would seem adequate for most individuals. Reports from most HBD studies (eg. Katkin, 1985) demonstrate that the majority of subjects need substantial training on HBD procedures to enable them acquire the requisite discrimination skills. In this connection, it is important to note that although Ross and Brener report that 40 percent of their subjects solved the WH task after 20 training trials with KOR, the group as a whole took a mean number of 71 training trials.

As predicted, subjects are not all influenced by HBD training to the same degree, suggesting that individual differences must play an important role in heartbeat discrimination ability. Katkin, Blascovich and Goldband (1981) illustrated this by examining heartbeat discrimination ability among males and females on the Katkin HBD procedure. Those researchers found that prior to HBD training, male and female subjects performed at chance level. However, after all the subjects were submitted to 120 training trials with KOR, the male subjects acquired HBD skills, and showed a significant improvement in performance from pre-training levels whereas the female subjects continued to perform at chance level. Gender differences demonstrated in cardiac discrimination ability have also reported by Whitehead et al (1977) and Jones and Hollandsworth (1981). Other individual difference variables influencing heartbeat discrimination ability such as emotionality (Schandry, 1981; Hantas, Katkin and Blascovich, 1982; Jones and Montgomery, 1984), hemispheric laterality (Hantas, Katkin and Reed, 1984; Montgomery and Jones, 1984) and physical fitness (Jones and Hollandsworth, 1981; Montgomery, Jones and Hollandsworth, 1984) have been reported in the literature and Katkin (1985) has evaluated some of these factors in a series of experiments.

In an elaboration of neo-Jamesian theories, Katkin and his colleagues embarked on a systematic examination of the role of visceral perception in the experience and expression of emotion. It is reiterated here that the central theme in those theories is that the individual's perception of changes in autonomic arousal constitutes an experience of emotion compatible with the prevalent social environment. Several researchers have produced evidence of a link between experimentally induced arousal and accuracy of heartbeat detection, reporting evidence that improved accuracy in subjects' HBD ability correlates with increases in arousal induced both by physical (Donelson, 1966; Jones and Hollandsworth, 1981; Montgomery et al, 1984) and psychological means (Katkin, Blascovich, Reed, Adamec, Jones and Taublieb, 1982; Schandry and Specht, 1981). Furthermore, as reported earlier in this thesis, when subjects are exposed to unpleasant stimuli, more accurate heartbeat detectors report significantly more emotive responses to those stimuli than less accurate heartbeat detectors although both groups show similar levels of physiological activity (Hantas et al, 1982). Clearly, these experiments have produced results consistent with the prediction from James' theory of emotion that individuals' perception of visceral activity determines their subjective expressions and experiences of emotion.

In order to investigate further the influence of individual differences on heartbeat perception, Katkin logically proceeded on to examine the sensory and physiological mechanisms underlying these perceptual processes. Data from a variety of psychophysiological studies seem to support the possibility of a close association between autonomic perception and hemispheric activation. Walker and Sandman (1979) recorded visual evoked potentials (VEPs) from subjects in both hemispheres while they were showing fast, mid-range and slow heart rates. The researchers found that in the left hemisphere, the VEP magnitudes for fast and slow heart rates were similar to each other but different from the mid-range heart rates. In the right hemisphere the VEP magnitudes for all three heart rate ranges showed up differently. In another study, Walker and Sandman (1982) recorded VEPs from both the right and left hemispheres during the diastolic and systolic phases of the heartbeat. They found that in the right hemisphere, VEPs recorded during the systolic and diastolic phases were clearly different whereas this differentiation was not apparent in the left hemisphere. Hence both studies suggest that cardiac-related activity is represented more clearly in the right rather than in the left hemisphere. Related studies reported by Galin (1974), Davidson, Horowitz, Schwartz and Goodman (1981) and Hugdahl, Franzon, Andersson and Walldebo (1983) all present evidence to suggest that the right hemisphere may be specialized for processing information from the cardiovascular system.

It has often been suggested that emotional functions are mediated in the right hemisphere (Schwartz, Davidson and Maer, 1975; Suberi and McKeever, 1977; Sackeim, Gur and Saucy, 1978). With reference to the cited evidence linking emotionality to heartbeat discrimination and hemispheric specialization to the processing of cardiovascular afference, one could tentatively hypothesise that heartbeat discrimination performance will be closely associated with right hemispheric activation. Hantas, Katkin and Reed (1984) tested this hypothesis using a modified version of the Katkin task to evaluate HBD among subjects who differed in cerebral activation as indexed by differences in conjugate lateral eye movements (CLEMs).

Hantas et al (1984) interviewed 31 right-handed male subjects using a series of verbal and spatial questions suggested by Gur and Gur (1977) as a measure of CLEM. On the basis of this interview, two groups of ten subjects each were made up of left eye movers (right hemispheric preferent) and right eye movers (left hemispheric preferent). All subjects were run initially on 40 HBD trials without KOR which was followed by 120 training trials with KOR on correct discriminative responses. The results showed that during the No-KOR trials session, left movers performed significantly better than right movers whose performance was only at chance level. During the training trials both groups showed a steady improvement in HBD performance with the left movers performing significantly better than the right movers. Those remarkable results shown by the left movers (right hemispheric preferent) support the hypothesis that heartbeat discrimination ability is closely related to right hemispheric activation and may even be mediated in the right hemisphere.

However, although that hypothesis has been confirmed by Montgomery and Jones (1984) in an independent study employing a different HBD procedure, Hantas et al (1984) discovered that subjects could have solved the modified Katkin task without reference to their heartbeat sensations. When subjects were presented with trains of S+ and S- stimuli generated by tape recorded heartbeats, they were able to discriminate S+ from S- trains at a better than chance level. Therefore, the differences existing between right and left movers may not neccessarily demonstrate differences in heartbeat perception and are more likely to reflect the differences between right and left movers in pattern perception. Further research is neccessary in the future to shed more light on this issue.

The results of the evaluation of individual difference factors in the ability to discriminate heartbeats show that the most reliable individual difference factor is gender. Males are shown to perform the HBD much better than females. Speculative proposals have been made in an attempt to explain this gender difference. Katkin (1985) is currently gathering evidence to support his proposal which states that as induced arousal in males results in increases in accuracy of HBD performance and as cognitive challenge elicits greater adrenergic arousal in males than females (Frankenhauser, 1976), the presentation of a challenging HBD task to males and females will elicit different levels of adrenergic arousal in them which will be reflected in their differential HBD performance.

Emotionality has also been isolated as an important individual difference factor closely linked to the induction of arousal and associated with the accuracy of heartbeat perception. The role of right hemispheric preference in visceral perception remains unresolved and necessitates more thorough evaluation. That final issue highlights some of the matters raised earlier in the chapter concerning the validity and sensitivity of HBD procedures. The modified version of the Katkin procedure used in that case appeared operationally valid until it was submitted to thorough examination whereupon it was declared unsuitable as a measure of cardiac perceptual sensitivity. Unfortunately such stringent tests are not carried out on all the HBD procedures in use although it is imperative that all those procedures be evaluated carefully to assess the adequacy of their measures.

This review has raised issues that reveal that our understanding of the mechanisms, mediation and the role of individual differences in visceral perception is far from complete and those issues are more complicated than previously envisaged. One expects that continued investigative research and the further refinement of cardiac discrimination procedures should augur well for a fuller understanding of the phenomenon. The experimental work in this thesis was directed towards this end.

The main aim of this work was to evaluate the design and adequacy of a standard heartbeat discrimination procedure in the assessment of individuals' sensitivity to heartbeat sensations. For this purpose, the design and efficacy of the Whitehead heartbeat discrimination procedure was submitted to a detailed examination, the results of which were incorporated into the design of an improved HBD task. The reliability and validity of the devised HBD task were evaluated employing accepted standardization procedures. Finally, a variety of factors was explored through further experimentation in an attempt to account for individual differences in cardiac discrimination.

CHAPTER FOUR

EXPERIMENTS I & II: THE DISCRIMINABILITY OF THE TEMPORAL ARRANGEMENTS USED IN HEARTBEAT DISCRIMINATION PROCEDURES

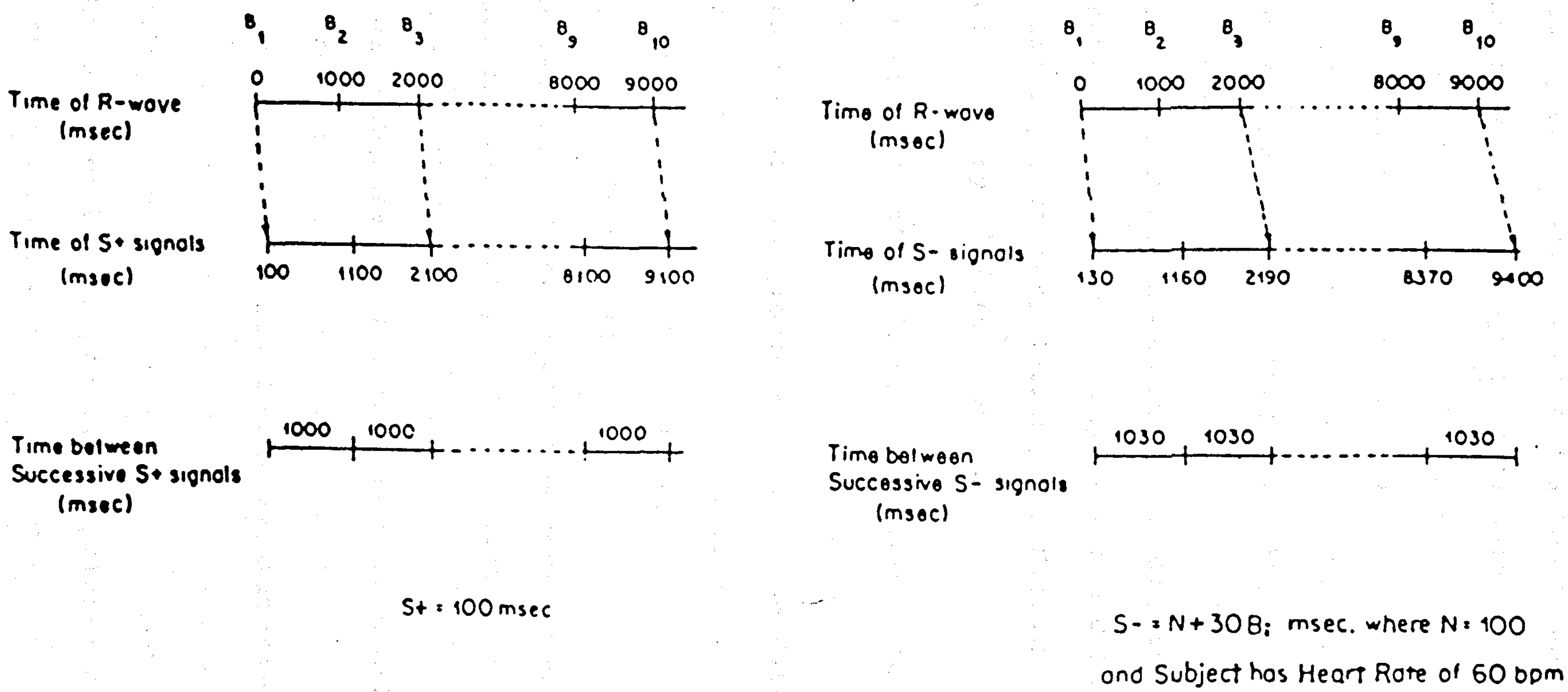
INTRODUCTION

Of the various objective heartbeat discrimination (HBD) procedures developed, the Whitehead (WH) procedure has come to be regarded as the standard method for the assessment of the ability of individuals to detect internal sensations of their heartbeats. In that procedure subjects are required to discriminate between external stimuli occurring either 128 or 384 milliseconds after each heartbeat. The most important feature of this procedure is that since both stimulus types are contingent on subjects' ongoing cardiac activity, any muscular or respiratory manoeuvres they might engage in to differentiate the stimuli will affect both sets of feedback stimuli equally (cf. Brener and Jones procedure). Therefore, the requisite to successful performance on the WH procedure is the ability to accurately detect discrete heartbeats and the ability to discriminate between signals separated from sensations of the heartbeats by either the long (384 ms) or the short (128 ms) time periods used in the WH task.

Katkin, Reed and DeRoo (1983) claim that because the discrimination of these time intervals is not easy for many individuals, only a small proportion of people are able to solve the WH task successfully (Whitehead et al, 1977; Jones et al 1984). In order to prove their point, those investigators presented subjects with external signals temporally arranged as in the WH task paradigm. A 500 Hz tone presented simultaneously with each heartbeat (EKG R-wave) was, on S+ trials, followed after 128 ms by a 1000 Hz tone. On S- trials the 1000 Hz tone was delayed 384 ms after the 500 Hz tone. The results of the experiment showed that subjects could make correct discriminations on only 57% of the trials, a level of performance which seems to support the suggestion that subjects' poor performance on the WH task is due to their inability to accurately discriminate the temporal difference between the immediate and delayed feedback stimuli types. At this point Katkin, Blascovich and Goldband (1981) went on to devise a new HBD procedure which they anticipated would permit easier temporal discrimination between the S+ and S- stimuli types.

However, when a similar study to that of Katkin et al (1983) was undertaken in this laboratory, it was found that all the ten subjects that were tested were able to make correct discriminations on 97% of trials in a session of 150 WH-type trials using the 128 and 384 ms delays. Moreover, the high level of performance was maintained by the subjects whether or not they were given KOR on correct and incorrect reponses on each trial. Furthermore, results from a more extensive test of the temporal features of the WH task by Dabkwoski, Collins, Jones and Jones (1986) also showed that subjects displayed a high level of temporal discrimination. Those workers presented groups of subjects with one of five combinations of stimulus pairs, the first stimulus was denoted, S1 and the second of the pair was S2. These stimuli were presented in three different modalities (visual, vibratory and auditory) and subjects were required to discriminate pairs of stimuli separated by 128 ms from those separated by 384 ms. The S1 stimuli were heartbeat-coincidental on half of the trials of the session and were unrelated to heartbeat occurrences on the rest of the trials. The results from this experiment showed that 85% of the subjects were able to make correct responses at above chance levels on the discrimination tasks and there was no significant difference between performance on heartbeat-coincident and non-coincident trials. These data are in accord with those observed during pilot studies mentioned earlier, and strongly suggest that subjects can make the temporal discrimination implicit in the WH task when using externally generated stimuli.

The main difference between the HBD task devised by Katkin et al (1981) and the WH task was that in the former task, instead of discriminating between two external stimuli both fixed in time from the heartbeats, subjects were required to discriminate between stimuli presented at a fixed delay of 100 ms after the heartbeat (S+) and stimuli that followed heartbeats after a variable delay (S-). The S- stimuli were generated according to the formula: S- = N + 30BI msecs, where S- represents the stimulus latency on progressive heartbeats, N is a random number between 1 and 200 msecs (fixed for any trial), and BI represents the Ith heartbeat (B) in a train of ten heartbeats. In effect, the S- stimuli followed the heartbeats at a delay which increased on successive heartbeats within a trial and also varied between successive trains of ten heartbeats. Figure 4.1 illustrates this procedure. In order to find out if subjects could make the temporal discrimination



<u>Figure 4.1</u> Schematic diagram of the Katkin Heartbeat Discrimination Procedure. (From Katkin, Blascovich and Goldband, 1981, page 1097).

between S+ and S- stimuli, Katkin et al (1983) tested the HBD paradigm using externally generated stimuli pairs. The results of the test showed that subjects were able to make correct discriminations on 68% of the trials, a level of performance that was significantly better than chance and better than that exhibited on a similar test of the WH task. However, when the Katkin task was performed by subjects using internal cardiac sensations, very few subjects were able to solve the task. This implied that the task was still too difficult to solve and it was further modified by Hantas, Katkin and Reed (1984) and by Davis, Langer, Sutterer, Gelling and Marlin (1986), independently and by different means.

Hantas et al (1984) effected a modification by making the delay between the heartbeats and the S- stimuli much more variable than in the original version of the Katkin procedure. The random number N was now changed after each heartbeat instead of after a train of 10 heartbeats with the result that on S- trials the auditory feedback was presented at a delay anywhere between 0 and 400 ms after each heartbeat. It was thought that the variability of the S- stimuli would make those signals more discriminable from the S+ stimuli and when this procedure was subjected to testing using externally generated stimuli pairs, subjects made correct discriminations on 81% of the trials, a performance level that was superior to that of both the WH and Katkin procedures under the same testing method. Using this method of generating S+ and S- stimulus trains, the modified Katkin procedure appeared capable of producing results comparable to those of other HBD procedures.

Davis et al (1986) claimed that the difficulty experienced by subjects in solving the Katkin procedure was attributable to the S- generating formula. The investigators pointed out that given that N in this formula varies from 1 to 200 (held constant within a trial), the S- feedback delay after a heartbeat can vary from 30 ms to 500 ms within an experimental session. Consequently, on some occasions the S- interval will be as short or even shorter than the S+ interval, producing potentially confusing situations for reliable discrimination between S+ and S- feedback stimuli. To eliminate those ambiguous instances, Davis et al (1986) devised the Constant Initial Delay (CID) procedure, a variant of the Katkin task where on S- trials, stimuli were delayed after the heartbeat by at least 330 ms. The modified S- generating formula was S- = 300 + 30BI, the random value N replaced by a constant initial delay of 300 ms, to which a 30 ms delay was added after each heartbeat in a series of 10 beats.

As mentioned in Chapter Three, when compared with the WH and Katkin procedures, the CID procedure led to significantly better heartbeat discrimination than the WH or Katkin procedures. On the second part of that study, Davis and his colleagues tested the possibility of subjects discriminating between the S+ and S- trials by the detection of differences in the periodicities of the feedback trains rather than detection of sensations of their heartbeats. The results of that test dispelled this hypothesis and the reasearchers attributed the apparent superiority of the CID task over the WH and Katkin tasks to the clear difference between the arrangement of feedback stimuli in S+ and S- trials in the CID procedure.

An investigation of the relative discriminability of S+ and S- feedback stimuli in a WH-type heartbeat discrimination task was carried out by Clemens (1984). In the first of a series of three studies subjects were required to discriminate between three WH-type stimulus delays. There were two types of S+ trials, each with trains of light flash stimuli delayed a constant interval from then R-Wave. On one type of S+ trial, the external stimuli were presented coincidental on each R-Wave (R+0 ms) and on the other S+ trial type, stimuli were presented 100 ms after the R-Wave (R+100 ms). On S- trials the stimuli were presented 400 ms after each heartbeat (R+ 400 ms). When subjects had experienced all three stimulus trial types, the data showed that subjects could reliably distinguish either the R+0 ms or R+100 ms stimuli trains from the R+400 ms feedback stimuli but were unable to discriminate between the R+0 ms and R+100 ms S+ stimulus trains.

In a second experiment subjects were asked to judge which of five trains of S+-type stimuli presented 0, 100, 200, 300 and 400 ms respectively after their heartbeats they perceived as "most heartlike" (ie. which train produced stimuli which were most synchronous with sensations of heartbeats). The subjects judged R+0, R+100 and R+200 stimuli trains as synchronous with their heartbeat sensations significantly more often than R+300 and R+400 ms delays. From the findings of these studies, Clemens proposed that the crucial time period in HBD tasks during which subjects could detect a heartbeat spanned from the onset of the R-Wave to approximately 200 milliseconds after its occurrence, a time span coinciding with cardiac events of approximately the first quarter second following the R-Wave.

To recapitulate, the basic feature of the Katkin, Hantas and CID variants of the WH task, involves the discrimination of stimuli that follow heartbeats after a fixed delay (S+) from stimuli that which follow heartbeats after a delay that increases on progressive heartbeats within a trial (S-). Although the S+ stimulus delay is the same (R+100 ms) in all those procedures, the range of potential S- stimulus delays varies within and between procedures; from R+30 to R+500 ms (Katkin et al, 1981), from R+0 to R+400 ms (Hantas et al, 1983) and from R+330 to R+600 ms in the CID procedure (Davis et al, 1986). It is only the CID and the WH procedures which conform to the recommendations of Clemens that S+ feedback stimuli should be presented within the first quarter second after the R-Wave and S- feedback stimuli should be presented outside that time period.

Those two time periods were used as useful starting points in the following examination of the temporal arrangement of both S+ and S- external stimuli in HBD procedures. In most HBD procedures the definition of an S+ feedback stimulus is an external signal that occurs simultaneously with a specific internal heartbeat sensation while an S- feedback stimulus is an external signal that bears a temporal relationship to the internal sensation but does not coincide with it. Accordingly, accurate discrimination between S+ and S- feedback stimuli in HBD procedures requires the ability to reliably distinguish stimulus pairs in different modalities which occur simultaneously from similar stimulus pairs that are separated by a short time interval. If one recalls, this requirement was unfulfilled in Clemens' study where the subjects were unable to distinguish stimuli that occurred simultaneously with the R-Wave from those occurring 100 ms after the R-Wave. Two related possibilities can be proposed to explain this finding. One is that the sensations arising from cardiac activity such as ventricular contraction on which the subjects may have based their discriminative responses, are not clearly defined and therefore may be detected over a relatively wide time space. The second possibility is that subjects may have been unable to make the psychophysical judgement imposed by the task as suggested by Katkin et al (1983). The latter point underscores the necessity of ensuring that HBD procedures do not involve temporal discriminations that exceed individuals' capacities. The experiments to be reported address this issue by employing externally-presented paired stimuli in different exteroceptive modalities which represented the implicit pairing of interoceptive and exteroceptive stimuli involved in HBD tasks.

Experiment I examined the ability of individuals' to discriminate between different short time intervals. Although pilot studies have been conducted to explore this aim, it was felt that the issue justified a more formal investigation. As reported earlier, Katkin et al (1983) found that subjects were unable to discriminate above chance level, pairs of tones separated by a long delay of 384 ms (S- stimulus pairs) from pairs separated by a short delay of 128 ms (S+ stimulus pairs). Experiment I tested these findings and elaborated on the procedure by ascertaining the shortest inter-stimulus interval between S- stimulus pairs that subjects could discriminate from

S+ stimulus pairs separated by 128 ms. Such data would indicate the proximity of S- to S+ stimuli appropriate for reliable discrimination within an HBD paradigm. This information would also be relevant to the Whitehead procedure if subjects detected the heartbeat on the basis of events that were contiguous with the R-Wave.

