SLOW CORTICAL BRAIN POTENTIALS
IN CRIMINAL PSYCHOPATHS

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ABSTRACT

Slow cortical potentials and electrodermal activity were recorded while criminal psychopaths performed a two-stimulus anticipation task with monetary reward and punishment. Twelve psychopathic and twelve nonpsychopathic male criminals received auditory stimuli signalling that monetary gain, monetary loss, or no reinforcement would occur at the end of a 6-second foreperiod. There were no electrodermal differences between groups across the reinforcement conditions. Slow EEG activity consisted of two components, identified as the early and late contingent negative variation (CNV). The late CNV did not vary as a function of group. Statistically significant group differences did emerge for the early CNV, with the early CNV of psychopaths being larger across all conditions that those of the nonpsychopaths. The latter result was consistent with the hypothesis that psychopaths have a heightened capacity to selectively attend to events that interest them.
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I. INTRODUCTION

The attempt to define clinically the concept of psychopathic personality has a long and controversial history. In the early 18th century, Pinel (1809) described a condition he called "manie sans delire" in which reason remained intact but emotion or affect was disturbed. Rush (1812), an American psychiatrist, described cases characterized as "morally deranged", and Prichard (1835) used the term "moral insanity" to describe those in whom

the moral and active principles of the mind are strongly perverted or depraved; the power of self-government is lost or greatly impaired and the individual is found to be incapable not of talking or reasoning upon any subject proposed to him, but of conducting himself with decency and propriety in the business of life (p. 15).

In Germany, Kraepelin (1915) proposed a topology of psychopathy and divided the disorder into seven subtypes: the impulsive, the unstable, the eccentric, the liar and the swindler, the antisocial and the quarrelsome. He attributed the disorder to an inborn defect. Birnbaum in 1917 was the first to use the term sociopath, and in contrast to Kraepelin, stressed the importance of sociogenic causes in the development of psychopathy.
The confusion and controversy surrounding the concept of psychopathy is still prevalent. For example, the term psychopath has been used as a synonym for criminality or as a "wastebasket" diagnosis for antisocial patients who do not fit into other psychiatric categories or who are difficult to treat. Lindner's (1944) description of the problems surrounding the concept of psychopathy is still valid today. Lindner wrote:

Among those categories by which man describes his fellow-man is one that has served as a miscellany for many decades. It is only half-understood and less than half-appreciated. It is a Pandora's box, brimful with the makings for a malignant social and political scourge. The name of this category is psychopathic personality. Its half understood nature, evidenced by the multitude of terms by which it has been and is called -- constitutional psychopathic inferiority, moral imbecility, semantic dementia, moral insanity, sociopathy, anethopathy, moral mania, egopathy, tropopaphy, etc. --is further attested to by the contradictory multiplicity of its signs and symptoms (p. 1).

Perhaps the largest obstacle to research in this area has been the unsystematic and variable way in which psychopathy has
been assessed. Because of the lack of any consistent assessment criteria and the absence of any unitary theoretical perspective, it is difficult to assess the validity of research or to compare findings. Despite the differing assessment methods, most researchers agree on a common core of symptoms. Cleckley (1976) has provided the most influential and complete description of the psychopathic personality. He believes that psychopathy is distinct from neurosis and psychosis. According to Cleckley, the psychopath's behavior seems to lack rational motivation; he does not seem to experience anxiety, remorse or guilt, nor does he appear to profit from experience. Other salient characteristics of the psychopath are his unreliability, pathological lying, impulsively, and lack of empathy (Cleckley's criteria are listed in Appendix A). McCord and McCord (1964) describe the psychopath as "an asocial, aggressive, highly impulsive person, who feels little or no guilt, and is unable to form lasting bonds of affection with other human beings". Craft (1966) distinguishes between primary and secondary features of the psychopath. The primary features are a lack of affect and a tendency to behave impulsively. Secondary features are aggressiveness, lack of guilt, inability to profit from experience and the lack of appropriate motivation.

There is disagreement concerning the presence or absence of anxiety in this disorder. A clinical distinction is often drawn between the primary or "true" psychopath and the secondary or neurotic psychopath. This distinction implies that the secondary
psychopath shares the same basic characteristics as the primary psychopath, except for the presence of anxiety. However, unlike the primary psychopath, secondary psychopaths are able to experience guilt and remorse arising from their actions and can form lasting interpersonal relationships. The secondary psychopath's behavior is attributed to underlying psychogenic causes such as neurosis, whereas the behavior of primary psychopaths cannot be accounted for by these causes. Hare (1970) has pointed out that the secondary psychopath label should not be used, but rather the neurotic component should be stressed, since the life-history, personality structure and motivations of the secondary psychopath differ from those of a primary psychopath.

Many clinical accounts of psychopathy have emphasized the lack of anxiety and an inability to profit from experience (Cleckley, 1976; McCord and McCord, 1964; Karpman, 1961; Buss, 1966; Areiti, 1963). These authors describe the psychopath as one who cannot learn socially acceptable forms of behavior, or whose behavior is unaffected by punishment. Their actions are committed with total disregard for suffering or hardship that may arise for themselves or others as a result. Lykken (1957) described the psychopath's inability to profit from experience as "a seemingly self-destructive failure to modify this pattern of behavior in spite of repeated painful consequences" (p. 6). Trasler (1978) believes that many of the behaviors seen in the psychopath, such as opportunism, unreliability, and
impulsiveness can be explained by postulating that the psychopath is under-socialized. In other words, the psychopath lacks the usual internalized inhibitions that restrain other people.