EXPERIMENT I: Judgements of the temporal relationships between external stimuli.

METHOD

SUBJECTS

The subjects were ten (five males and five females) first-year undergraduates aged 22-35 years (mean, 25.0 yrs) from the Psychology Department of Hull University. All the subjects received one hour's course credit for participating in the experiment.

APPARATUS

The subjects were reclined in a chaise-longue which had been fitted with head and arm rests and which was situated in a sound- and light-attenuated cubicle. The cubicle measured 230 by 145 cms by 225 cms high and was housed in the laboratory. Fixed to the wall at eye level was a display board which held a red light bulb and panels which illuminated to display instructions and information when appropriate. Situated below the display board was a speaker through which auditory signals were presented. The subjects were provided with two microswitch buttons fixed into a hand-held unit which they held in their left hands. They registered a response on each trial by pressing one of the two buttons (see Appendix; Figures A1 and A2). Communication between experimenter and subjects was maintained via an audio intercom.

Heart rate was recorded from three rectangular nickel-plated limb electrodes placed in the Standard Lead II configuration with attachments on the right wrist, left ankle and the earth electrode placed on the right ankle. Beckman electrode paste was used as the conducting medium between the electrodes and skin. The EKG signals were amplified by a Grass Model 7P3B pre-amplifier and displayed on the polygraph. Signals from the output of the driver amplifier were delivered to a Heath Binary Information Module Schmitt trigger which triggered a 20 ms logic pulse on each R-Wave and was fed to the digital port of an Amstrad CPC464 computer. The logic circuitry could also be set to generate false heartbeat feedback at a frequency equal to the subject's mean heartrate.

The computer scanned the digital port 300 times a second in order to detect and time the occurrence of heartbeats. It also recorded the interbeat intervals (IBIs) and other time intervals required for the data analyses described in the Results section. In addition it was programmed to present all the visual and auditory stimuli necessary during the both experiments, to display KOR when appropriate, to record subjects' responses on each trial and to store all the data on floppy discs for subsequent analysis.

PROCEDURE

After electrode attachments had been made, subjects were escorted to the experimental cubicle and instructed on the discrimination task. They were shown a diagram illustrating the arrangement of auditory stimulus pairs on S+ and S- trials and told they would be presented with a train of either of those stimulus types on each trial. The session consisted of 150 discrimination trials with 2-3 minutes rest periods after a block of 50 trials. A session took about an hour to complete.

The Discrimination Task.

The task required the ability to discriminate S1 (first stimulus of pair) and S2 (second stimulus) paired tones which were separated by 128 ms from pairs of tones which were separated by a longer time interval. The S1 tone was always presented simultaneously on the R-Wave and was 1000 Hz in frequency. The S2 tone was 1500 Hz and both tones each lasted 50 ms. On S+ trials, S1 and S2 tones were separated by a constant interval of 128 ms. On S- trials, the time interval between S1 and S2 tones was continously adjusted to an interval which was always longer than 128 ms and not more than 384 ms.

The computer was programmed to analyse data in blocks of ten trials during the course of the experiment. In each block of ten trials equal numbers of S+ and S- trial types were presented and trials were presented in a quasi-random fashion with the restriction that one trial type did not occur more than three times in a row. After each block of ten trials the computer produced a printout of the subject's performance on the preceding block.

The computer was also programmed to adjust the inter-stimulus interval (ISI) on S- trials after every block of ten trials. If the subject achieved a score of eight or more correct responses on a block of ten trials, the ISIs of the S-trials on the next block of ten trials would be shortened by a value equal to half of the preceding block's ISI less 50 ms. The value of 50 ms was subtracted from the ISI to prevent an overlap of the S2 and S1 stimuli, each of which had a duration of 50 ms. The adjustment would be made using the formula:

$$D = D' - [\ 0.5(D' - 50)\ ] \text{ milliseconds,}$$

where D is the adjusted interval for the next 10 trials and D' is the interval of the previous block of 10 trials. When a score was less than eight correct discriminations in a block of 10 trials then the interval was lenghtened according to the formula: $D = D' + [\ 0.5(D' - 50)\ ]$ milliseconds.

The subjects were informed about the continous adjustments made to the ISIs on the S- trials and in order to allow them identify the S+ and S- trial types and to experience features of the procedure, three practice trials were run. When it was established that they fully understood the procedure, the first trial of the session was commenced.

To alert the subjects to the start of a trial, the 'GET READY' sign on the display panel was illuminated for 500 ms prior to the initiation of the trial. Trial lengths were not predetermined in this experiment and subjects were allowed unlimited time to attend to the external stimuli before they registered a response. Hence, stimulus pairs were continually presented until a response button was pressed. The subjects were instructed to hold the the response unit in a specified way and told to press the right-placed microswitch button if they thought the stimuli presented were separated by the short time interval and the left-placed button if they judged the stimulus trains as S- type. After a response was made either the 'CORRECT' or 'WRONG' panels lighted up, each accompanied by a different pitched beep to signify a correct or incorrect discrimination. The time lapse from the onset of the first tone on every trial until a button press was made was recorded as the response latency and the next trial was initiated five seconds after a button press.

RESULTS

Discrimination Performance

The shortest time interval on S- trials subjects could reliably discriminate from a fixed time interval of 128 ms (S+ trials) was recorded for each subject. Reliable discrimination was defined as obtaining at least eight correct responses over a block of ten trials with the same D intervals on the five S- stimulus trains. Table 4.1 shows the shortest ISIs on S- trials discriminated from the S+ trials for each subjects. Subjects' genders are also shown.

The discrimination performance data showed that for the group as a whole, events separated by 128 ms could be reliably differentiated from events separated by 139.68 ms. In effect, given externally generated pairs of tones, subjects could make correct discriminations on 80% of the trials about an eleven-millisecond temporal difference between unimodal external stimuli.

TABLE 4.1 Shortest ISIs reliably discriminated from 128 ms interstimulus interval for each subject.

SUBJECTS	SHORTEST ISI/ms
1.(F)	149.52
2.(F)	135.17
3.(M)	136.07
4.(M)	133.38
5.(F)	152.21
6.(F)	137.56
7.(M)	137.56
8.(M)	133.38
9.(M)	138.76
10.(F)	143.19
Mean	139.68
Median	137.56

There was a tendency for males to discriminate shorter S- interstimulus intervals from the S+ interstimulus interval. However, a t-test failed to indicate any significant differences between the males' and females' discrimination performance.

The highly accurate discriminative ability exhibited by subjects on this study substantiated the finding reported in pilot studies undertaken earlier that subjects can make the discriminations associated with the Whitehead HBD procedure. However, in order to extend these findings to other cases, a second experiment was conducted within a similar framework but with modifications which would produce results more appropriate for drawing conclusions about the discriminability of stimulus arrangements in other conventional HBD tasks.

Experiment II was aimed at determining how short a time interval subjects can reliably discriminate from simultaneity. It was anticipated that judgments of the simultaneity of external stimuli would generate information relevant to procedures where external signals are assumed to be occurring simultaneously with heartbeat sensations. Furthermore, the experimental procedure employed required subjects to make temporal discriminations involving externally generated stimuli in two different modalities, as it was reasoned that this bimodal stimulus-pairing would more closely mimic the implicit pairing of interoceptive and exteroceptive stimuli in HBD tasks.

In one experimental condition of the study one of the pairs of external signals was triggered by the subjects' heartbeats because it was hypothesized that the summation of the internal heartbeat signal and external stimulus would provide subjects with an augmented signal which might provide a clearer basis for making judgements and therefore improve their discriminative ability. In the other experimental procedure the external stimuli were generated from a multivibrator and were therefore unrelated to cardiac activity.

EXPERIMENT II: Judgements of the simultaneity of external stimuli

METHOD

SUBJECTS

The subjects were 24 (12 females and 12 males) graduates and undergraduates aged 18-34 years (mean age, 22yrs) recruited by advertisement from the University of Hull. They were told that they would be required to participate in two experimental sessions involving some simple discrimination tasks over two consecutive days and were assigned to MV-HB and HB-MV groups according to their arrival at the laboratory. At the end of the experiment, each subject was paid £3 for expenses.

APPARATUS

The apparatus and recording equipment employed in this experiment were identical to that used in Experiment I.

PROCEDURE

After recording electrodes had been attached and the subjects were seated in the experimental cubicle, they were instructed about the task with the aid of a diagram showing the stimulus arrangements on S+ and S- trials. Each session consisted of 200 discrimination trials with a 2-3 minute rest period after a block of 50 trials. A session took an hour on average to complete and one session was performed each day for a total of two days.

The Discrimination Task

Subjects were required to discriminate trains of paired visual and auditory stimuli occurring simultaneously (S+ trials) from pairs of those stimuli occurring a short time apart (S-trials). The auditory stimulus was a 50 ms, 1000 Hz tone and the visual stimulus was a red light flash also 50 ms in duration. On the S- trials, the S1 stimulus was the light flash and the tone was the S2 stimulus.

The interstimulus interval (ISI) on S- trials was set at the maximum duration of 400 ms at the beginning of each session. During the course of the task, systematic increases and decrease of the ISI were conducted as described in the previous experiment with the restriction that the ISI was never less than 50 ms to prevent an overlap of the light and tone stimuli, each of which lasted for 50 ms. Subjects were given KOR after each response from Trial 1 to Trial 150.

After 150 trials, the printout of the subject's discrimination performance was consulted to find the shortest time interval between the external stimuli on the S- trials that the subject had reliably discriminated from the S+ trial type. This value was keyed into the computer and for the last block of 50 trials (Trials 151-200) the time interval between visual and auditory stimuli presentations in the S- trials was kept constant at this value. Additionally, during Trials 161 to 190, subjects were not given any KOR and resumed once more during the last ten trials (Trials 191 to 200) of the session. A diagram of the procedural features in a session is shown in Table 4.2.

TABLE 4.2: Schematic representation of procedural changes in a session of 200 discrimination trials.

TRIAL NOS.	PROCEDURE
1 - 150	KOR available Time interval between auditory and visual stimuli in S- trials was varied systematically depending on performance.
151 - 160	KOR available Time interval between auditory and visual stimuli on S- trials was kept constant at the shortest discriminable value.
161 - 190	KOR withdrawn Time interval between auditory and visual stimuli on S- trials was kept constant at the shortest discriminable value.
191 - 200	KOR available Time intervale between auditory and visual stimuli on S- trials was kept constant at the shortest discriminable value.

Once subjects fully understood the procedure and any questions had been answered, they were presented with a block of ten practice trials. For those trials the interstimulus interval (ISI) between the visual and auditory stimuli was set at 500 ms during the S- trials and during the S+ trials the stimuli were presented simultaneously. On completion of the practice block the subjects were informed that throughout the experiment, the S+ stimulus train would remain unchanged from what they had been presented but that the ISIs on the S- trains would be systematically shortened or lenghtened as their level of discrimination performance improved or decreased respectively. Finally, they were told to aim at making as many correct discrimination responses as possible.

There were two versions of the discrimination task (HB and MV Procedures) and the subjects were run on a different version on each session. Subjects in group MV-HB performed the MV procedure followed by the HB procedure on the second session. and members of the HB-MV group performed the tasks in the opposite order. During the HB Procedure the first stimulus (S1) of a stimulus pair was triggered by the R-Wave signals of the subject's ongoing heartbeats while on the MV Procedure the stimuli were generated by logic circuitry at a constant rate of 60 stimulus pairs per minute. In effect, on the MV Procedure the stimulus pairs were delivered at a constant rate and on the HB Procedure they mirrored the variability of the subject's normal heart rate rhythm.

RESULTS

Discrimination Performance

The shortest interval a subject could reliably discriminate from simultaneity was recorded as the shortest interstimulus interval (ISI) between the auditory and visual stimuli on the S- trials of a block of ten trials on which the subject made at least eight correct discriminations. This ISI value was recorded for each subject over the first 150 discrimination training trials for the HB and MV Procedures and those data are shown in Table 4.3. The summary table (Table

TABLE 4.3: The shortest interstimulus intervals on S- trials reliably discriminated from simultaneously presented stimuli by each subject on HB and MV Procedures.

HB-MV GROUP			MV-HB GROUP		
	Procedures			Procedures	
Subjects	HB	MV	Subjects	MV	HB
BM(M)	160.74	225.00	MD(F)	190.16	123.83
JC(M)	112.29	55.19	VR(F)	148.44	123.83
MC(F)	239.84	143.44	SB(F)	197.66	174.58
GM(F)	148.44	174.58	JC(F)	81.15	65.57
AM(M)	68.46	68.46	AE(M)	174.58	143.44
ZN(F)	133.06	133.06	RA(F)	133.06	143.44
AL(F)	112.29	112.29	PW(M)	77.69	77.69
JK(F)	115.63	97.46	AS(M)	143.44	88.22
AW(M)	74.61	86.91	JH(F)	96.72	160.74
EC(F)	190.16	148.44	SD(M)	176.56	174.58
PB(M)	133.06	81.15	PD(M)	225.00	190.16
FC(M)	70.76	66.41	JG(M)	86.91	148.44

F=FEMALE : M=MALE

4.4) of the data indicates that the subjects exhibited very similar discrimination performance on both procedures.

TABLE 4.4: Range and Mean minimum D values for HB and MV Discrimination Procedures.

PROCEDURE	RANGE/ms	MEAN/ms
HB Procedure	65.57 - 239.84	129.63
MV Procedure	55.19 - 225.00	128.70

Mean discrimination values for the HB-MV and MV-HB groups on both procedures were also inspected and are tabulated below in Table 4.5.

TABLE 4.5: Mean shortest ISI values for HB-MV and MV-HB groups on HB and MV Procedures.

	HB PROCEDURE/ms	MV PROCEDURE/ms
HB-MV Group	129.94	116.03
MV-HB Group	134.53	144.28

In order to test the reliabilty of these observations, mean ISI values for all subjects were entered into a two-way ANOVA for repeated measures (Groups: HB-MV/MV-HB by Procedures: HB/MV). This analysis yielded no significant main effects or interactions, confirming the observations that there were no significant differences between performance on the HB and MV Procedures and there was no transfer of training effects between the tasks.

Gender Differences

Considering the absence of significant performance differences in the procedures and groups, the data were reclassified to allow testing of performance variations associated with gender.

TABLE 4.6: Mean discrimination scores for males and females on HB and MV Procedures.

	HB PROCEDURE/ms	MV PROCEDURE/ms
MALES	120.20	122.27
FEMALES	144.28	138.04

A two-way ANOVA for repeated measures (Tasks: HB/MV by Gender: Males/Females) performed on the mean shortest ISI scores failed to show any significant differences between males and females in their performance on the MV and HB procedures (shown in Table 4.6).

Response Latencies

As the analyses above revealed no significant differences between the two procedures, performance data obtained from the procedures were pooled and treated as one sample. To examine the relationship between response latencies and discrimination performance, the percent mean correct discriminations and mean response latencies for all subjects were tabulated (Table 4.7) for each block of ten trials over the last 50 trials (Trials 151 to 200) of an experimental session.

KOR presentation seemed to be associated with the amount of time subjects took to make a discriminative response. When KOR was withdrawn during Trials 161 to 190, the number of correct discriminations was maintained from the first block (Trials 151 to 160) where KOR had been available, and this corresponded with a slight tendency of longer response latencies. Furthermore, during the final block when KOR was re-introduced, subjects seemed to take less time to make responses. Although those variations are not statistically significant, they suggest that subjects tend to require longer exposure to the external stimuli before making a correct discrimination when they are not being given any information on the correctness of their responses.

TABLE 4.7: Covariation of Mean Response Latencies and Percent Correct Discriminative Responses on Trials 151 to 200 for all subjects on both MV and HB Procedures.

	BLOCKS OF TRIALS				
Trial No.	151-160	161-170	171-180	181-190	191-200
Treatment	KOR	NKR	NKR	NKR	KOR
% Correct Responses	70.83	66.25	67.50	71.67	69.58
Response Latency/s	3.82	4.99	5.42	5.65	3.99

DISCUSSION OF RESULTS FROM EXPERIMENTS I & II

The results from Experiment II show that individuals can reliably discriminate instances where auditory and visual stimuli occur simultaneously from instances when these stimuli are separated by time intervals of as short as 55 ms. Although both the stimuli employed in that experiment were externally presented, subjects' performance on the discrimination task can be related to the skills required in the solution of HBD tasks. In those tasks a subject's ability to detect the different temporal relationships between internal and external stimuli is assessed and while the external stimuli have been presented in the tactile, visual and auditory modalities, the internal stimuli are always heartbeat sensations. As no internal stimuli were explicitly employed in this experiment, the conclusion at this stage is that on average, subjects can accurately discriminate occasions when two stimuli of different modalities occur simultaneously from occasions when those stimuli are separated by a time interval of 130 ms. These results suggest that the inability of subjects to discriminate between R+0 ms and R+100 ms intervals in Clemens' (1984) study was most likely limited by temporal discrimination ability. Evidence in support of this is from the performance data recorded during Experiment II which indicated that less than fifty percent of the subjects were able to discriminate the simultaneously presented events from those separated by 100 ms.

The HB procedure was examined on the premise that the interoceptive-exteroceptive stimuli combination would augument the sensory information on discrimination trials such that on HB trials subjects would be judging delays from visual plus internal sensations whereas on MV trials, delays had to be judged from visual stimuli alone. Hence, on HB trials the internal heartbeat sensations might be a crutch in identifying the temporal position of S1 relative to S2. However the finding that there were no significant differences between performance on the HB and MV procedures indicates that subjects were not aware of and were not influenced by the added information introduced into the HB task. Thus the results support those of Mandler and Kahn (1960) which suggest that subjects are unable to make connections between external stimuli and internal stimuli without any explicit information about the existing relationships.

Providing subjects with information about the accuracy of their responses was shown to be an important feature in this discrimination task. In the last 50 trials of the task when KOR was withdrawn for 30 trials, even though the level of difficulty on the task during that time period had been previously encountered and performance at that level then was near perfect with KOR, most subjects verbally reported that they found the task during that time as much more difficult than when KOR was provided. There was also the suggestion of a slight increase in the period of stimulus inspection prior to the registration of a decision. Existing theoretical frameworks claim that external reinforcement allows the formation of internal criteria for judging response accuracy (Adams, 1971; Brener, 1974) and might suggest that subjects experienced difficulty in obtaining access to the 'internal template' or the perceptual criterion of a correct discriminatory response when KOR is withdrawn. However, as there were no significant changes in performance with KOR withdrawal, these explanations are only tentative and must await further investigation.

The discrimination performance exhibited in Experiment I substantiates that individuals can make the discrimination involved in the WH task. In the WH task subjects are required to detect the difference between events separated by 128 ms and those separated by 384 ms, a time difference of 256 ms. The results showed that a mean time interval difference of as short as 11 ms could be detected accurately. The disparity between these results and those reported by Katkin et al (1983) when fundamentally similar procedures were used in both studies, questions the authencity of their data. Although they did not report giving their subjects KOR during discrimination trials, as was done in the present study, it is not expected that that effect could be attributable to the marked difference in findings.

To conclude, on the basis of the evidence presented, subjects are highly capable of discriminating temporal relationships characteristic of S+ and S- stimuli in HBD procedures. The performance data from Experiment I appeared to indicate better discrimination ability than performance in Experiment II (ie. discrimination of 11 ms temporal difference between S+ and S- trials in constrast with 130 ms). Although it is not possible to compare the task performances on the same criteria, it is likely that this difference is related to whether the stimulus pairs employed are in the same or different modalities, with temporal discrimination between unimodal stimuli being easier to achieve than discrimination between bimodal stimuli. Furthermore, the S+ standard interval against which the S- was being compared was 128 ms in Experiment I and 0 ms in Experiment II. Hence, as from basic psychophysics principles it is to be expected that the difference threshold would be longer in Experiment I, the difference in temporal discrimination must be attributable to differences in stimulus modality (ie. unimodal versus bimodal stimulus pairs). Data from Experiment II should be more relevant to HBD procedures as paired stimuli in different modalities are involved. Thus, assuming that subjects perceive the occurrence of heartbeat sensations which are contiguous with the presentation of an S+ signal (eg. a tone on the R-

Wave), the S- signal must be located at least 240 ms from the S+ signal to allow unequivocal heartbeat detection. Hence, if heartbeat sensations occur 128 ms after the R-Wave, as implied in the Whitehead procedure, then subjects should not experience any difficulty in identifying heartbeat-noncontingent stimuli presented 384 ms after the R-Wave (a time separation of 256 ms between stimuli). Therefore, it is doubtful that the difficulty that subjects experience during performance on the WH task can be attributed to the requisite temporal discriminations associated with the identification of S+ and S- stimuli. Possible explanations could be that subjects are unable to detect internal heartbeat sensations accurately or they are unable to associate those internal sensations with the external signals presented in the procedure. Both these possibilities will be explored in the experimental work to be reported which will attempt to determine the nature and causes of difficulty encountered in procedures assessing cardiac discrimination.

CHAPTER FIVE

EXPERIMENT III: DETECTION OF INTEROCEPTIVE STIMULI

INTRODUCTION

By the use of externally generated signals in different sensory modalities, the previous experiments have established that subjects can accurately distinguish between the various interstimulus intervals used in several HBD procedures. Consequently, it is expected that if heartbeats are substituted for the external signals in those paradigms, subjects should be capable of performing the necessary temporal discriminations required in most HBD tasks and the WH task in particular. However, overwhelming evidence reveals that the majority of subjects are unable to solve these tasks and exhibit a low incidence of cardiac perception when presented with the WH HBD procedure. It is rather difficult to provide reasons why individuals exhibit poor cardiac discrimination ability since they are able to make the temporal discriminations involved in the task and internal sensory processes are available to undertake the demands involved in the process of visceral perception (Adam, 1967; Chernigovskiy, 1967; Newman, 1974). One possibility proposed from a review of the experimental procedures undertaken in HBD studies is that subjects are unable to fully comprehend the requirements imposed by the HBD tasks.

Admittedly the HBD task is a novel task to the majority of subjects and it seems reasonable to entertain the idea that subjects might be unable to understand the task instructions and sensory requirements of the procedures and consequently prove incapable of performing satisfactorily on the task. This view is supported by remarks made in a few published reports of HBD studies. Ross and Brener (1981) reported that two subjects had to be excluded from the analyses of experimental data because those subjects "seriously misinterpreted the instructions" (page 63). The same reason was given by Davis et al (1986) when those investigators also had to exclude two subjects from the data analyses of their HBD study.

In an effort to provide subjects with the best opportunity of exhibiting cardiac perception on the WH task, some modifications were made to several procedural features of the original WH procedure. Firstly, the subjects who underwent the temporal discrimination procedures in Experiment II were recalled to take part in this experiment thus satisfing the condition that they were able to perform the temporal discriminations associated with the WH task. Secondly, a modified version of the WH task named the Radial Pulse (RP) Discrimination Procedure was introduced into the experimental design. In this procedure the subjects were told to palpate the radial pulse during one phase of the experimental session and to employ the tactile sensations in solution of the discrimination task. In all other respects this version was identical to the basic design of the WH procedure.

There were two reasons for introducing the RP task. Firstly, it provided subjects with the opportunity to detect explicit cardiac-related sensations with relative ease. Secondly, if they were able to solve this task then it could be inferred that they could acquire the requirements of the WH HBD procedure using a cardiac-related mechanical sensation. Presentation of this task was counterbalanced with performance on the HBD task to evaluate its influence on the performance of the HBD task.

Two other procedural alterations were made to the original WH HBD procedure. On the modified procedure named the R-Wave (RW) Discrimination procedure, the placements of S+ and S- stimuli and the definition of trial lengths were altered. The decision to alter the placement of the S+ and S- signals in this study was based on evidence from the subjects performance during Experiment II. The S+ signals were presented coincidental on the heartbeats and the S- signals were presented 400 ms after the heartbeat. All the subjects used in the present experiment had been able to discriminate at 100% on all the trials requiring discrimination between these two stimulus positions. This arrangement also allows the much longer time difference of 400 milliseconds between the immediate and delayed feedback (compared to 256 milliseconds in the original Whitehead procedure) and in this case also, all the subjects were able to make this temporal discrimination in the previous experiment. Hence, this experimental design is expected to provide a condition in which the detection of S+ and S- stimuli would be easier to make without compromising the assessment of heartbeat perception.

The second procedural modification involved the delineation of trial lengths. Most of the HBD procedures developed (eg. the Katkin, BJ and WH procedures) involve presenting subjects with a series of trials each approximately ten seconds long with subjects allowed a five-second intertrial interval in which to register a discriminative response. In the BJ task, the trial lengths varied, each trial period defined as the time it took for the production of fifteen heartbeats. This short trial duration accomodated approximately ten to fifteen heartbeat-related stimuli. One can envisage the creation of a potentially "noisy" situation especially on S- trials where the possibility of heartbeat-feedback overlap would be increased (Clemens, 1979). Not suprisingly, several subjects tested in pilot studies reported that they found the trials too short to enable them make authentic discriminations and also reported feeling pressurized into registering a decision within the time limit allowed. These critisicms were curtailed when the trial arrangement used in the previous experiments was adopted for the HBD tasks. Hence, in Experiment III trial durations were not predetermined and subjects had unlimited time to attend to and record their discrimination responses.

In summary, this study was undertaken to evaluate the ability of individuals to discriminate sensations of their heartbeats in a situation where the main prequisites for the solution of a heartbeat discrimination task had been fulfilled. It was hypothesized that heartbeat discrimination performance on the RW procedure would compare favourably with performance on other HBD procedures because all the subjects had been tested and trained on Experiment II. Furthermore, it is expected that subjects who trained on the RP Procedure prior to performing on the RW Procedure would show superior heartbeat discrimination performance on the RW Procedure.

METHOD

SUBJECTS

Subjects used were those from Experiment II. They were re-assigned to two groups; RW-RP and RP-RW groups. Each group consisted of twelve females and twelve males.

APPARATUS

The apparatus was identical to that used in the previous experiments.

PROCEDURE

After electrode attachment and subjects were comfortably reclined on the chaise-longue, the discrimination task was fully explained to them with the aid of a diagram showing the stimuli trains on the S+ and S- trial types. During half the trials on the HDB tasks, the onset of 50 ms, 1000 Hz tones followed the R Waves of the EKG by 400 ms (S- trials) and during the remaining half of the trials those tones were presented coincidentally on the R Waves of the EKG (S+ trials). The subjects were told they could attend to the tones on each trial for as long as they wished before making a decision about whether the tones occurred simultaneously with sensations of their heartbeats or occurred at a short interval after those sensations. The subjects registered their discrimination response by pressing the appropriate one of two microswitch buttons fixed into a unit held in their left hands. A button press terminated the stream of tones.

On the RW task subjects were asked not to use any peripheral pulses during the procedure to solve the task.

During the RP task, subjects on instruction, palpated their left wrists for a radial pulse using the fingers of their right hands and employed the sensation in solving the task. After any questions had been answered and the subjects appeared to understand the task fully, they were advised to relax and to minimize all movements so as not to interfere with the heartbeat recordings. After a resting baseline period of four minutes, the session began.

The onset of each trial was signalled by the 'GET READY' sign on the wall display lighting up for five seconds. Trials were presented in blocks of ten trials, each block with five trials of S+ type and five of S- type presented in a predetermined random order with the constraint that the probability of the presentation of S- and S+ trial types on each block of ten trials was 50% . There was the additional restriction that a trial type did not occur more than three times successively.

The first session of a HBD task began with the Pre-training Phase which consisted of the presentation of 20 HBD trials during which subjects were not informed about the correctness of their discriminative responses. The heartbeat Discrimination Training Phase began about five minutes after completion of the Pre-training Phase. On discrimination training (DT) trials, after subjects had made a response, depending on the correctness of the response either the 'CORRECT' or 'WRONG' signs on the display panel was illuminated briefly, each accompanied by a characteristic 'beep'. Knowledge of results (KOR) was presented in two modalities (ie.

auditory and visual) because during pilot studies undertaken earlier, several subjects disclosed that they kept their eyes closed during trials to "block" out extraneous stimuli in order to accentuate their awareness of internal sensations.

A maximum of 200 DT trials was run in one day with a three-minute rest period after each block of 50 trials. These trials were terminated when subjects had achieved the criterion for successful discrimination or when they had been presented with a total of 400 DT trials over two days. The criterion set for successful discrimination was a score of 80% or more correct responses over two consecutive blocks of ten DT trials. The subjects were not given any information about the existence or details of the criterion level. If this criterion was not attained on the first day of training, subjects continued the task on the following day. Subjects who were successful on the task were run through the Post-Criterion Phase which was identical to the Pre-training Phase.

On completion of one HBD procedure either by completion of the Post-Criterion Phase or 400 discrimination trials, subjects started on the second task the next day. Half the subjects were tested on the RP procedure first (RP-RW group) and the other group (RW-RP group) received the tasks in the reversed order. Following completion of both procedures all subjects were debriefed and paid a flat fee of £3.

Measures of Performance and Data Analysis

Two measures of discrimination performance were recorded for each subject on each procedure. The first measure was only applicable to those who achieved the criterion for successful discrimination on a procedure during a Discrimination Training Phase. This was calculated from the number of discrimination training trials subjects were presented with prior to achieving the criterion for successful discrimination and was termed the 'trials-to-criterion' performance measure. Subjects who did not achieve this criterion after 400 DT trials were considered unsuccessful cardiac discriminators.

The second measure was the percentage of correct responses each subject made during the experimental Phases (Pre-Training, Training, Criterion and Post-Criterion). The duration of time from the onset of a trial to when the subject made a button press response was termed the response latency and was recorded on each trial for each subject.

These data were analyzed in order to ascertain whether all subjects were able to solve the cardiac discrimination tasks and whether discrimination performance improved with training. Performance on the RP and RW Procedures was analysed for inter-task transfer effects.

RESULTS

Discrimination Performance

Table 5.1 shows the amount of training required by each subject to reach the criterion for successful discrimination on the RW and RP cardiac discrimination procedures.

Twenty-three subjects (98.8%) were able to solve the RP task and 15 (62.5%) solved the RW task. All the subjects who were successful on the RW task were also successful on the RP task. Only one subject was unable to solve the RP task and she was also unsuccessful on the RW task.

TABLE 5.1: Trials to criterion of 80% correct discrimination for all subjects on both procedures.

* Indicates subjects who did not achieve the criterion for successful discrimination performance.

RP-RW GROUP			RW-RP GROUP		
	Procedures			Procedures	
Subjects	RP	RW	Subjects	RP	RW
JC(M)	30	400*	MD(F)	120	400*
VR(F)	70	300	SB(F)	20	80
GM(F)	100	140	BM(M)	190	100
AL(F)	60	400*	MC(F)	400*	400*
FC(M)	20	120	AM(M)	50	90
RA(F)	40	50	ZN(F)	20	30
PW(M)	50	400*	JC(F)	70	240
AS(M)	270	300	AE(M)	100	400*
JH(F)	120	40	SD(M)	90	400*
AW(M)	50	220	JK(F)	100	400*
EC(F)	100	170	PB(M)	120	330
PD(M)	60	140	JG(M)	170	400*
Mean	80.83	223.33	Mean	120.83	272.50
Median	60.00	195.00	Median	100.00	365.00

In order to determine any differences in the rate at which the tasks were solved, a two-factor ANOVA for repeated measures (two Groups by two Procedures) was performed on the trials-to-criterion data. This yielded a main effect for Procedures [$F(1/22)=24.77$, $p<.01$] and indicated that criterion performance was acquired more rapidly on the RP task than on the RW task. Since neither the Groups effect nor Groups by Procedures interaction were significant, it may be concluded that the order of presentation of procedures did not have any effect on the rate of the acquisition of the criterion level of performance and there was no transfer of training.

Since gender has previously been reported to be an important variable in cardiac perception all the subjects' data were combined and submitted to a two-factor ANOVA with repeated measures (Gender by two Procedures). The analysis yielded significant main effects only for Procedure [$F(1/22)=25.78$, $p<.01$] with no support for gender differences in cardiac discrimination.

Heartbeat Discrimination Training

In order to determine whether subjects acquired success on the tasks in an incremental fashion with training, their performance data from the Discrimination Training Phase, were examined. Since the number of trials each subject received during the training phase varied widely between subjects, a means of analyzing acquisition was obtained by dividing up the training phase into quartiles and calculating the percentage of correct responses in each quartile. In each case, the last 20 DT trials with which the subjects were presented (during which they achieved the criterion performance) were excluded from the total number of DT trials before the phase was divided into four quartiles. When the total number of trials was not divisable by four, the first two DT trials of the Phase were discarded. In addition, data from subjects who had less than 60 trials-to-criterion (ie. 40 pre-criterion DT trials) were excluded from the analysis. This was because those data would result in placing too few trials in the training quartiles and would consequently render the analysis unreliable. Moreover, the small number of trials those subjects required to attain the criterion level, can be regarded as evidence that they did not acquire discriminative ability incrementally. Data from three subjects who were successful on the RW task and seven successful subjects on the RP task were excluded from this analysis on those bases. The percentage correct data for each quartile for each subject were submitted to one-way ANOVAs for each procedure. There were no significant differences between performance during the four training quartiles of either the RW or RP tasks. In each case, performance was at chance level throughout the discrimination training session. These results indicate that training improves discrimination performance through what appears to be a relatively sudden process.

The overall performances on the RW and RP tasks by the successful subjects were evaluated by comparing the correct discriminative responses they made on all the experimental phases (Pre-training, Training, Criterion and Post-criterion) of each procedure. Percentage correct indices were calculated for each Phase for each subject and were entered into one-way correlated ANOVAs for each procedure. Three subjects' data were excluded from the analysis on the RP procedure because they solved the task after only 20 DT trials and those trials could not constitute both or either of the Training and Criterion Phases. Highly significant effects were exhibited for Phases for each procedure (RW: $F(3/42)=21.84$, $p<.01$; RP: $F(3/57)=62.84$, $p<.01$]. Post hoc analysis using Tukey's test indicated that performance during the Criterion Phase was significantly superior to performance in all the other Phases and the performance during the Post-criterion Phase was better than that during both the Training and Pre-training Phases. The associated mean performance data are shown in Figure 5.1. These results indicate that performance during the Pre-training

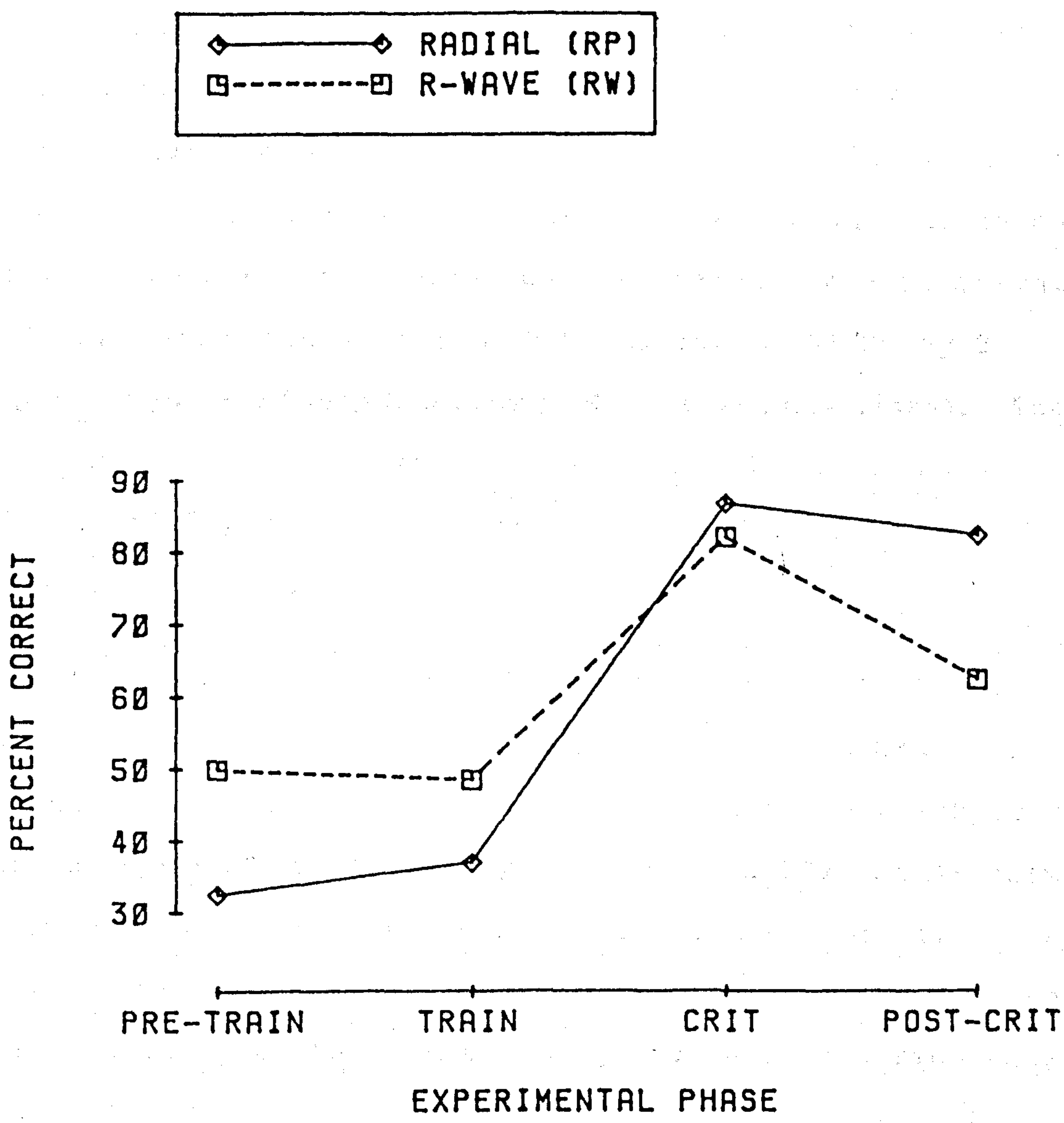


Figure 5.1 Mean Percent correct responses made during four Phases of the RP and RW Discrimination Procedures.

and Training Phases did not differ and although there was a significant decrease in the percentage of correct responses during the Post-Criterion Phase relative to the Criterion phase, performance was still maintained at a level better than that achieved prior to reaching the Criterion phase.

The analysis of Response latencies across experimental phases also produced similar results. Data of subjects' discriminative responses made on S- and S+ trials during all the experimental phases and information about whether those responses were right or wrong were submitted to a three-way ANOVA with repeated measures (2 Trial Types: S+/S- by 2 Response Types: Right/Wrong by 4 Experimental Phases). The analysis yielded main effects due to Experimental Phase [$F(3/210)=5.50$, $p<.01$] and Trial Type [$F(1/210)=10.66$, $p<.01$] and none due to Response Type.

The effect due to the Trial Type indicates that subjects spent a longer time attending to the S+ stimulus trains than S- ones before making a decision. This suggests that subjects might have found it relatively easy to identify the S- stimuli but they needed more time to identify the S+ stimuli. There was also the tendency for subjects to take a longer time to make a decision on the Pre-training and Post-criterion phases than on the Training and Criterion phases. A Tukeys' test comparing the mean response latency on each phase indicated that subjects exhibited their longest decision-making times during the Post-criterion phase. The response latency during the Pre-training phase was also longer than that during the Criterion phase. These data indicate that when subjects were not given KOR, they tended to take a much longer time to make a discriminative response.

Individual Differences in Performance

Following the solution of each procedure all subjects were asked to describe the cues they had employed in discriminating the S+ stimuli from S- stimuli. Many subjects reported that during the RW procedure they were aware of sensations arising from various parts of their bodies which were more closely associated with the S+ stimulus trains than with the S- stimulus trains. Five subjects reported being aware of heartbeat sensations in their chests, two subjects mentioned employing cues from the whole body, two subjects used sensations from the head, one subject was aware of sensations in both the head and chest and two subjects employed sensations from their hands. One subject was aware of cues arising in her abdomen and another subject reported using cues from the lower back region. These discriminative cues which subjects reported using are summarized in Table 5.2.

TABLE 5.2: Subjects' reports of different cues employed in discrimination of S+ and S- Trials in the RW Task.

Number of subjects reporting auditory feedback (S+) correlated with sensations in:	chest	6
	hands	2
	head	3
	back	1
	abdomen	1
	whole body	2

The subjects reported that intensity and apparent ease of perception of those sensations varied throughout the sessions and on some occasions the sensations could be derived from more than one part of the body. Not suprisingly, the most popular location of these sensations was the chest where it is reasonable to expect that the internal sensations required for making judgements could be derived from mechanoreceptors in the chest stimulated by ventricular contraction. It is most likely that the discrimative cues from other locations were due to peripheral pulsations arising from various mechanoreceptors stimulated by the pressure pulse wave.

On the RP procedure subjects complied with the instructions to use explicit pulse sensations to discriminate the heartbeat coincident stimuli from those stimuli which were delayed from the heartbeats. Sixteen out of 24 subjects reported that sensations from their radial pulse coincided with the tones on the S- trains and not with the S+ stimuli while the rest of the subjects who were also able to accurately discriminate S+ trials from S- trials said their pulse sensations were more closely associated with S+ tones rather than with S- stimulus trains.

DISCUSSION

Of the 24 subjects who participated in this experiment, fifteen subjects on the RW procedure, and 23 subjects on the RP procedure achieved the criterion discrimination performance level (80% correct responses over 20 consecutive discrimination trials). These data are significant because they provide evidence that individuals can be trained to detect sensations associated with cardiac activity. The performance level shown on the RW procedure (which is a very close approximation of the Whitehead heartbeat discrimination procedure), is one of the higher levels of performance reported in the use of WH or WH-type heartbeat discrimination procedures. Ross and Brener (1981) were able to train over 95% of their subjects successfully on the WH task but other studies have reported much smaller numbers of successful subjects on this type of task (Clemens, 1979; Katkin, Morrell, Goldband and Bernstein, 1980; Jones, Jones, Cunningham and Caldwell, 1985; Davis et al, 1986).

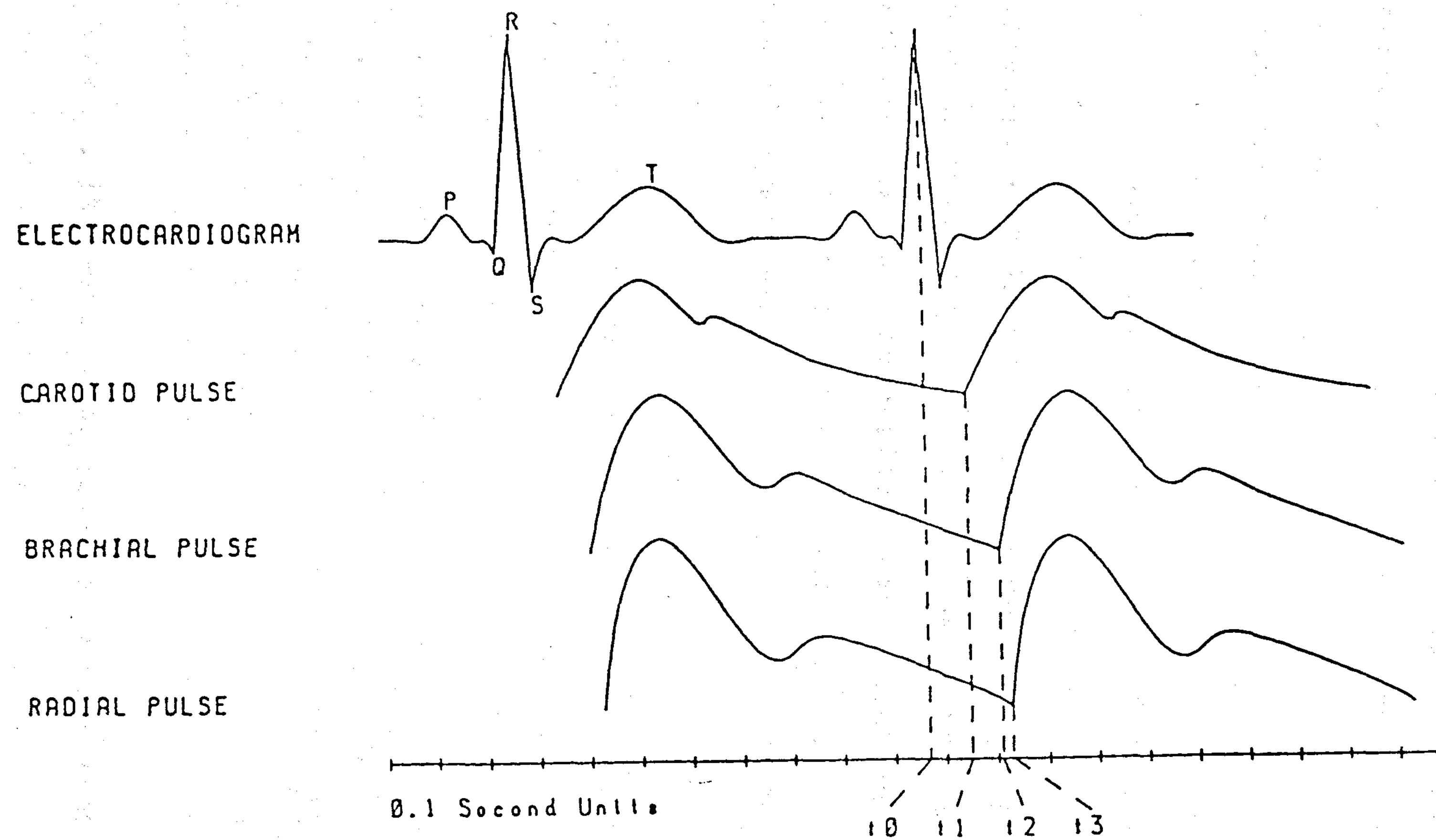
The data analysis did not indicate any transfer of training between the RP and RW procedures and it was not feasible to test for transfer between the tasks in Experiment II and those in Experiment III (because the measures of performance used were very different), but the high success rate of subjects on the RW procedure (62.5%) suggest that subjects may have acquired some effective discrimination skills through performing the tasks in Experiment II and also, amongst some subjects in the RP-RW group, the RP task (only the RP-RW group) prior to exposure to the RW procedure. Although the lack of transfer between the RP and RW procedures implies that the discrimination capacities probed in both procedures were not the same, the finding that all the subjects who solved the RW task had also been able to solve the RP task, and the knowledge that twice as many subjects in the RW-RP group as in the RP-RW group were unable to solve the RW task, suggests that performance on the RP procedure may have had some influence on the performance on the RW procedure. Data from Experiment II showed that subjects could accurately discriminate the simultaneity of external auditory and visual stimuli. Additionally, solution of the RP task ensured that subjects were able to judge the simultaneity of auditory signals and cardiac-related sensations. Therefore, prior to exposure to the RW task, it can be inferred that subjects had acquired discriminative skills neccessary for making both the temporal and sensory judgements about the coincidence or noncoincidence of auditory stimuli and heartbeat-related sensations.

On the RP procedure, sixteen subjects reported that the sensations from their radial pulses were more closely associated with the tones on the S- trials (R+400 ms intervals) than with those on the S+ trials (R+0 ms intervals). Therefore those subjects were sensing heartbeat signals that occurred 400 ms after the R-Wave, a locus after the point (R+384 ms) which Whitehead defined as unassociated with cardiac events. In retrospect, those subjects' reports should have been expected since literature concerning the timing of cardiovascular events in general and pulse wave velocity in particular, implies that the definition of S+ stimulus interval on the RP procedure should not have been the same as that on the RW procedure. One would expect that cardiac-related sensations arising from the stimulation of mechanoreceptors in the chest will occur closer to the R-Wave than sensations produced at a distal location (eg. the radial artery) through the stimulation of peripheral mechanoreceptors in the wrist (Obrist, Light, McCubbin, Hutcheson and Hoffer, 1979).

From Figure 5.2 which shows the transmission of the pulse wave to various arteries, the onset of the pulse wave in the radial artery occurs approximately 80-100 ms after the carotid pulse and peaks about 300 ms after the R-Wave. Therefore the subject's perception of the occurrence of the pulse wave will depend on which part of the wave he or she is detecting. However, as no recordings were taken of peripheral cardiovascular events, the specific sensic sensory events subjects were detecting and using as cues for their discrimination responses cannot be fully identified at this stage.

These differences in individual perceptions as shown in this procedure indicate the need for the re-evaluation of accepted placements of S+ and S- signals in HBD procedures. When individuals are required to attend to sensations of heartbeats, their subjective reports indicate that they detect such sensations through different peripheral mechanoreceptors located in the chest, head and limbs. It is unlikely therefore, that a single experimenter-determined criterion for heartbeat-coincident stimuli can be applicable to all individuals.

The effect of KOR on discrimination performance has also raised some interesting points in this experiment. Reference is made again to the finding that about 30% of the subject sample perceived sensations from their radial pulse as coincident on auditory stimuli presented simultaneously with the R-Wave. The inability to totally reconcile that finding with cardiodynamics, implies that the results cannot be totally attributed to cardiac discrimination. During the RP training



<u>Figure 5.2</u> Pulse Transmit Times to various arteries.

t0=time of R-Wave peak
t1, t2 & t3=times at which peripheral pulses begin their ascent.

Pulse Transmit Time (PTT) is measured by t1-t0, t2-t0 or t3-t0.

(From Brener and Connally, 1984, page 24).

phase subjects were informed they had made a correct response when they identified stimuli on S+ trials (R+0 ms intervals) as pulse-coincident and stimuli on S- trials (R+400 ms intervals) as noncoincidental on the radial pulse. They were informed they had made a wrong response if the identifications were different from those stated. As this was a learning program, subjects would be expected to comply with the KOR presented in order to improve their performance. In effect, the interaction of KOR effects and cardiac discrimination could affect the interpretation of discriminative responses obtained from such training procedures and thus cause some subjects to mislabel cardiac sensations. The earlier recommendation for the use of less experimenter-imposed definitions of behaviour will go some way towards overcoming this problem.

The data also showed that although the subjects' exhibited HBD during the Post-criterion phase that was significantly better than performance prior to the Criterion phase, their level of HBD performance during the Post-Criterion phase was poor compared to their performance during the criterion phase. This illustrates the detrimental effect that the withdrawal of KOR exerts upon HBD. The process through which this effect is achieved cannot be identified at this point and any possible mechanisms proposed can only be speculative.

However, it seems reasonable to suggest that during heartbeat discrimination training trials, subjects become aware of sensations which they associate with the external stimuli they are continously being exposed to. During training trials, KOR plays an informational role in enabling subjects identify which particular sensations provide appropriate cues for the discriminative responses. The task, according to subjects' verbal reports, was very difficult when KOR was withdrawn and the corresponding increase in response latency measures during this period implies that without KOR, the information processing involved in the accessing and identifying the appropriate internal sensations was more demanding and time consuming. The inability once again to fully and conclusively explain the role of KOR in the perceptual processing involved in the acquisition of cardiac discriminative skills suggests the need for more rigorous experimental manipulation of this variable in HBD studies.

CHAPTER SIX

EXPERIMENT IV: DETECTION OF EVENTS IN THE CARDIAC CYCLE.

INTRODUCTION

The investigations undertaken in the previous experiments raised various issues that question the effectiveness of the conventional design of heartbeat discrimination procedures. The study described in this chapter examined these issues and evolved a model for the design of a heartbeat discrimination procedure which was considered an improvement on other HBD procedures. The main issue that was investigated was the validity of an *a priori* definition of the temporal location of the heartbeat as practised in most HBD procedures. In addition, several new procedural factors were introduced.

In the third of a series of experiments undertaken to determine the optimal temporal locus of the S+ signal, Clemens (1984) provided subjects with the opportunity to examine freely and repeatedly a series of stimulus trains in which stimuli were delayed 0, 60, 120, 180 or 240 ms from the R-Wave. As before, subjects made decisions about which particular train of signals was most synchronous with their heartbeat sensations. The data analysis of those responses did not yield evidence of significant preferences for any stimulus train which implied that subjects were unable to discriminate between stimuli coincident on the R-Wave and those occurring 240 ms after the R-Wave. As a consequence of earlier findings that subjects judged signals coincident on the R-Wave and those delayed 100 and 200 ms from the R-Waves as more synchronous with heartbeat sensations than those delayed 300 and 400 ms from R-Waves, Clemens proposed that the optimal placement for S+ signals on WH-type procedures should be within the first quarter second after the R-Wave.

However, the inadequacy of a single placement for the S+ stimulus can be inferred from data from Experiment III in this thesis which suggested that the individual's definition of an S+ signal depends on which of the multiple potential sensory sources he or she employs to detect the heartbeat and which event in the production of the heartbeat is being sensed. As Yates, Jones, Marie and Hogben (1985) pointed out, if subjects were aware of sensations arising from ventricular contraction then the temporal location of the S+ stimulus defined by Whitehead et al (1977) and suggested by Clemens would be appropriate. However, subjects who were aware of sensations arising from for example, the second heart sound or peripheral blood pulsations would identify their sensations as being contiguous with signals occurring farther from the R-Wave and thus find those S+ stimuli inappropriate.

Yates et al (1985) investigated these individual differences in heartbeat detection by presenting subjects with one visual stimulus which on each trial could be delayed one of six time intervals: 0, 100, 200, 300, 400 or 500 ms from their R-Wave. Subjects were to indicate after each trial whether the stimulus presented was coincident or noncoincident with sensations of a heartbeat. It was found that for the group as a whole, stimuli that occurred 200, 300 and 400 ms after the R-Wave were perceived as heartbeat-coincident. Visual stimuli that had been presented simultaneously with the R-Wave and 500 ms after the R-Wave were least frequently chosen as coincident with sensations of heartbeats. These findings are in conflict with those reported by Clemens who found that subjects identified stimuli which occurred at intervals equal to or less than 240 ms after the R-Wave as most "heartlike". Differences between the tasks may account for the difference in results as often is the case in HBD studies.

The notable methodological innovation introduced in the Yates and Clemens procedures is that subjects were presented with a selection of potential S+-type stimuli and were permitted to choose the most appropriate temporal locus for the S+ or heartbeat-contingent stimulus. In all other HBD procedures, subjects are presented with only one S+ stimulus at a location pre-determined by the experimenter. Nevertheless, it may be argued that neither the Clemens nor Yates studies gained the full benefits of that method of stimulus presentation. In Yates et al's (1985) procedure subjects were required to make a firm judgement ("yes" or "no") on the basis of only one stimulus presented on each trial. This is very little data on which to make a judgement. In comparison, on Clemens' (1984) second procedure the subjects were presented with relatively more information and made a decision (indicating one of three degrees of certainty) after the exposure to a ten-second train of stimuli. The criticism raised against both procedures is that subjects were not provided with the opportunity to compare the different stimulus intervals before executing a discriminative response. Thus it might be that in both procedures, discrimination performance is data-limited rather than resource-limited (Norman and Bobrow, 1975). In other words, discrimination performance may be compromised by subjects not having sufficient information to reach a decision rather than their having a limited capacity to detect cardiac activity. Clemens' third procedure in which subjects were able to examine different intervals sequentially for as long and as often as they wished before making a decision goes some way in overcoming this problem.

However, in that procedure the five R-Wave to light flash intervals were arranged such that they could only be accessed in a fixed sequential order. This made interval comparisons quite demanding because subjects were required to remember the positions of potentially preferred intervals relative to their current position in the sequence so that comparisons could be made. It will be appreciated that the substantial demands that this operation imposes on the information processing capacities of the subjects may adversely affect their performance on the heartbeat detection task.

The heartbeat detection procedure described in the present study adopted the individual difference methodology initiated by Yates and Clemens and employed the interval-sampling feature of Clemens' third experiment but employed an alternative method of enabling subjects to select, retrieve and compare different R-Wave to Stimulus intervals. Subjects could switch immediately from the prevailing interval to any other by pressing one of six buttons each of which was uniquely associated with a particular R-Wave to Stimulus interval. Each of those six intervals could be inspected repeatedly and for as long as the subjects wished before selecting the button that yielded stimuli which were perceived as most synchronous with their heartbeats. The six intervals used in this study were the same as those employed by Yates et al (1985) and also covered the range investigated by Clemens (1984).

Another feature of the present study which was adopted from previous experiment was that prior to being tested on the HBD procedure, subjects participated in a task-familiarization procedure that did not involve cardiac sensations but which in all other respects was identical to the HBD task. During the Familiarization task, subjects were required to judge the simultaneity of visual and auditory stimuli and the reasons for introducing this task were twofold. Firstly, if subjects were able to solve this task, it could be inferred that they understood the requirements imposed by the ensuing HBD task. Secondly, solution of the Familiarization task would ensure that subjects were capable of making the necessary temporal discriminations involved in the HBD task.

In the second part of this report half of the subjects (the Experimental group) were tested on a WH-type HBD procedure where the S+ and S- stimulus intervals were defined as the subjects' Most Preferred and Least Preferred Intervals obtained from performance on the HBD task. These intervals were the R-Wave to Stimulus intervals that produced tones that were judged as most and least coincident with internal heartbeat sensations respectively. The rest of the subjects (the Control group) were presented with WH-type trials where the S+ and S- stimulus intervals were 128 ms and 384 ms after the R-Wave respectively. The performance of both groups on these tasks were compared to determine whether the issue of individual selection of S+ and S- placements in the WH task is a valid issue.

METHOD

SUBJECTS

The subjects were 32 (16 males and 16 females) lower sixth formers and undergraduates aged 17-37 years (mean 20.25yrs). They were informed that they would be required to participate in a heartbeat discrimination task over five consecutive days and were paid £5 at the end of the experiment for expenses.

APPARATUS

The recording equipment used in this experiment was identical to that used in Experiment III.

The subjects were provided with a rectangular hand-held response panel measuring 16.5 by 8.0 by 2.2 cm for selecting heartbeat-contingent auditory stimuli and registering discriminative responses (shown in Appendix; Figure A3). The control panel had on it, a row of six black buttons with a corresponding row of six yellow LEDs fixed above them. A button press activated one of six stimulus sequences and when a button was pressed the light directly above it flashed on and remained illuminated until another button was pressed. Situated below these buttons were three larger brightly coloured Response keys which were pressed to register a response and also to terminate a trial. Each Response key specified a level of certainty of the final discriminative response. A green key was pressed to indicate a "very certain" judgement, a black one for "not very certain" and a red one for "don't know". On each subsequent trial, the relationship between the tone intervals and the buttons was quasi-randomized so that each button could represent any one of the six intervals, while satisfying the rule that each interval could be represented by only one button during a trial.

PROCEDURE

On the first day the subjects were escorted to the experimental cubicle and instructed about the Familiarization task and taken through three practice trials. After ensuring that they understood the task fully the first of 30 Light-Tone discrimination trials began. After each block of 10 trials there was a 2-3 minute rest period and on average the task took an hour to complete. On completion of all 30 trials, subjects were debriefed and shown a printout of their performance if they wished.

The first session of the HBD task was started the next day. After electrode attachments had been made subjects were taken to the cubicle and given instructions about the HBD task. They were told that this task was very similar to the Familiarization task with their heartbeats substituted for the light flashes and therefore they were required to discriminate between heartbeat-tone intervals instead of Light-Tone intervals. It was emphasised that performance was dependent on individual perceptions and that there were no "right" or "wrong" answers. Furthermore, they were told that manual pulse taking was unacceptable and were advised to minimize all movements so as not to interfere with the heartbeat recordings. No practice trials were presented and after checking that the ongoing EKG recording was artefact-free the session was begun. A session consisted of 30 discrimination trials with 2-3 minute rest periods after each block of ten trials. During the rest periods the experimenter asked subjects "how they were getting on" and recorded their verbal reports of the use and location of perceptual cues and the apparent difficulty or ease on the task. On average (bearing in mind that trial lengths were not predetermined), a session took an hour to complete.

The second session was conducted on the following day in the same manner. Following completion of the second session subjects' weights and heights were recorded and they were debriefed and shown the printouts of their responses if they asked to see them.

The Familiarization Task

At the commencement of each trial the computer assigned each of the six inter-stimulus intervals (0, 100, 200, 300, 400 and 500 ms) to one of the six black buttons on the hand-held response panel. The assignment was performed on a quasi-random basis with the constraint that each interval was represented by only one button on that trial. In this task, the intervals were timed from the onset of a 50 ms light flash to the onset of a 50 ms, 1000 Hz tone. The trial commenced with the computer activating one of six intervals on a random basis and illuminating the LED corresponding to the button which had been programmed to activate that interval. All interval activations were accompanied by a "whistle" sound emitted from the speaker and the illumination of the appropriate LED. During trials the LED above the button which was responsible for activating the interval in force remained illuminated.

Subjects were told that by pressing those buttons they would be exposed to any of the intervals which they could freely examine for as long and as often as they wished before judging which button produced tones that were simultaneous with the light flashes. When they were satisfied that they had located the correct button, they were to press one of the coloured Response keys to indicate their certainty of that the interval associated with that button yielded tones that were coincident with the flashes. That interstimulus interval was recorded as the "Preferred Interval". The next trial commenced 30 seconds after a Response key had been pressed.

The Heartbeat Discrimination Task

This task was designed within the same framework as the Familiarization Task and the essential difference between the two tasks was that subjects' heartbeats were substituted for the red light flashes. In effect, subjects were given the opportunity to judge which of six trains of tones was in closest synchrony with sensations of their heartbeats.

These auditory stimuli were generated by the subject's ongoing heartbeats with each tone in each train occurring with a constant and specific temporal relationship to the R Wave. These interstimulus intervals (R Wave to Tone intervals) were approximately associated with a particular phase of the cardiac cycle. The shortest interval produced tones which coincided with the R-Wave (R+0 ms), approximating the occurrence of the first heart sound (closure of the atrioventricular valves), the next shortest (R+100), approximated the opening of the aortic valve, the third shortest interval (R+200 ms), maximal ventricular contraction, the fourth shortest interval (R+300 ms) coincided with the second heart sound (closure of the aortic valve), the fifth (R+400 ms), approximated the opening of the atrioventricular valves and the longest interval (R+500 ms), and was unrelated to any major cardiac event (after Yates et al, 1985). A diagram of the presentation of these tones in relation to cardiac events is shown in Figure 6.1.

Measures of Performance and Data Analysis

On each trial of both the Familiarization task and the Heartbeat Detection task, measures were taken of the frequency with which each interval was examined (Inspection Frequency), the duration of each interval examination (Mean Inspection Duration), the Preferred Interval (PI) and the certainty with which the PI was selected. These data were used as a basis for calculating the total time that each interval was examined on each trial (Total Inspection Duration). During the HBD task, subjects' average heart rate was recorded on each trial. Verbal reports from subjects on how they identified their preferred intervals were also recorded on each session. These data were analyzed in order to determine whether subjects showed definite preferred intervals, whether they exhibited strategies for identifying those intervals and whether task performance was stable over time.

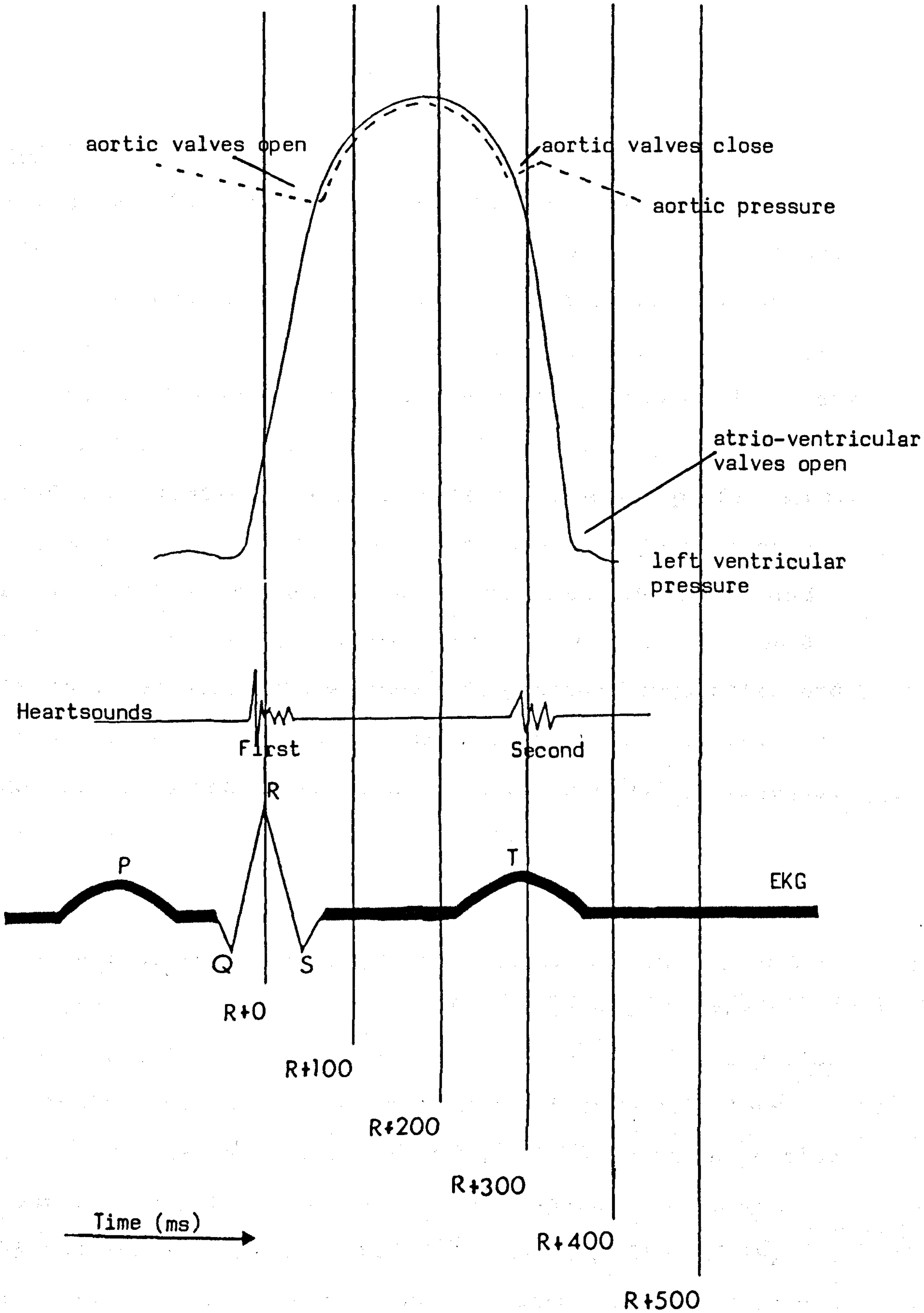


Figure 6.1 Position of external stimuli in relation to events of the cardiac cycle.

RESULTS

The Familiarization Task

The graphs in Figure 6.2 represent four performance variables examined on this task. It will be seen that subjects chose tones delayed 0 and 100 ms from the light flashes as simultaneous with the light flashes more often than the longer delayed tones. The frequency with which they inspected the six intervals and the durations of those interval inspections exhibited very similar profiles to their interval preferences. This suggests that subjects were able to easily judge light-tone intervals longer than 100 ms not to be simultaneous and did not spend as much time inspecting them as they did the 0 and 100 ms intervals. The elevated Inspection Frequencies and Durations associated with the 0 and 100 ms intervals indicated that despite substantial sampling of both intervals, subjects could not easily distinguish between 100 ms intervals and simultaneity.

The reliability of the effects illustrated in Figure 6.2 were examined using two-way ANOVAs (six Intervals by three Blocks of ten trials) on each variable. These analyses yielded highly significant Interval effects for all the variables; [Inspection Frequency: $F(5/155)=128.78$, $p<.01$; Mean Inspection Duration: $F(5/155)=49.93$, $p<.01$; Total Inspection Duration: $F(5/155)=80.75$, $p<.01$; Preferred Interval: $F(5/155)=93.19$, $p<.01$]. However, significant Blocks effects were found only for Mean Inspection Duration [$F(2/62)=12.57$, $p<.01$] and Total Inspection Duration [$F(2/62)=11.82$, $p<.01$]. The tendency for Inspection Durations to decrease with Blocks suggests that with

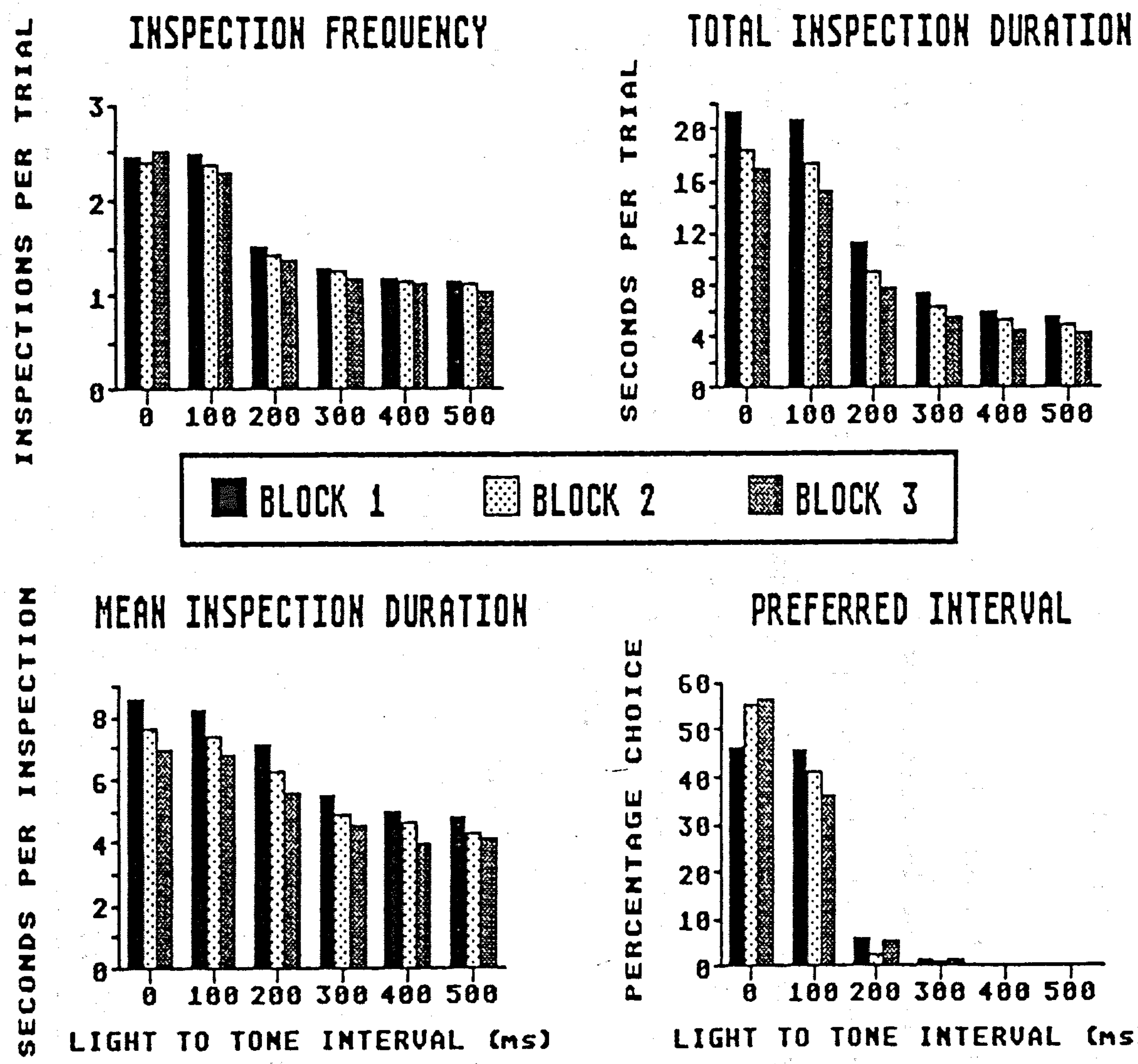


Figure 6.2 Discrimination performance on the Familiarization Task. Figures show Mean Inspection Frequency, Mean Inspection Duration, Total Inspection Duration and Preferred Interval.

experience, subjects improved their skills in processing the temporal information contained in the paired-stimulus presentations.

The Heartbeat Detection Task

Subjects' "don't know" responses were subtracted from the sum of their "very certain" and "not very certain" responses for each session and those positive ("very certain" and "not very certain") responses formed 97.14% of the total discriminative responses recorded. Table 6.1 shows the total frequencies with which each interval was selected on each session. It also shows the total frequency of "don't know" responses on each session. A summary of those responses is presented in Figure 6.3 which illustrates the mean percentage frequencies of positive responses to each interval on each experimental session for all 32 subjects.

TABLE 6.1: Total frequencies with which each of the R-Wave to Tone Intervals was chosen as simultaneous with heartbeat sensations during Sessions 1 and 2.

	INTERVALS/ms						RESPONSES	
	R+0	R+100	R+200	R+300	R+400	R+500	"positive"	"don't know"
S 1	96	169	214	224	150	88	941	19
S 2	63	159	258	242	133	92	947	13
TOTAL	159	328	472	466	283	180	1888	32

In order to examine the statistical reliability of the trends shown in this figure, the number of preferences by each subject for each interval was entered into a two-way ANOVA for repeated measures (six Intervals by two Sessions). This

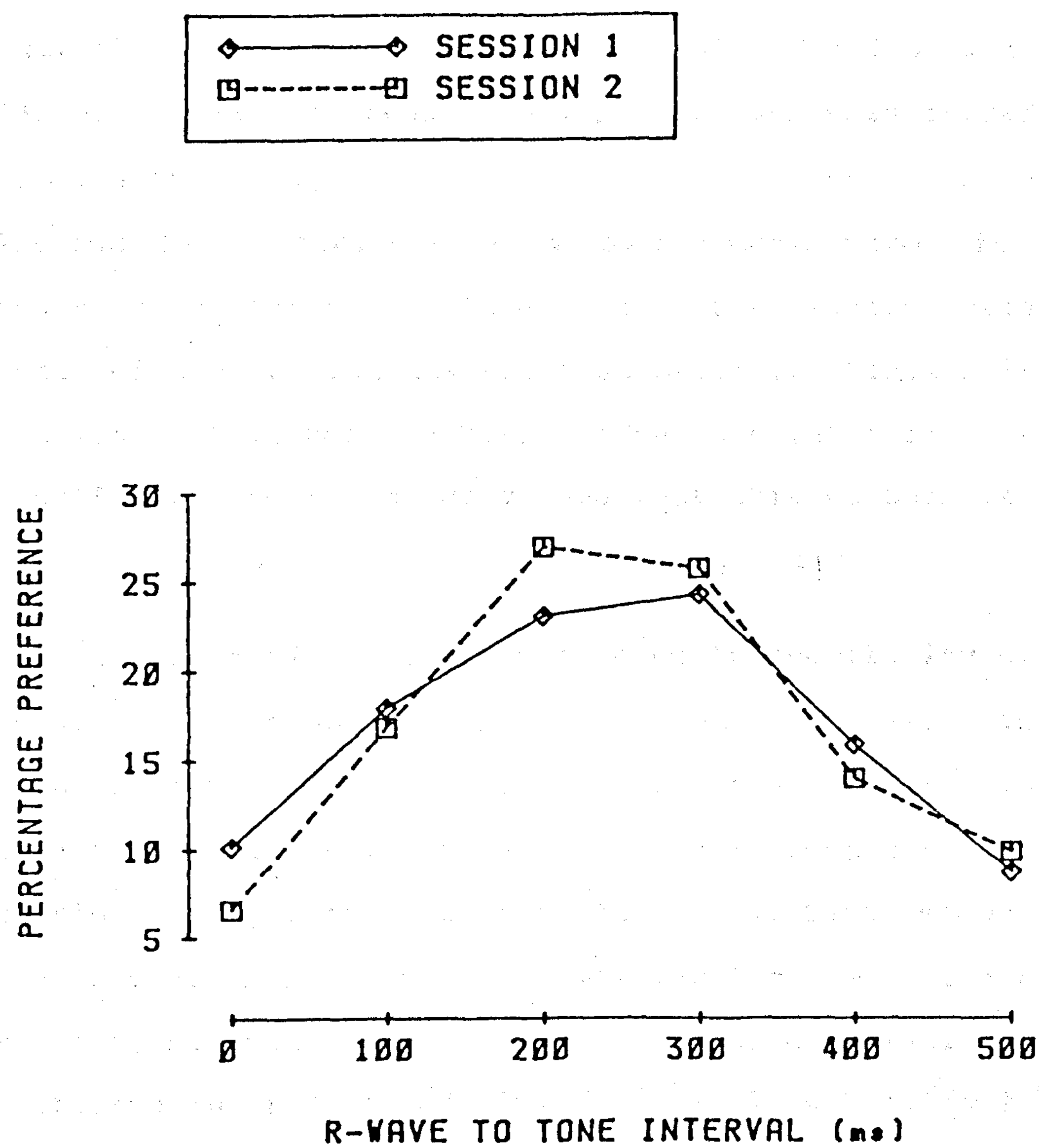


Figure 6.3 Percentage frequencies with which each of the R-Wave to Tone Intervals was chosen as simultaneous with heartbeat sensations during Sessions 1 and 2.

yielded a main effect for Interval [$F(5/155)=14.615$, $p<.01$]. Post hoc analysis using Newman-Keuls' test showed that the R+200 and R+300 intervals were chosen more often than the other intervals. The R+400 and R+100 intervals were also chosen significantly more often than R+0 and R+500 intervals. The number of preferences for the R+200 and R+300 intervals were equivalent as were those for the R+100 and R+400 pair and the R+0 and R+500 pair respectively. This analysis therefore implies that subjects identified events which occurred between 200 and 300 ms after the R-Wave as being most coincident with heartbeat sensations. Since neither the Sessions effect nor most coincident with heartbeat sensations. Since neither the Sessions effect nor the Sessions by Interval interaction were significant, it may be concluded that this pattern of response preference was stable over the two days of testing.

In order to examine the changes in specificity of responding over the course of the experiment, means and standard deviations were computed for the Preferred Interval data for all the subjects and these were compared across sessions using correlated t-tests. These tests showed no significant changes in mean Preferred Interval (PIm) but there was a significant decrease in the standard deviation of the Preferred Interval (PIsd) from Session 1 to Session 2 [$t(31)=2.297$, $p<.01$], indicating that the choice of preferred intervals became more specific with practice at the task.

Using the data from both sessions, 29 subjects (90.5%) showed a modal preference for the R+100, R+200 or R+300 intervals and three subjects (9.375%) showed a preference for the R+400 interval. A breakdown of these figures revealed that eight subjects exhibited a modal preference for the R+100 interval, 11 for the R+200 interval and 10 for the R+300 interval. No subject exhibited modal preferences for either the R+0 or R+500 intervals. For purposes of statistical group comparisons, the three subjects with R+400 modal preferences were combined with those subjects who exhibited a modal preference for R+300 interval, resulting in a R+300 group of 13 subjects.

In order to test the validity of those Group classifications, the mean percentage frequencies with which each Interval was chosen during Sessions 1 and 2 by each Group member was submitted to a three-way ANOVA for repeated measures (3 Groups by 6 Intervals by 2 Sessions) using the GENSTAT package. In agreement with previous analyses, there was a reliable Intervals effect [$F(5/348)=32.569$, $p<.01$]. Further, a significant Intervals by Groups Interaction [$F(10/348)=13.262$, $p<.01$] supported the classification of subjects by their modal Interval preferences. The absence of a Sessions main effect and of any interactions involving Sessions confirmed the earlier finding that Interval preference were stable across Sessions.

To explore the stability of those Group effects further, the interval preference data for each session for each of the groups were submitted to a two-way ANOVA (two Sessions by six Intervals. Highly significant Interval effects were found for each of the groups examined [R+100: $F(5/35)=12.01$, $p<.01$; R+200: $F(5/50)=17.10$, $p<.01$; R+300: $F(5/60)=13.638$, $p<.01$] but in accordance with the previous analysis, in no case was a

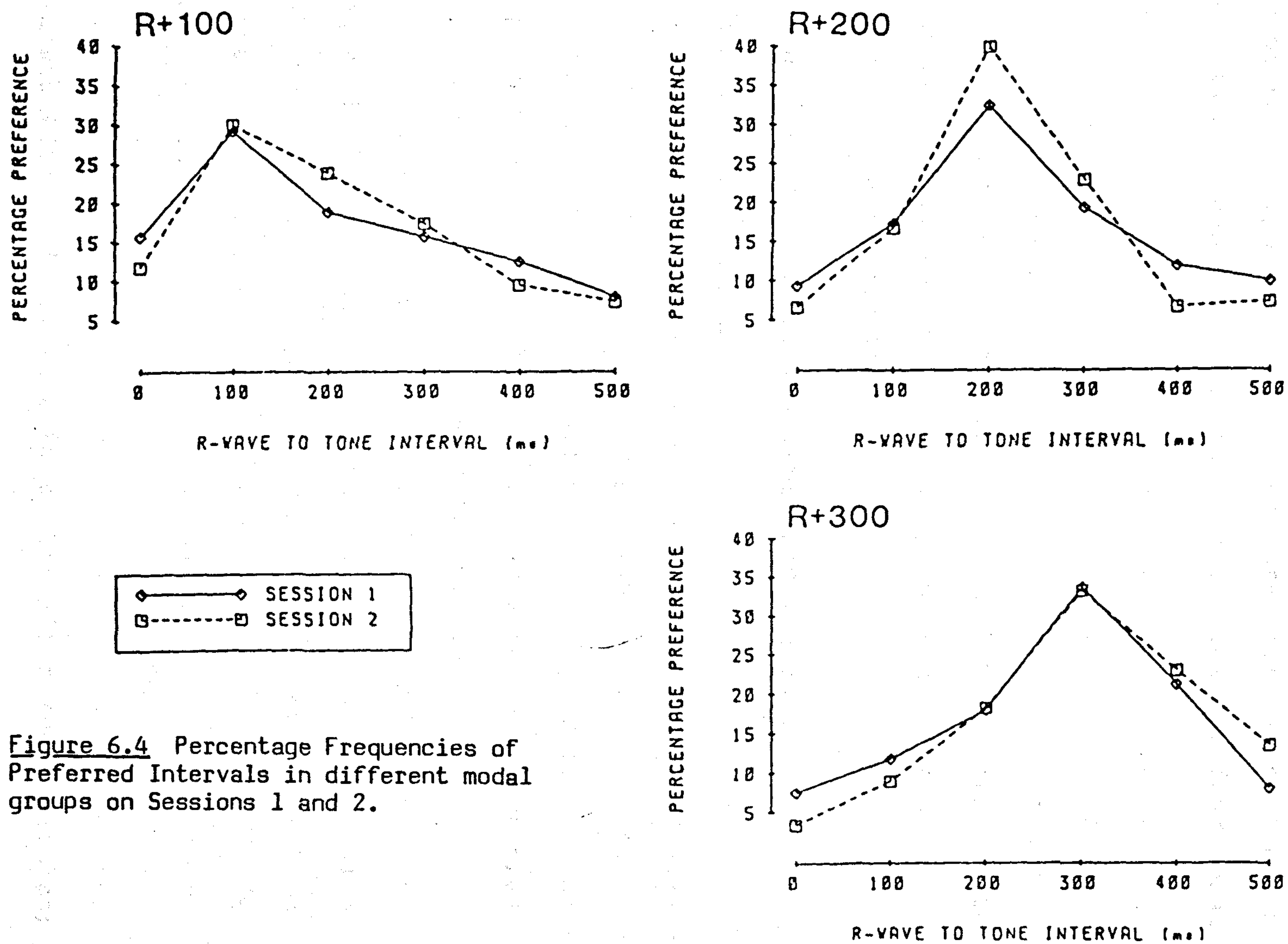


Figure 6.4 Percentage Frequencies of Preferred Intervals in different modal groups on Sessions 1 and 2.

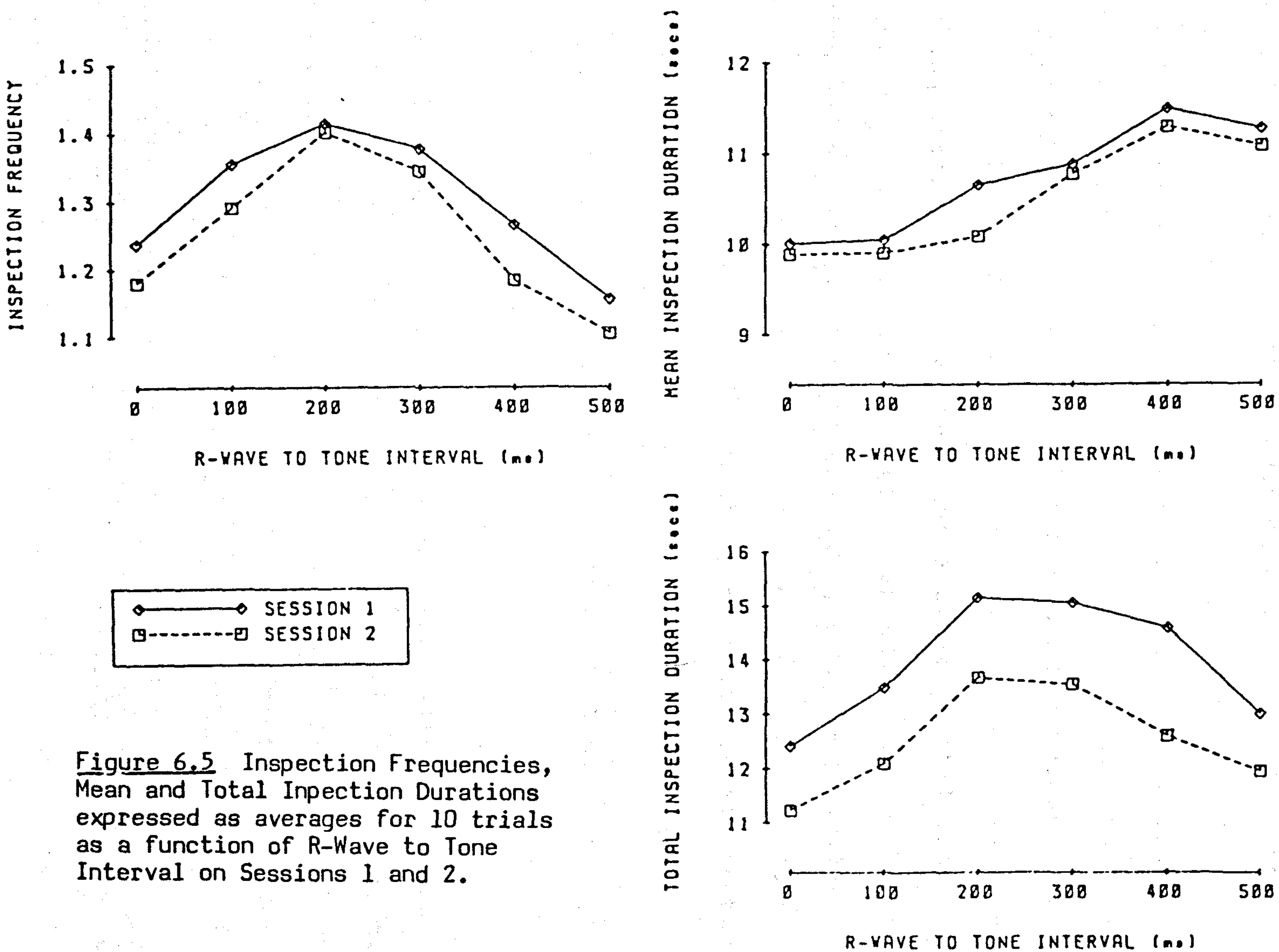
significant effect found for Sessions or for the Session by Interval interaction. These results indicate that subjects in each of the groups exhibited strong preferences for their modal intervals and these did not change significantly from session to session. Graphs illustrating these data are shown in Figure 6.4 where mean interval preferences for each session are expressed as percentages of the total number of preferences recorded for each group. The data are consistent with the idea that subjects in each group might be perceiving heartbeat sensations from a common source.

Strategies used in identifying Preferred Intervals

(i) Inspection of Intervals

To identify the development of discrimination strategies, the Inspection frequency, Mean Inspection Duration and the Total Inspection Duration variables were analyzed over Sessions 1 and 2 and examined for all subjects as a group by a series of two-way repeated measures ANOVAs (six Intervals by two Sessions). It was anticipated that the inter-relationships between variables emerging from these analyses would provide an idea of the strategies subjects adopted to discriminate from six types of heartbeat-tone intervals the one which was most synchronous with their heartbeat sensations.

The analysis of the data from all the subjects together yielded significant Interval effects for all three variables; Inspection Frequency [$F(5/155)=13.746$, $p<.01$], Total Inspection Duration [$F(5/155)=4.372$, $p<.01$] and Mean Inspection Duration [$F(5/155)=4.829$, $p<.01$]. These effects which are displayed in Figure 6.5 show that the Inspection Frequency and Total



<u>Figure 6.5</u> Inspection Frequencies, Mean and Total Inpection Durations expressed as averages for 10 trials as a function of R-Wave to Tone Interval on Sessions 1 and 2.

Inspection Duration distributions exhibit the same profiles as that of the Preferred Interval (shown in Figure 6.3), showing that subjects inspected those intervals they preferred more often and for significantly longer on each trial than non-preferred ones. The significant Interval effect for Mean Inspection Duration, due to subjects spending longer time periods inspecting longer R-Wave to tone intervals, could be partly attributed to the increasing time delays between R-Waves and tones. Since durations were measured from the first R-Wave occurring after an Interval had been activated until the subject pressed a button to switch intervals, this may be attributed in part to subjects switching from a particular interval following a tone. However, since the increments of duration are not equal to the absolute time differences between the Intervals, this explanation is not complete.

The tests show that subjects paid more attention to preferred intervals than non-preferred intervals and this indicates that subjects could discriminate between those two classes of intervals. One might expect that with experience at the task, the frequency of interval inspection and the duration of inspections would decrease, particularly in the case of non-preferred intervals. However, Total Inspection Duration was the only variable to yield a significant Sessions effect [$F(1/31)=4.95$, $p<.01$]. Although the tendencies of both Inspection Frequency and Mean Inspection Duration to decrease across sessions were not significant, the data in Figure 6.5 suggests that those variations contributed to the Sessions effect found for the Total Inspection Duration variable. These results support the hypothesis that with experience, subjects required less exposure to the different R-Wave to Tone intervals before selecting the Preferred Interval.

(ii) Verbal Reports

Each subject was asked during the experiment to verbally describe in as much detail as possible, the nature and location of the sensations they employed in discriminating their preferred interval from the other intervals. Most subjects reported that they were aware of pulsatile sensations derived from various parts of their bodies which had been more closely correlated with tones of the preferred interval than the other intervals. Some subjects reported more than one source from which they were aware of cardiac-related sensations. Fifteen subjects reported only one source, nine subjects reported two sources, five reported three sources and one subject reported using four sources. Four subjects were unable to articulate the basis on which they made their decisions. Table 6.2 summarizes the discriminative cues which subjects in each group reported using in the selection of their Preferred Intervals.

It seemed reasonable to expect that there would be patterns of responding which would differentiate the groups. For example, that members of the R+300 and R+400 groups should report using sensations arising from distal and peripheral parts of the body compared to subjects in the other groups. The data that fits this hypothesis and indeed the only apparent group differences are the observation that no subject in the R+100 group reported using cues arising from either the head or the abdomen. A similar group difference shown was that the use of sensations arising from the thighs was reported only by a subject from the R+4ØØ group. However, when the frequencies of the use of particular bodiliy cues in each group were submitted to a series of Chi-squared tests, neither of those findings emerged as significant differentiating group characteristics.

TABLE 6.2: The number of subjects in each group reporting different interoceptive and exteroceptive cues used in identifying the Preferred Interval (PI).

		GROUPS			
		R+1ØØ	R+2ØØ	R+3ØØ	R+4ØØ
No. of subjects reporting PI stimuli synchronized with sensations in:	chest	4	4	3	1
	abdomen	Ø	3	5	Ø
	head	Ø	3	3	1
	neck	1	2	Ø	1
	hands	2	3	3	Ø
	back	1	Ø	3	Ø
	thighs	Ø	Ø	Ø	1
	whole body	1	1	1	Ø
No. of subjects selecting PI on the basis of audible cardiac cues		1	2	Ø	Ø
No. of subjects unable to verbalize their mode of PI selection		1	Ø	Ø	2

Other variables were examined with the purpose of finding factors on which to predict discrimination performance and choice of preferred interval. The proportion of males and females in groups R+2ØØ and 3ØØ was about 5Ø:5Ø. However, in the R+1ØØ group there were three times as many women as men whereas in the R+4ØØ group there were only male subjects. The males were significantly taller than the females in the R+1ØØ and R+3ØØ groups and difference in heights of males and females only approached significance in the R+2ØØ group. [R+1ØØ:

t(6)=3.65, p<.05; R+300: t(9)=2.81, p<.05; R+200: t(8)=1.86]. Overall, the male subjects in this experiment were significantly taller [t(30)=4.53, p<.01] and they also tended to be heavier than the females but this measure only approached significance [t(30)=1.69]. It seems this size difference might explain the gender proportion in the R+100 group as it is reasoned that maybe heartbeat sensations arising from the periphery will arise sooner after the R-Wave in smaller than larger people. However, subjects' choice of preferred intervals did not correlate with body weight, height or an obesity index (W/HxH) calculated from the weight (W/kg) and height (H/m) data (Lee, Kolonel and Hinds, 1981).

A possible drawback of this procedure is that for subjects with elevated heart rates of 120 bpm (IBI=500 ms) or more, it may be impossible to generate reliably, external stimuli at R+400 ms and R+500 ms intervals for every cardiac cycle. An examination of each subject's average heart rate showed that this experiment was not prone to the artefact. Subjects' average heart rates ranged from 52.76 bpm to 82.19 bpm and in no case did the mean heart rate for a subject (+ 3 SDs) exceed 120 bpm. The heart rate data were submitted to a two-way ANOVA with repeated measures on Blocks of ten trials (2 Sessions by 3 Blocks of 10 trials) and this showed that subjects' average heart rate decreased significantly within sessions [F(2/62)=23.45, p<.01], an effect most likely due to habituation to the task and uninfluenced by heartbeat detection performance per se.

Individual Differences in Performance

In order to obtain a more general measure of discriminative accuracy, the PIsd (the standard deviation of the Preferred Intervals) was employed as measure of response specificity on the assumption that the smaller the PIsd score, the more precise and reliable the discriminative response. This score was calculated for each subject from the total responses over both sessions and subjects were then ranked accordingly from 1 (smallest) to 32 (largest).

The consistency of discrimination response was also examined by calculating the inter-session correlation of each individual's response frequency to each interval. Highly significant inter-correlation measures were obtained for only seven subjects who exhibited coefficients which ranged from .84 to .97 with $p<.05$ or better. In addition, eight other subjects exhibited modest but non-significant correlations ranging from .65 to .77. The very small number of degrees of freedom in these analyses renders the evaluation of these correlations difficult.

PIsd measures were calculated for each subject from Preferred Intervals selected on both the Light-Tone task and the HBD task. Between-subject correlations between the PIsd's on the two tasks yielded a coefficient of .44 ($p<.05$) which suggests that individuals who were accurate on the Light-Tone discrimination task were also accurate on the heartbeat discrimination task.

In an attempt to characterize good and poor heartbeat discriminators, the ten uppermost ranked subjects according to their PIsd were compared across several variables with the ten lowest ranked subjects (Shown in Table 6.3). Gender distribution, Modal frequency of PI, Age and Average heart rate were found to be similar in the two groups. The variables which were significantly different between the groups were the intersession Preferred Interval correlation [$t(18)=3.78$, $p<.01$] and as expected, PIsd on both the HBD task [$t(18)=8.33$, $p<.01$] and the Light-Tone Familiarization task [$t(18)=2.99$, $p<.01$]. The PIsd's on both the HBD and Light-Tone tasks exhibited by the upper ranked group were smaller than those exhibited by the other group. As those variables denoted consistency and specificity of discrimination in this study, the results indicate that good heartbeat detectors are more consistent and precise in their general discriminative abilities than poor heartbeat detectors.

Although Age did not differ significantly between the two groups it is worth noting that seven subjects out of the ten in the top ranking group were 17 years old whereas only two in the bottom ranking group were that young. This observation may be related to the suggestion of Jones, Jones, Cunningham and Caldwell (1985) and Jones, Jones, Rouse, Scott and Caldwell (1987) that older subjects are less proficient cardiac discriminators than younger subjects.

TABLE 6.3 Data from ten uppermost ranked and ten lowest ranked subjects according to the standard deviation of their Preferred Intervals during Sessions 1 and 2.

HIGH RANKING SUBJECTS.

Rank	Subjects	Sex	Age	Modal PI	Av.Hr	Ltsd	PIsd	PIm	Intersession correlation	W/H^2
1	PW	M	17	300	67.25	24.94	42.54	323.73	0.94	21.56
2	JB	M	17	200	76.57	0	69.52	150	0.90	21.08
3	ST	M	17	300	76.93	24.94	84.59	246.67	0.96	20.94
4	CR	M	17	300	68.30	48.99	86.92	333.33	0.72	21.60
5	WS	F	17	200	69.80	42.69	100.29	255.17	0.97	24.17
6	FM	F	17	200	76.42	65.74	106.41	296.67	0.38	21.77
7	RC	F	17	200	73.35	56.27	107.19	253.33	0.74	25.94
8	DBM	M	19	200	59.44	33.99	111.75	246.67	0.72	20.94
9	AL	F	21	100	69	44.22	113.17	155	0.21	24.80
10	LI	F	25	100	61.39	45.17	115.07	183.33	0.84	22.17

LOW RANKING SUBJECTS.

Rank	Subjects	Sex	Age	Modal PI	Av.Hr	Ltsd	PIsd	PIm	Intersession correlation	W/H^2
32	DM	F	23	100	69.98	64.98	167.17	232.20	0.69	23.32
31	ES	F	17	100	70.97	67.08	166.42	211.67	0.33	18.64
30	TH	M	22	100	67.31	46.70	166.13	230	0.48	20.41
29	PM	M	18	300	76.14	80.35	162.70	273.58	0.11	27.99
28	JD	M	37	400	62.53	49.89	161.55	270	0.25	19.84
27	AW	M	20	200	75.61	56.17	158.85	210	0.27	22.17
26	JA	F	17	100	77.94	56.17	156.49	213.33	.05	20.44
25	PB	M	23	400	52.76	55.88	153.70	310.17	0	23.18
24	SW	M	24	400	78.44	104.40	147.16	296.67	.45	25.55
23	CB	M	19	300	81.27	48.84	144.87	296.67	.08	20.73

EXPERIMENT IV (PART 2):

Comparison of Performance on the new Heartbeat Detection Procedure and the Whitehead Procedure.

This second experiment was run to test the idea that subjects do poorly on the conventional WH procedure because the pre-selected S+ and S- intervals do not always correspond with the temporal locations of events they employ for detecting heartbeats. For this purpose, half the number of subjects (the Experimental group) were tested on a slightly modified WH heartbeat detection procedure where their most Preferred Intervals and least Preferred Intervals were substituted into WH-type S+ and S- stimulus trains respectively. The rest of the subjects (the Control group) performed the WH task using 128 ms and 384 ms R-Wave to stimulus intervals for S+ and S- stimulus trains respectively.

PROCEDURE

The recording equipment and experimental procedure used were very similar to those used for running the RW procedure described in Experiment III. The only differences were the S+ and S- interval changes as described above. On the first day of testing (which was also the fourth day of Experiment IV) each subject was run on 20 Pre-training HBD trials with no performance feedback (KOR). The trial lengths were not pre-determined and trials terminated after the subject indicated a discriminative response by a button press. Inter-trial intervals were 30 seconds in duration.

On completion of the Pre-training trials, subjects were presented with the appropriate S+ and S- stimulus HBD trials and KOR was given after each discriminative response. The performance criterion for successful completion of the procedure was set at 16 correct responses during two successive blocks of ten HBD training trials. The subjects were not informed of the exact details of the criterion but were told when they had achieved it. The HBD training trials were terminated either when the subject had been presented with 200 HBD training trials, or had achieved the criterion performance level. Subjects who were successful on the task were tested on a Post-criterion phase which was identical to the Pre-training phase. For those who did not not achieve criterion performance level on the first day, heartbeat discrimination training was continued on the next day according to the same procedure. Hence, subjects who were unsuccessful on the task underwent 400 HBD training trials over the two days of testing and were not presented with a phase of Post-criterion trials. On completion of this second heartbeat discrimination procedure, each subject was debriefed and paid £5 for participating in both parts of the experiment.

RESULTS

All 16 subjects in the Experimental group achieved the criterion for successful discrimination (80% correct responses over two successive blocks of ten trials) with eleven subjects solving the task after only 20 discrimination training trials. In the Control group, three subjects were unable to reach the criterion and only two subjects were able to solve the task after 20 discrimination training trials. Since prior to exposure to the WH procedure, both groups exhibited similar patterns of performance on the heartbeat detection task as shown by a Mann-Whitney U test performed on the frequency of discriminative responses for each R-Wave to Stimulus intervals for both groups (UControl=17, UExperimental=19, p>.1), the superior performance of the Experimental group on the WH task can be attributed to the temporal placements of their S+ and S- external stimuli.

Despite the lower standard of heartbeat discrimination performance exhibited by the Control group relative to that of the Experimental group, the former group's success rate of 81.25% compares favourably with that (62.5%) shown by subjects in Experiment III performing on the WH-type (RW Procedure) HBD procedure. These results are summarized in Table 6.4.

TABLE 6.4: Summary of the trials-to-criterion results on the Whitehead-type procedure for the Experimental and Control groups and subjects performing the RW Task in Experiment III.

	GROUPS		
	EXPERIMENTAL	CONTROL	RW TASK
Mean Trials to Criterion	66.25	181.87	247.92
Standard Deviation	88.66	141.92	143.22
Median	20.23	100.50	270.00

A one-way ANOVA run on the trials-to-criterion measures from these three groups yielded a significant difference in solution rates [F(2/53)=9.14, p<.01] and Post hoc comparisons with Tukeys' test confirmed the observation that the Experimental group trained significantly more rapidly than the other two groups on the WH-type of task.

DISCUSSION

The results of this study provide strong evidence that most subjects detect and label sensations occurring 200 to 300 milliseconds after their R-Waves as heartbeats. This period includes ventricular systole, probably the most discriminable phase of the cardiac cycle, and it is likely that those subjects were sensing the mechanical events associated with ventricular contraction and ejection which comprise ventricular sytole. Interestingly, the period of 200 to 300 ms following the R-Wave has also been reported to coincide with the the period of maximum vagal input to the heart as judged by cardiac cycle time effects (Jennings and Wood, 1977; Lacey and Lacey, 1980; Coles and Strayer, 1985). Other information related to this issue comes from a study conducted by Schandry, Sparrer and Weitkunat (1986) to investigate the hypothesis that cardiovascular afferent information influences cortical processes. They recorded EKG signals concurrently with EEG signals from subjects under four different task conditions and found that the recordings were charaterized by a stable and reliable event-related potential (ERP) waveform which peaked in the range of 200 to 300 ms after the R-Wave under all four conditions. These investigators suggested that the events which give rise to heartbeat sensations in the individual are initiated during that time epoch. The results from those two different areas of psychophysiology might provide potential explanations of the sensory processes involved in the subjective detection of heartbeats and clearly require further investigation.

The extent to which this procedure provides clear evidence of the ability of subjects to detect heartbeats is primarily due to the adoption of an individual difference methodology. The essential feature of this test is that unlike several other HBD procedures, it does not institute *a priori* judgements of which events the individual will employ in detecting heartbeats. Consequently, this procedure recorded individual perceptual experiences of cardiac activity. The results which it generated question the interpretation of findings from those studies which have evaluated the ability of subjects to discriminate heartbeats by how closely their discriminative responses match experimenter-imposed definitions of what constitute heartbeats. In those cases it is plausible to assume that the tests will favour some individuals and be biased against others.

In earlier HBD procedures and studies, the heartbeat has been operationally defined as the occurrence of the R-Wave (Brener and Jones, 1974; Hamano, 1977, 1980; Clemens, 1979). This represents the R+0 ms interval in this study and the tones associated with that interval elicited the lowest percentage (8.42%) of positive judgements pronouncing them as coincident with internal heartbeat sensations. Furthermore, none of the subjects exhibited a modal preference for that interval. Also of interest is the observation that only 25% of the subjects in this study judged the tones presented 100 ms from the R-Wave as being coincident with internal heartbeat sensations. External stimuli presented at this interval are defined as heartbeat-coincident in the Katkin (Katkin et al, 1981) and Davis (Davis et al, 1986) HBD procedures. Similarly, in the Whitehead (Whitehead et al, 1977) procedure, the 'immediate' heartbeat feedback is presented 128 ms after the R-wave. That procedure also defines external stimuli occurring 384 ms after the R-Wave as being unassociated with any heartbeat activity. This conflicts with data reported by Yates et al (1985) who showed that an appreciable number of subjects judged stimuli presented 400 ms after the R-Wave as coinciding with internal heartbeat sensations. In this study three subjects reported modal preferences for tones occurring 400 ms after the R-Wave as heartlike stimuli and for the group as a whole, this interval was preferred significantly more than either the R+0 or R+500 ms intervals. Hence these latter two intervals would be most suitable as S- intervals in HBD procedures. The potential influence of an experimenter-determined criterion of the occurrence of the heartbeat on subjects' HBD performance, as used in the examples cited, was examined in the second part of this chapter. The results yielded the expected conclusion that HBD performance was significantly better in instances where subjects were required to respond according to self-established heartbeat criteria rather than to criteria preset by the experimenter.

Other methodological modifications which contributed to the production of unambiguous evidence that individuals are capable of detecting cardiac activity include the introduction of task-familiarization on the Light-Tone discrimination task and the subject-controlled trial lengths. These factors ensured that the subjects had the adequate preparation and information to exhibit their HBD abliity at the task.

Furthermore, unlike some other procedures of cardiac detection, subjects in the present task were not given any explicit HBD training (with KOR) therefore their responses were a true indication of visceral sensitivity uncompromised by reinforcement effects (Roberts, 1977).

Very low correlations have been reported between subjects' performances on different HBD tests (Ross and Brener, 1981; Grigg and Ashton, 1982; Jones, O'Leary and Pipkin, 1984) which reflects on the poor uniformity among the tests and questions the validity of those procedures. However, the results from this study are highly consistent with those obtained by Yates et al (1985) who used a related but different method. Those investigators found that subjects perceived stimuli presented 200 to 300 ms after the R-Wave most frequently as coincident with their heartbeat sensations. An additional similarity with those results was that unlike other tests of cardiac detection (Clemens, 1979; Grigg and Ashton, 1982, Wildman and Jones, 1982), performance recorded independently on both tasks proved to be stable over sessions despite the absence of performance feedback (KOR). The standard deviations of interval preferences employed in this study provide a basic indicator of the specificity of cardiac discrimination but although this measure does possess face validity as an index of discrimination it would clearly be desirable to check its validity using external criteria.

Ideally, one should be able to predict the characteristics that differentiate people who differ in their ability to detect internal cardiac activity. The extent to which the present procedure was able to achieve this was however, limited. Apart from the general temporal discrimination ability reflected by the PIsd on the Light-Tone familiarization task, the procedure was unable to identify any reliable characteristics that explained individual differences revealed in the analysis of response patterns examined. Unfortunately, subjects' verbal reports about the cues they employed in solving the task were not sufficiently informative either in the identification of individual response strategies or in the differentiation of events underlying the discriminations. Likewise, gender differences and measures of body dimensions gave little indication of any differential predisposition to cardiac discrimination. However, on the basis that this procedure provides a valid experimental approach to the assessment of cardiac perception and generates unambiguous evidence of individual heartbeat perceptions, in the following experiment individual differences in heartbeat detection were further explored using this HBD procedure.

CHAPTER SEVEN

EXPERIMENT V: LATERALITY, EMOTIONALITY AND HEARTBEAT DETECTION

INTRODUCTION

Recent research in visceral perception has indicated that hemispheric specialization and emotionality may account in part for the individual differences between subjects in cardiac perception. This experiment was designed to examine the relationship between those two variables and the detection of cardiac activity.

Several investigators working in different research areas have independently reported findings which suggest the existence of a relationship between autonomic perception and right cerebral hemispheric activation (Hecaen, 1969; Galin, 1974; Luria and Simernitskaya, 1977; Davidson, Horowitz, Schwartz and Goodman, 1981; Walker and Sandman, 1979, 1982). The results most relevant to this study are those obtained from the experiments of Walker and Sandman (1979, 1982. see Chapter Three) which suggested that the right hemisphere may be specialized for processing afference from cardiovascular events. One might accordingly expect that right hemispheric activation to be associated with perception of cardiac activity. This prediction was supported by Hantas, Katkin and Reed (1984) and also by Montgomery and Jones (1984). Independently, those workers reported that subjects classified as right hemisphere preferent performed significantly better on heartbeat detection tasks than subjects who were classified as left hemisphere preferent. Those investigators used different

HBD tasks to assess heartbeat detection ability but both determined their subjects' "hemispheric preference" (hemisphere activation bias) on the basis of the directionality of conjugate lateral eye movements (CLEMs) elicited by the administration of selected questions as suggested by Gur and Gur (1977).

Conjugate lateral eye movements are directional gazes to either the right or the left that individuals exhibit while engaged in cognitive activity. Gaze shifts to the left are presumed to reflect right hemispheric activation and shifts to the right, left hemispheric activation (Bakan, 1969; Kinsbourne, 1972). The evidence offered in support of the presumption that CLEMs reflect hemispheric asymmetry of function was criticized as being insubstantial by Ehrlichman and Weinberger (1978) after a thorough evaluative review. However, some substantial and more recent evidence has been produced by several workers (Gur and Reivich, 1980; Shevrin, Smokler and Kooi, 1980; Newlin, Rohrbaugh and Varner, 1982) which lend support to the use of CLEMs as valid indicators of individual differences in hemisphere activation bias.

The second individual difference variable under examination which has been linked with visceral perception is emotional experience (Mandler, Mandler and Uviller, 1958; McFarland, 1975; Whitehead, Drescher, Blackwell, 1976; Schachter and Singer, 1979; Marshall and Zimbardo, 1979; Maslach, 1979). Additional evidence linking emotional experience to good performance on a heartbeat detection task has also been reported by Schandry (1981) and Hantas, Katkin and Blascovich (1982). Evidence of hemispheric involvement in emotion and affect has been provided by various researchers eg. Gainotti (1972), Harman and Ray (1977), Smokler and Shevrin (1979) and Tucker, Roth, Arneson and Buckingham (1977) who found that individuals exhibited significantly more left LEMs to emotional questions than to unemotional questions. That evidence and others formed the basis of the claim that there existed "a special role for the right hemisphere in the regulation of emotional processes" (Schwartz, Davidson and Maer, 1975, p.288).

From the foregoing it appeared worthwhile to examine the relationship between the variables, emotionality and hemispheric laterality within the context of cardiac perception. Therefore, employing the heartbeat detection task developed in the previous Chapter the present study was aimed at examining the role of cerebral hemispheric preference and emotionality as predictors of individual differences in the accuracy of heartbeat detection. This issue has been researched by Montgomery and Jones (1984). They tested two groups of 20 male subjects classified as either good or poor discriminators on their performance on 100 WH HBD trials, on three emotionality measures and on a CLEM eliciting questionnaire. The researchers found that good heartbeat discriminators made significantly more left LEMs (significantly right hemisphere-preferent) than poor discriminators. However, the two groups did not differ significantly in their emotionality scores. The latter results do not conform with those reported by Schandry (1981) and Hantas et al (1982) where good heartbeat detectors were found to report greater subjective experience of emotion than poor heartbeat detectors.

Although support for the correlation observed between laterality and accuracy of heartbeat discrimination was given by Hantas et al (1984), their results were pronounced inconclusive by Katkin (1985) after discovering that the differences between right and left hemisphere preferent subjects may not necessarily reflect differences in heartbeat perception but may rather reflect differences in general pattern perception. Clearly, this issue concerning the nature of inter-relationships between cerebral laterality, emotionality and heartbeat detection calls for further research.

Other issues that were investigated in this study were the reliability and stability of the heartbeat detection procedure developed in the previous chapter. In order to achieve this, several of the subjects who performed the task described in Chapter Six were recalled and re-tested. There was an average time period of six months between the two experiments and this was considered adequate for the examination of the stability of performance. The bases of those judgements were revealed by the investigation of performance strategy variables which like the emotionality and laterality variables were explored as potential predictors of individual differences in cardiac discrimination.

METHOD

SUBJECTS

An attempt was made to contact and re-recruit for further testing, all 32 subjects who had participated in Experiment Four. Twenty-four of those subjects were succesfully contacted but two of them failed to turn up for the experiment. Of the 22 subjects who took part in this study, twelve were females and ten were males aged 17-37 years. Each subject underwent two consecutive daily tests and was paid #2 at the end of the experiment to cover expenses.

APPARATUS

The recording equipment used in running the Heartbeat Detection task were identical to that used in Experiment Four. The equipment used for recording eye movements will be described in the Procedure section.

A modified version of the series of 11 verbal and 9 spatial questions previously used by Hantas et al (1984) was employed to test lateral eye movements. A copy of this questionnaire can be found in Appendix B. The State-Trait Anxiety Inventory (STAI), Forms X-1 (State Anxiety) and X-2 (Trait Anxiety) (Speilberger, Gorsuch and Lushene, 1970) and the Eysenck Personality Inventory (EPI) (Eysenck and Eysenck, 1968) were used to assess emotional states. Cardiac discrimination ability was assessed from the subjects' performance on the heartbeat detection task developed in Experiment IV.

PROCEDURE

In the set-up for testing lateral eye movements the subject was seated in a cubicle at a small table facing a one-way mirror and the experimenter was seated approximately 0.8m behind him or her. In an adjoining room a video camera and video cassette recorder were set up to record the subject's eye movements and verbal responses during the session. The subjects were naive to the presence of the one-way mirror and the video recording equipment. On the first day of testing, each subject was taken into the cubicle and asked to concentrate on answering a series of questions and told to ignore the presence of the experimenter. The 20-item lateral eye movement (LEM) elicitation questionnaire was then read out to each subject. After completion of the LEM test the subjects were escorted to the laboratory and asked to complete the STAI Form X-1 (State Anxiety). On completion of the inventory the subjects were submitted to a 30-trial session on the heartbeat detection test, observing a procedure identical to that outlined in Experiment IV.

On the second day of testing subjects underwent another session of 30 heartbeat detection trials. Following the completion of the last HBD trial, the subjects were asked to complete the STAI Form X-2 (Trait Anxiety) and the EPI. After completing the inventories the subjects were debriefed and paid £2 for their participation in the experiment.

Measures of Performance and Data Analysis

Data reduction was identical to Experiment IV, with measures of the average heart rate, Preferred Interval (PI), Inspection Frequency and Mean Inspection Duration recorded on each trial. These data provided the basis for calculating the Total Inspection Duration of intervals and mean and standard deviations of the Preferred Intervals selected on each session. In order to examine any variations with time in the accuracy of heartbeat detection, the subjects' performance data from the two sessions in Experiment IV were analyzed together with the two sessions of the present experiment. The former set were designated Sessions 1 and 2 and those of the present experiment, as Sessions 3 and 4.

Cerebral hemispheric preference was scored by the direction of the first gaze shift each subject made immediately after each question of the CLEM questionnaire. A Percent right eye movement score for each subject was calculated by dividing the right LEMs by the sum of the left and right LEMs (Right LEMs / Right+Left LEMs). The STAI Forms X-1 (State Anxiety) and X-2 (Trait Anxiety) and the Neuroticism scale of the EPI (N) were used to assess the subjects' subjective reports of emotionality. These measures of emotionality and performance strategy were submitted to several correlational analyses in order to identify any relationships among the variables.

RESULTS

Heartbeat Detection

The positive responses for each R-Wave to Stimulus Interval for Session 3 and Session 4 formed 98.94% of the total number of discriminative responses recorded in the present study. Table 7.1 shows the frequency distribution of discriminative responses for each Interval on all four Sessions.

TABLE 7.1: Total frequencies of subjects' discriminative responses to the six R-Wave to Stimulus Intervals during all four Sessions.

	INTERVALS/ms						RESPONSES	
	R+0	R+100	R+200	R+300	R+400	R+500	"positive"	"don't know"
S1	60	113	155	154	110	60	652	8
S2	45	107	161	167	106	72	658	2
S3	38	104	196	153	103	56	650	10
S4	49	136	166	159	103	43	656	4
TOTAL	192	460	678	633	422	231	2616	24

S1=Session 1 : S2=Session 2 : S3=Session 3 : S4=Session 4

In order to examine changes in the distribution over sessions, the data were submitted to a two-way ANOVA for repeated measures (Six Intervals by four Sessions). This analysis yielded a significant main effect for Intervals [$F(15/105)=14.619$, $p<.01$]. Newman-Keuls' post-hoc analysis revealed that as in the previous experiment, tones which were delayed 200 and 300 ms from the R-Wave were selected more frequently than the other intervals as heartbeat-coincident and

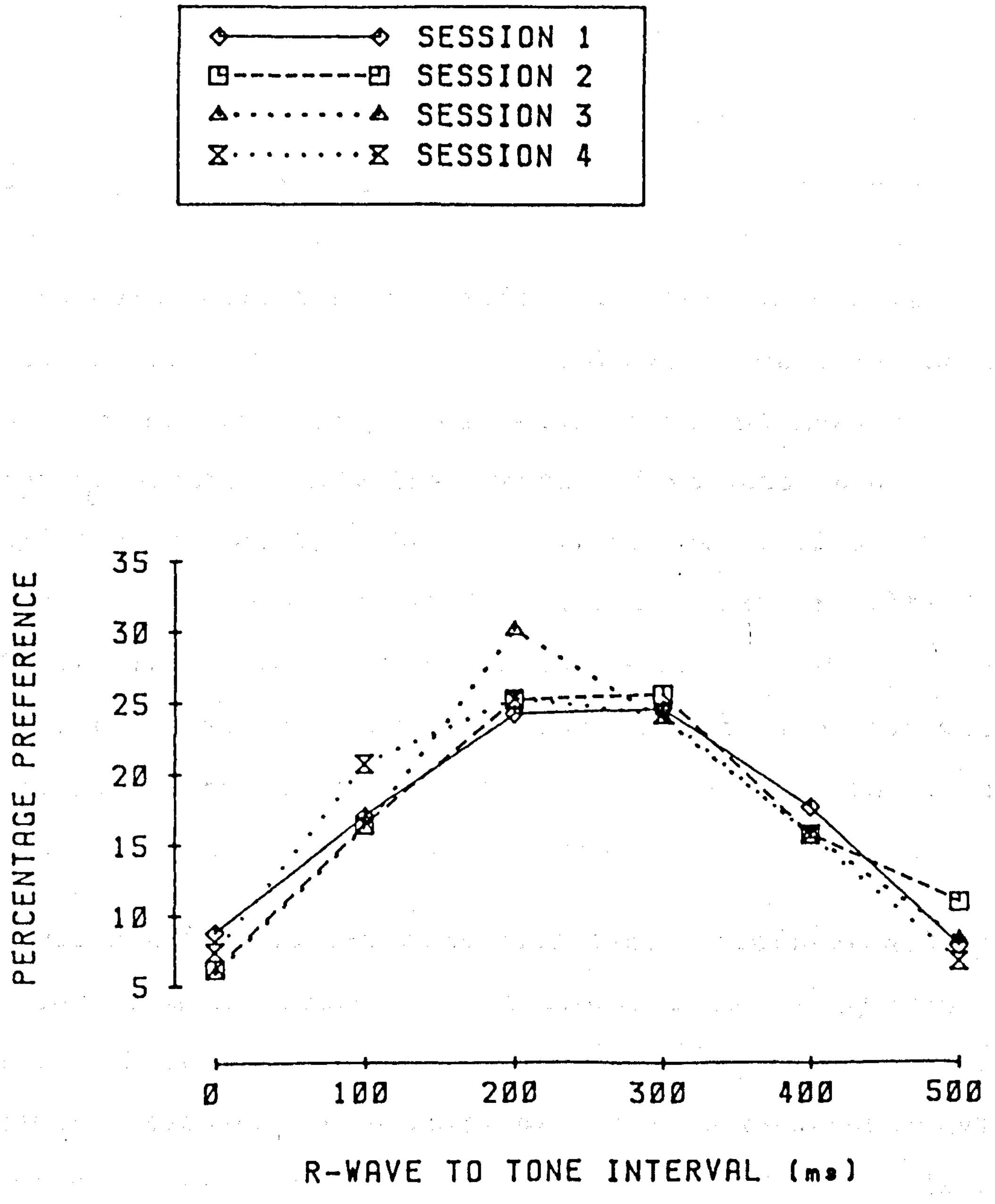


Figure 7.1 Percentage frequencies with which each of the R-Wave to Tone Intervals was chosen as simultaneous with heartbeats during Sessions 1,2,3 and 4.

the 100 and 400 ms intervals were chosen more often than the 0 and 500 ms intervals. The 200 and 300 ms intervals were equivalent as were the 100 and 400 pair and the 0 and 500 ms pair. These findings are illustrated in Figure 7.1 which shows the mean percentage frequencies of positive responses to each interval for each of the four sessions.

It was anticipated that with experience on the task, subjects would exhibit less variability in their choices of preferred interval and hence comparisons were made of the mean and standard deviations of preferred intervals between sessions. Separate one-way repeated ANOVAs were run on these measures. For the group, the means of the SD measures decreased significantly from Session 1 to Session 4 [$F(3/63)=4.30$, $p<.01$]. The test on the means of the PI however failed to produce any reliable effects. These results (shown in Figure 7.2) indicate that the subjects as a whole showed similar response patterns from session to session but with experience on the task, exhibited an increase in the precision of their choices of preferred interval.

Pearsons' product-moment correlation coefficients were computed from the standard deviations of each subject's preferred interval for each session in order to examine the session-to-session reliability of the PIsd (standard deviation of the Preferred Interval) which was proposed in the last chapter as an index of the precision of HBD. Table 7.2 contains the resulting intercorrelations between PIsds of all sessions. The robust inter-session correlations indicate a significant tendency for subjects to maintain their performance levels relative to the other subjects from session to session.

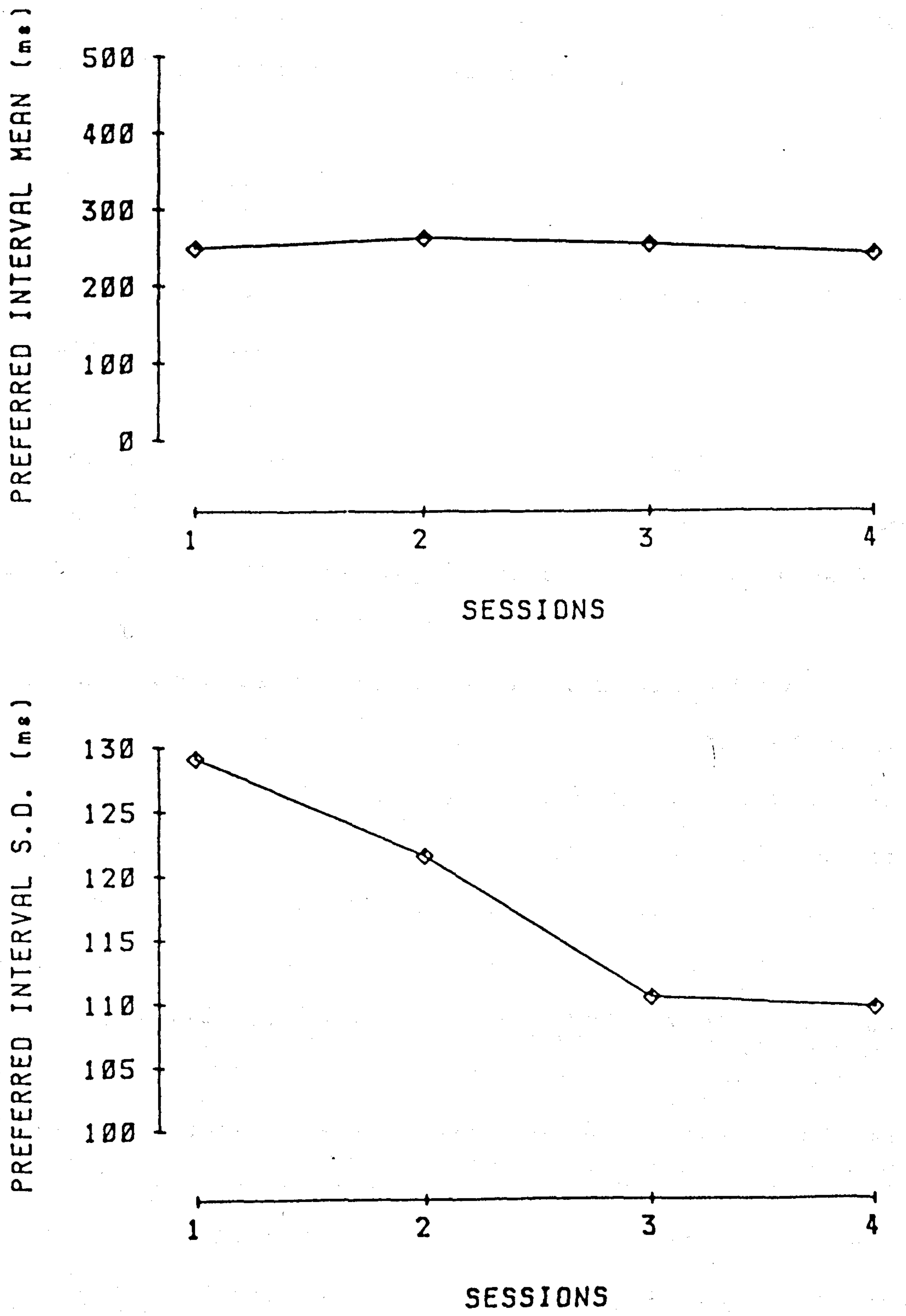


Figure 7.2 Means and Standard Deviations of Preferred Intervals selected during Sessions 1,2,3 and 4.

Furthermore, the inter-session correlation indices also suggest a level of task stability not apparent in other HBD tasks (eg. Clemens, 1979; Grigg and Ashton, 1982).

TABLE 7.2: Intercorrelations of Standard deviation measures of Preferred Intervals for successive Sessions.

	Session 1	**Session 2**	**Session 3**	**Session 4**
Session 1	1.00			
Session 2	.55	1.00		
Session 3	.67	.51	1.00	
Session 4	.59	.64	.77	1.00

[0.53 was required for significance at the .01 level]

Heartbeat Detection, Emotionality and Laterality.

Having established the reliability of the PIsd, testing was focused upon determining the relationships between the PIsd and the individual difference variables mentioned in the Introduction. Correlational analyses were performed on the subjects' PIsd measures calculated from all four sessions and their LEM, EPI(N), State and Trait Anxiety scores. From Table 7.3, it will be seen that Trait anxiety was the only variable which was significantly related to PIsd. The correlation coefficient between hemispheric preference and PIsd only approached significance as did the correlation between hemispheric preference and Trait anxiety. The significant correlations between State anxiety and EPI(N) scores and that between Trait and State anxiety scores would suggest that to some extent, those three variables were assessing a common factor. In summary, the results indicated that less anxious subjects were more accurate at detecting heartbeats than more anxious subjects and cerebral hemispheric specialization was found not to be significantly related to either emotionality or accuracy of heartbeat detection.

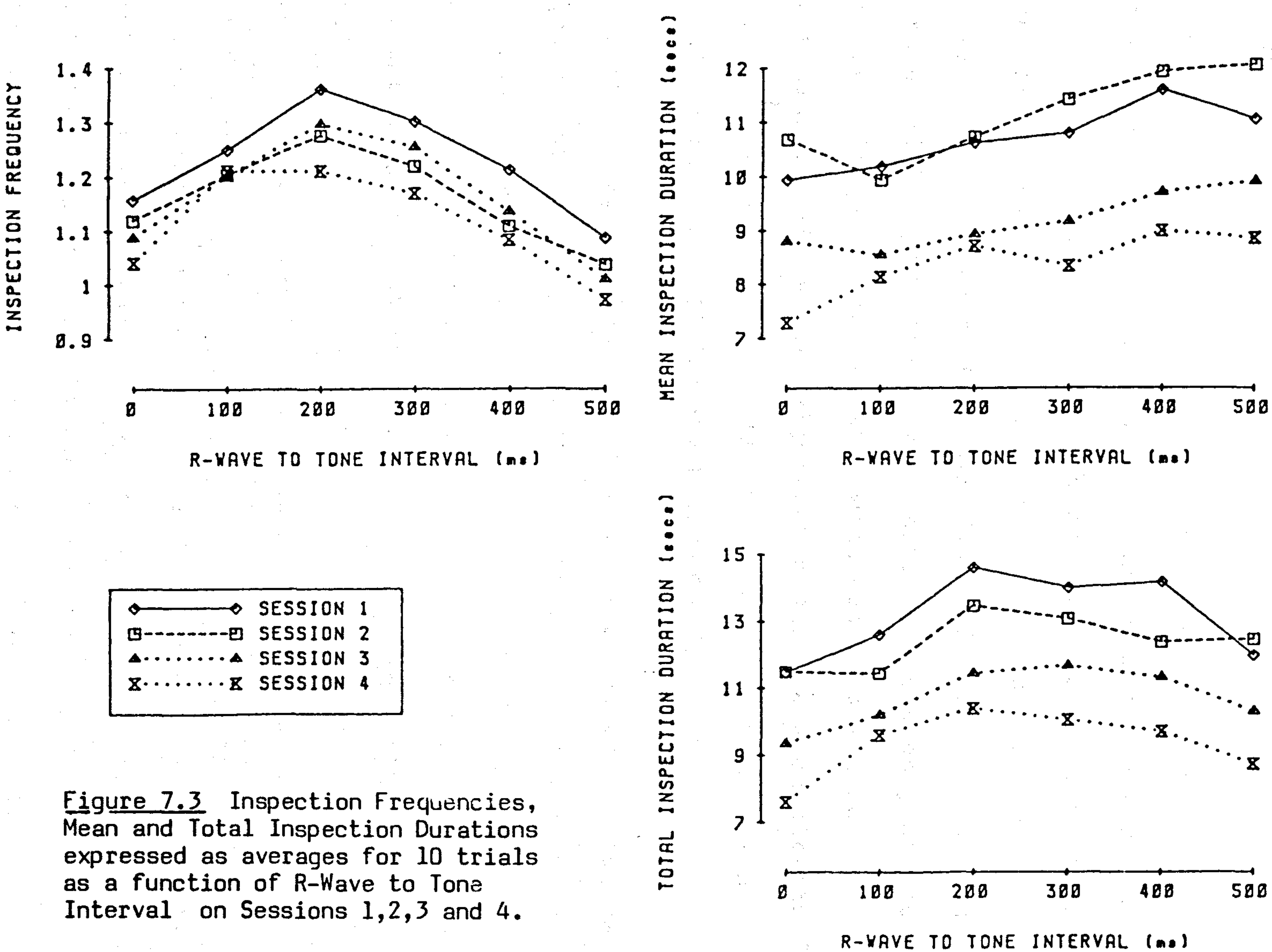
TABLE 7.3: Intercorrelations between Emotionality, Laterality and Heartbeat Detection Scores.

	PIsd	LEM	EPI(N)	STATE	TRAIT
PIsd	1.00	.39	.26	.24	.47
LEM		1.00	.22	.25	.39
EPI(N)			1.00	.65	.38
STATE				1.00	.63
TRAIT					1.00

0.41 required for significance at the .05 level.
0.53 required for significance at the .01 level.

Task Performance variables and Heartbeat Detection Accuracy

In order to explore the strategies employed by subjects for selecting Preferred Intervals (PIs), the three performance measures calculated for each subject on each session; Inspection Frequency, Mean Inspection Duration and Total Inspection Duration were submitted separately to two-way repeated measures ANOVAs (Four Sessions by six Intervals). These yielded very similar results and conclusions to those found in the previous study. Significant Intervals effects for all the variables [Inspection Frequency: $F(5/105)=9.693$, $p<.01$; Mean Inspection Duration: $F(5/105)=4.241$, $p<.01$; Total Inspection Duration $F(5/105)=2.876$, $p<.05$]. These effects are illustrated in Figure 7.3. It will be seen here that the graphs of Inspection Frequency and of Total Inspection Duration



<u>Figure 7.3</u> Inspection Frequencies, Mean and Total Inspection Durations expressed as averages for 10 trials as a function of R-Wave to Tone Interval on Sessions 1,2,3 and 4.

show similar profiles to the Interval preference data (Figure 7.1). Thus, subjects inspected the intervals they preferred significantly more often and for longer than non-preferred intervals.

The results of the analyses performed on the task performance variables were in agreement with those reported in the previous experiment. The subjects exhibited very similar performance strategies to those shown previously, improving their ability to discriminate the coincidence of heartbeat sensations and tones with experience on the task. The tendency of the Inspection Frequency to decrease with sessions was not significant but there were significant main session effects for Total Inspection Duration [$F(3/63)=10.20$, $p<.01$] and Mean Inspection Duration [$F(3/63)=7.118$, $p<.01$].

Further exploration of how these performance strategies influence the accuracy of heartbeat detection was undertaken by computing the averages of the Inspection Frequencies (IFm), Mean Inspection Duration (MDm) and Total Inspection Duration (TDm) for each subject for all the HBD sessions and then calculating the correlations between these variables and PIsd. As it was found in the previous experiment that there was a relationship between HBD performance and performance on the Familiarization (Light-Tone) discrimination task, the standard deviation scores of the 22 subjects on that task (LTsd) were also included in the correlational computation. The correlation coefficients are summarized in Table 7.4.

TABLE 7.4: Intercorrelations between Task Performance variables and the standard deviation of the Preferred Interval on the HBD Task.

VARIABLES	PIsd
LTsd	0.45
IFm	-0.44
MDm	0.02
TDm	-0.29

[0.41 required for significance at the .05 level]

Inspection Frequency was found to be reliably negatively associated with HBD accuracy. It can be proposed that subjects who examined the R-Wave to Stimulus intervals thoroughly (indicated by high Inspection Frequency) were more likely to perform accurately on the task (small PIsd). Furthermore, previous assumptions about the relevance of performance on the Light-Tone task to performance on the HBD task were confirmed by the significant correlation between the accuracy of performance on both tasks. These results show that the acquisition of the discriminative skills essential for performing the HBD task significantly improves HBD accuracy.

From the correlational analyses, Trait anxiety and accuracy on the Light-Tone task emerged as the best predictors of cardiac sensitivity. Both variables were therefore entered into a multiple regression analysis as predictors of PIsd. The analysis yielded a coefficient of multiple correlation [r(PIsd/TRAIT, LTsd)] of 0.59. It also provided the following regression equation which predicts the PIsd of subjects with a standard error of 23.914 [$F(2/19)=5.199$, $p=0.0156$]:

$$PIsd=0.364\ (LTsd) + 2.152\ (TRAIT) + 7.394.$$

DISCUSSION

The proposed relationships between hemispheric preference (as determined by lateral eye movements) and the precision of heartbeat detection and also with emotionality were not supported by the results of this study. Hemispheric preference was poorly correlated with emotionality assessed by the EPI(N) and State Anxiety scores and the coefficient with Trait anxiety only approached significance (-0.39). The relationship between emotionality and hemispheric specialization has been explored by only Montgomery and Jones (1984) to date and they reported that groups of subjects with high scores on both the EPI(N) and STAI (Trait Anxiety) had significantly low right LEM scores. These investigators also reported finding no relationship between LEM scores and scores from the STAI (State Anxiety), leading them to propose that hemispheric specialization may be associated with only the more stable trait measures of emotionality.

It was also hypothesized that subjects who exhibited accurate heartbeat detection would exhibit significantly more left lateral eye movements (right hemisphere preferent). Although the correlation coefficient between percent Right LEM scores and the SD of the preferred intervals was in the anticipated direction (0.39), it was not sufficiently strong to indicate a reliable relationship (0.41 was required for significance at the .05 level). These results do not conform with those of Hantas et al (1984) and Montgomery and Jones (1984), who in independent studies reported strong evidence that "left-movers" (right hemisphere preferent) exhibited significantly better performance on heartbeat detection tasks than "right-movers" (left hemisphere preferent). It is probable that procedural differences between this study and those workers' contributed to this disparity in results.

Firstly, in both of those studies, the experimenter or interviewer sat directly in front of the subject and recorded the subject's LEMs in the test situation whereas in this study, the experimenter was seated behind the subject and LEMs were recorded on videotape for subsequent scoring. It is possible that the different seating arrangements adopted in the studies accounted for the difference in results. Kinsbourne (1972) suggested that the socially interpersonal face-to-face situation may be anxiety provoking especially for an anxious subject and might elicit behaviours characteristic of his or her emotive state. He therefore recommended the relatively impersonal test situation with the experimenter seated behind the subject which should minimize the emotive aspect and thereby permit unconfounded recording of LEMs. Other workers however, have disagreed with this view (White, Hegarty and Beasley, 1970; Gur, Gur and Harris, 1975).

Secondly, both Hantas and Montgomery tested the hypothesis using subjects who had been definitely classified as either "right or left movers". Additionally, the researchers tested male subjects exclusively as males have been reported to be more lateralized for hemispheric functioning than females (McGlone and Davidson, 1973). In this study, laterality was assessed using data from a group consisting of twelve females and ten males and only seven subjects achieved the criterion employed by Hantas et al (1984) for unequivocal classification as left or right hemisphere preferent, of at least 70% scorable gaze shifts in the appropriate direction. Despite those procedural differences, there was some suggestion that the right hemisphere is involved in cardiac perception and these findings support Katkin's (1985) call for further investigation of this issue.

Evidence has been presented indicating a link between accurate heartbeat perception and subjective reports of emotion (eg. Schandry, 1981; Hantas, Katkin and Blascovich, 1984). However, the results indicated that low scores of trait anxiety were significantly correlated with accurate heartbeat detection. No reliable relationships were found between heartbeat detection and scores from the two other measures of emotionality employed; EPI(N) and STAI (State Anxiety). In the previous studies cited, there is the implication that emotional experiences or states improve the accuracy of HBD performance because by operating as arousal-inducing factors, they accentuate the subjects' perception of internal events. However, the findings from this experiment indicate that subjects who report being less anxious exhibit better accuracy at detecting heartbeats. Unfortunately, the available data do not provide an adequate basis on which to interprete this apparent disparity.

Examination of the performance strategies subjects' engaged in showed that the mean of the Inspection Frequency (IFm) was significantly negatively correlated with the precision of heartbeat detection (PIsd). This finding endorses the design of a HBD procedure which deviates from the conventional paradigms and permits subjects the opportunity to examine potential heartbeat-coincidental stimuli repeatedly and for as long as they wish before making a final discriminative response. Support is also given for the introduction of a familiarization task in the HBD procedure. The significant correlation between the SDs of both tasks would seem to substantiate the claim that they tapped a common performance skill.

Another important result was the convincing proof of the stability and reliability of the HBD procedure developed in Experiment IV. The correlations between successive sessions showed a high degree of stability of performance on the HBD procedure despite a time period of about six months between Sessions 2 and 3 (and Sessions 1 and 4). Overall patterns of subjects' discriminative responses were also unambiguously defined as in Experiment IV, indicating strong evidence of test-retest reliability and consistent R-Wave to Stimulus Interval preferences in the subjects. The increase in the precision of heartbeat detection ability (PIsd) across sessions implies that subjects retained the discriminative skills they acquired for discriminating external signals which were simultaneous with heartbeat sensations but that those skills improved thereby making subjects more accurate on the task with experience.

In summary, the results of this study demonstrate that cardiac sensitivity of subjects as assessed by the HBD procedure described in the previous and current Chapters is relatively stable and the PIsd (standard deviation of the Preferred Interval) score appears to produce acceptable levels of score consistency and precision.

CHAPTER EIGHT

GENERAL DISCUSSION

The lack of consistency in published reports of heartbeat discrimination may be attributed to the wide variety of methods and measures employed to evaluate the abilities of individuals to detect cardiac activity. Little progress has been made in standardizing tests and the few attempts which have been made to assess the validity and reliability of methods have yielded disappointing results.

Experiments reported in this thesis indicate that contrary to the suggestions made by Katkin, Reed and DeRoo (1983), poor performance on the Whitehead-type tasks cannot be attributed to the difficulty of the temporal discriminations required in these methods. However, a number of other problems inherent in the tasks were revealed. Most importantly, by arbitrarily defining the temporal location of heartbeat sensations, those procedures tend to favour good performance in some subjects and obscure potentially good performance in others. This fundamental problem was dealt with in the design of a new heartbeat detection (HBD) procedure which also eliminated other arbitrary sources of bias associated with WH-type procedures reported in the literature. In particular, restrictions on the opportunity of subjects to inspect different heartbeat-contingent stimuli were withdrawn thereby reducing the possible biasing effect of data-limitations (Norman and Bobrow, 1975) on HBD performance. Furthermore, KOR, which implies *a priori* judgements of the temporal locations heartbeat sensations was not provided.

Finally, pre-testing on non-cardiac aspects of the procedure was introduced. The incorporation of this Familiarization task into the HBD paradigm served two purposes. Firstly, performance on the Familiarization task would ensure that the subjects understood the procedural requirements of the HBD task. Secondly, if subjects accurately solved the Familiarization task, then it could be inferred that they were able to perform the temporal discriminations necessary on the HBD task. In effect, those two conditions must be fulfulled before a HBD procedure can permit the unconfounded assessment of heartbeat perception.

The HBD procedure incorporating all of these features yielded results that provided unambiguous evidence of heartbeat detection and which were also highly consistent with results from another study that employed a related but different method (Yates et al, 1985). Furthermore, performance on the HBD task was convincingly stable over time. These findings relate favourably to the validity and reliability of HBD procedures.

In an attempt to understand more about the selection and decision processes involved in heartbeat discrimination, detailed analyses were performed on the stimulus inspection behaviour subjects engaged in during the HBD task. The only previous attempt to identify discrimination strategies appears to have been by Ross and Brener (1981) who classified subjects according to the "active" or "passive" strategies they employed to discriminate the coincidence and non-coincidence of heartbeats and tones.

The analyses of the performance variables defined in Experiments IV and V, produced information which indicated that after only 30 HBD trials, subjects showed appreciable evidence of heartbeat discrimination and could differentiate between external signals which bore different temporal associations to their heartbeats. The process of stimulus identification was manifested by the differential amounts of time subjects allocated to each stimulus interval; inspecting preferred intervals more often and for longer total time periods than non-preferred ones. The expectation that subjects would become more proficient at the task was also supported by the observation that the frequency with which they inspected intervals and the duration of interval inspections decreased as a function of experimental sessions.

The standard deviation of the Preferred Interval (PIsd) which was employed as an index of perceptual sensitivity was shown to decrease with experience on the task. It could be argued that the decrease in PIsd reflects subjects becoming more proficient at operating the requirements of the task rather than reflecting increases in cardiac perception. This is supported by the observation that subjects exhibited stable mean values of Preferred Intervals which remained unchanged even after a time period of about six months. These values of PImean were stable within and between subjects suggesting that they are a measure of individual detection characteristics.

Evaluation of the results of these studies support the view that the individual difference methodology in general and the HBD procedure developed in this work in particular, has the potential for asking new research questions and generating new kinds of data. To reiterate, the procedure has generated convincing evidence of heartbeat detection and satisfied the criteria for a valid and reliable HBD test. Three essential features underlie the development of this procedure: ascertaining that subjects are able to perform the requirements imposed by the task by requiring the initial performance on a related task, the introduction of sampling technique which permits the free examination of available stimuli, no provision of KOR thereby preventing any contamination of the results from reinforcement effects and no arbitrary criteria for right or wrong answers so that the performance recorded is based on individual perception. The most crucial modification was allowing for individual differences in the definition of heartbeat by eliminating experimenter-determined criteria for the occurrence of heartbeats.

It is difficult to account for the discrepancies between observations made in this work and those of previous reports because HBD procedures have not been standardized. Therefore, it would seem premature to make statements about individual differences in the ability to percieve cardiac activity. Various hypotheses involving psychological and physical variables have been investigated but at the moment as expected, the findings have been inconsistent primarily because of the inconsistency of the basic measuring tools. For example, the validity of some HBD procedures has been questioned (eg. Schandry, 1982, Hantas et al, 1984) as have the reliability of findings from procedures which have assessed HBD ability by measuring subjects' conformity to arbitrarily defined perceptual criteria (eg. Whitehead procedure). Moreover, reports have established that there are very low inter-correlations between measures from different HBD procedures (Ross and Brener, 1981; Grigg and Ashton, 1982; Jones, O'Leary and Pipkin, 1984). Clearly, the large degree of methodological variability among published investigations and the lack of proper standardization among the task measures have clouded comparisons among experiments and it is only after all these considerations are adequately dealt with that questions such as those which inquire about what characteristics differentiate people who differ in their ability to discriminate heartbeats can be addressed.

Several individual difference variables employed in other studies were also investigated in this thesis. The data analyses did not yield the gender differences often reported in the literature (Whitehead et al, 1977; Katkin et al, 1981; Jones and Hollandsworth, 1981). Neither did the data conform with results from studies reporting a relationship between heartbeat detection and right cerebral hemisphere activation (Montgomery and Jones, 1984; Hantas et al, 1984). The relationship between heartbeat detection and self-reports of situational emotion (Schandry, 1981; Schandry and Specht, 1981; Katkin et al, 1982) was suggested but was not significant. The individual difference variable which was shown to be related to HBD performance was Trait anxiety. However, contrary to prevailing theory, (eg. Katkin, 1985), that variable was found to be negatively related to heartbeat detection accuracy.

It is possible that the individual differences in the perception of heartbeats might be attibutable to differences in physical or anatomical features and not necessarily to cognitive processes associated with the individual difference variables mentioned previously. Most subjects defined heartbeats as sensations occurring either 200 or 300 ms after the R-Wave but others reported that stimuli presented 100 ms and 400 ms after the R-Wave were simultaneous with sensations of heartbeats. These findings suggest that subjects may be detecting cardiac sensations from different sensory sources.

Although the issue has not been sufficiently explored, visceral perception is thought by some (eg. Brener, 1974) to be based on visceral afferent pathways with individuals sensing cardiac activity via the cardiac-specific visceral afferent pathways. The receptors implicated in this model are the cardiac baroreceptors, which are abundantly present in the carotid sinus, aortic arch and the brachio-cephalic regions. They are highly sensitive to pulsatile variations associated with cardiac activity (Paintal, 1972) and appear to be the most credible source of cardiac specific feedback. Hence, it would be expected that increases in myocardial contractility, cardiac output and stroke volume should increase the strength of the 'cardiac signal' and presumably lead to stronger detectible sensations. It seems plausible to suggest that the members of the R+100 ms group detected heartbeat sensations via these cardiovascular baroreceptors. Although no experimental proof can be offered in support of this claim at the moment, such support may soon be made available from Katkin's (1985) current investigation into the relationship between myocardial contractility and the accuracy of heartbeat perception.

Contrary to the view that cardiac detection is based on visceral afference, Jones (1982) has proposed and recently (Jones et al, 1987) presented a model which suggests that visceral sensations are mediated through primary somatosensory pathways. This view might be partially endorsed by inferences drawn from verbal reports of some subjects who participated in Experiments III, IV and V about how they sensed heartbeats. The majority of subjects reported detecting cardiac sensations from the periphery and such information can be derived from receptors stimulated by the pulsatile action of the pressure pulse wave on non-cardiovascular mechanoreceptors. This is applicable to the situation where the subject is seated in a recliner, as in this body position the additional pressure exerted on the back and the back of the neck, legs and arms will bring peripheral somatosensory receptors into closer contact with the vasculature and may augment pulse sensations.

Other likely receptors would be the Pacinian corpuscles of the somatosensory system which are very sensitive to transmitted vibration. Those Pacinian corpuscles located in the thoracic wall are known to have dendrites penetrating into the pericardium (Paintal, 1972). Therefore, they could readily detect the vibrations associated with cardiac activity and carry this information via somatosensory pathways. It is also conceivable that the mechanical events of the heart could be detected at a distance by Pacinian corpuscles which occur adundantly in the feet, hands and the dermal layer of the chest (F. Cervero, personal communication, 1987). It is worth noting that the chest and hands ranked as the first and second most reported locations of where subjects detected heartbeat sensations.

These views on the sensory mechanisms underlying the perception of cardiac sensations seem credible and may provide pathways through which cardiac sensations can be made accessible to the individual. It may be that the use of these different sensory pathways is responsible for the individual differences reported in the perception of cardiac activity. Clearly, there is the need for further investigation of this particular issue and the others raised in this thesis.

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APPENDIX A

Photographs of experimental equipment.

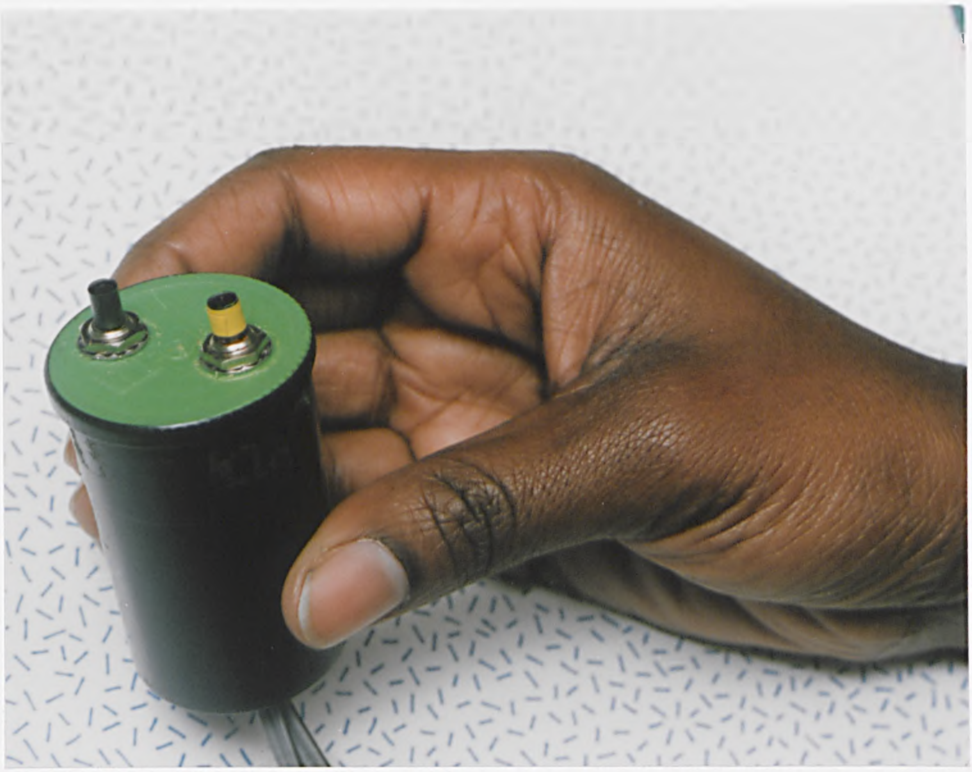

Figure A1: Two-button response unit.

Figure A2: Subject seated in experimental cubicle.

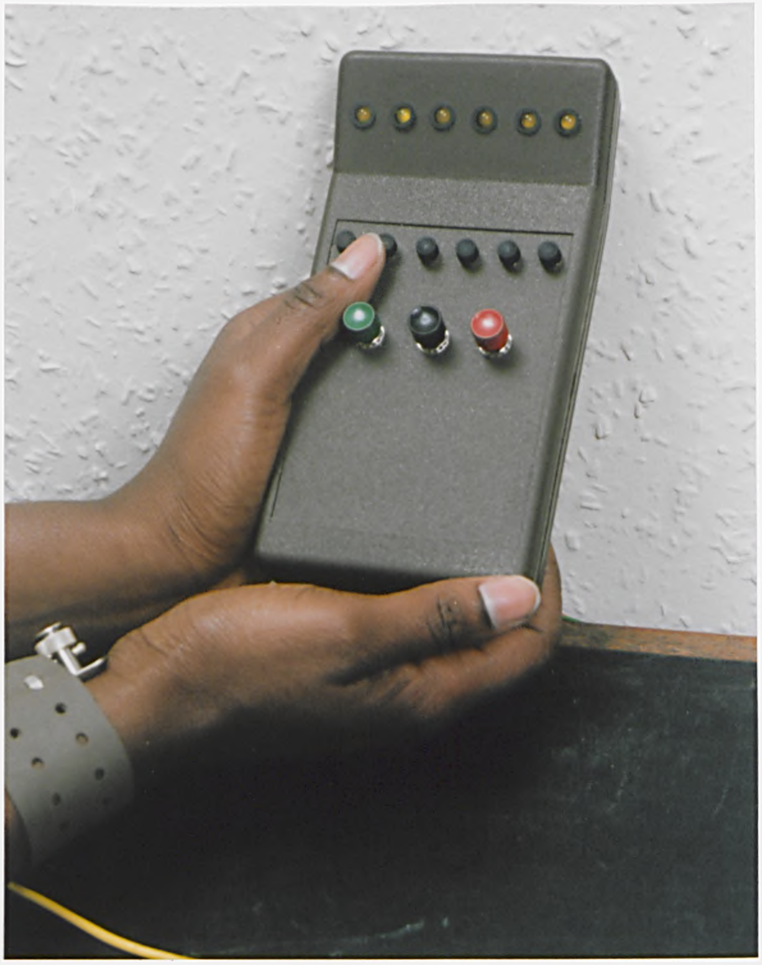

Figure A3: Hand-held six-button response panel.

Figure A4: Subject seated in position for performance on the new Heartbeat Detection Procedure.

APPENDIX B

Questions for Eliciting Eye Movements.

APPENDIX B

QUESTIONS FOR ELICITING EYE MOVEMENTS

1. Name some synomyms for the word good.
2. Where is Liverpool relative to Newcastle?
3. What is the meaning of fortitude?
4. Which direction does Queen Elizabeth face on the penny?
5. What is a male goose called?
6. What is on the face of the 10p coin?
7. In what way are praise and punishment alike?
8. Where is Sheffield relative to Birmingham?
9. Where is "F" relative to "O" on the typewriter?
10. Explain the meaning of the saying "A bird in hand is worth two in the bush".
11. Which major towns do you pass through while travelling from Hull to London?
12. What is the meaning of the word "Rational"?
13. What is meant by the saying "A stitch in time saves nine"?
14. What is the meaning of the word "Impervious"?
15. Where is "R" relative to "B" on the typewriter?
16. What is the colour of the outside of this building?
17. Where is Bristol relative to London?
18. Why should people pay taxes?
19. Explain the meaning of the saying "Don't judge a book by its cover"
20. In which hand is the spear held by Britannia?