Researchers have looked for evidence of a deficit in associative conditioning to aversive stimuli. Supportive evidence comes from psychophysiological studies examining the psychopaths anticipatory autonomic activity to aversive stimuli (electrical shock and loud tones). Psychopaths are poor electrodermal conditioners to signals of aversive stimuli (see review by Hare, 1978), suggesting that they may lack anticipatory anxiety or fear.

One consequence of an absence of anxiety in the presence of normally threatening stimuli may be an inability to inhibit behavior in the face of threats of punishment. Because psychopaths frequently engage in antisocial behavior with apparent disregard for the consequences, several investigators have suggested that they are defective in passive avoidance learning. Experimentally, psychopaths do show poor passive avoidance learning (Lykken, 1957; Schmauk, 1970). However, Schmauk (1970) found that although psychopaths were deficient at passive avoidance when the reinforcer was shock or social disapproval, there was no deficiency in passive avoidance when loss of money was substituted for the shock. This study suggests that psychopaths can make passive avoidance responses if motivated to do so.
Recent theoretical formulations have suggested that psychopathy may be related to a defect in the "inhibitory" system (Fowles, 1980; Gorenstien and Newman, 1980). The psychopath's weak anticipatory skin conductance (SC) response to aversive stimulation and significantly poorer passive avoidance learning provide an empirical basis for these theories. However, the failure of monetary punishment to produce effects similar to those produced by physical punishment (Schmauk, 1970; Seigel, 1978) is contrary to this weak or deficient inhibitory system hypothesis.

Much of the biological research with psychopaths, has relied on peripheral measures of the central nervous system (CNS). Over the past two decades there has been a substantial increase in our understanding of the neurophysiological substrate underlying many disorders by the use of evoked brain related techniques. However, there have been few such studies examining the electrocortical basis of psychopathy. The use of evoked potentials may provide the much needed source of convergent information to further our understanding of psychopathy. A correlate of anticipatory processing is the contingent negative variation (CNV), one of several slow cerebral event-related potentials. This wave refers to the slow negative shift in voltage found during the warning period, between the presentation of a warning stimulus and an imperative stimulus, which typically calls for an overt or covert response from the subject. Researchers have found that the amplitude of
the CNV varies relative to the affective quality of the stimulus presented at the end of the foreperiod (Simons, Ohman, and Lang, 1979; Rochstroh, Elbert, Birbaumer, and Lutzenberger, 1982; Barbas, Solyom and Dubrovsky, 1978; Birbaumer, Lutzenberger, Elbert, Rockstroh, and Schwartz, 1981). For example, Rockstroh et al. (1982) found that as the aversiveness of the stimulus increased, the amplitude of the CNV also increased.

The above research provides the background for the present study, which is concerned with the psychopath's anticipatory autonomic and cortical responses to monetary rewards and punishments. My approach will be to review the physiological correlates of psychopathy, followed by a review of studies examining passive and active avoidance in psychopaths, and then a discussion of several theories that have attempted to explain the behavior of psychopaths. Finally the literature on the CNV will be reviewed followed by a discussion of the studies examining the CNV in psychopaths. The literature review ends with a discussion of the present experiment designed to investigate the psychopath's autonomic and cortical functioning to monetary reward and punishment.
II. REVIEW OF THE LITERATURE

A. AUTONOMIC CORRELATES OF PSYCHOPATHY

One of the basic characteristics of psychopathy is a lack of anxiety, guilt, and remorse over antisocial and interpersonal behaviors. This has led investigators to look for evidence of some autonomic deficit in the psychopath's ability to respond to aversive stimuli or to conditional stimuli associated with aversive stimuli. The experimental research has focused primarily on two measures of the autonomic nervous system: electrodermal and cardiovascular activity.

Tonic physiological measures, electrodermal (EDA) activity and heart rate (HR), do not reliably distinguish between psychopaths and nonpsychopaths. Some studies have reported a lower level of resting skin conductance (SC; Dengerink and Bertilson, 1975; Hare, 1965; Mathis, 1970), while others report no differences or a higher level of resting SC (Hare, 1972; Hare and Craigen, 1974; Schmauk, 1970, Goldstein, 1965). Hare (1978) combined the results of several of his studies and found that psychopaths have a significant lower tonic SC level than other criminals, but the absolute difference was small. Researchers have found no consistent relationship between tonic HR and psychopathy.

There is some evidence that tonic SC differences between psychopaths and others may increase during monotonous
experiments. In these studies tonic SC of psychopaths decreased while that of the nonpsychopath either increased or remained the same (Hare, 1968; Schalling, Lidberg, Levander, and Dahlin, 1973). London, Schubert, and Washburn (1972) suggested that boredom can produce an increase in arousal. If so, it does not seem to apply to psychopaths. This finding may be explained by the fact that psychopaths tend to become drowsy during monotonous stimulation and the electrodermal results may reflect this drowsiness.

Similar results have been found with a different measurement of electrodermal activity, non-specific fluctuations (NSP). No difference between groups in NSP activity was found during an initial rest period (Hare, 1968; Schalling et al., 1973). However, like tonic SC, the differences between groups may increase during a boring experiment or during an experiment with aversive elements, with the NSP activity of the psychopath remaining the same or decreasing and that of other subjects increasing (Hare, 1968; Hare and Quinn, 1971; Schalling et al., 1973).

Based on these findings one can conclude that psychopaths tend to be less electrodermally aroused during some experiments than other criminals, but it is difficult to explain why. Perhaps in experiments with aversive elements the low level of tonic electrodermal activity reflects a relative lack of fear, anxiety or apprehension. However, since electrodermal activity is relatively non-specific, responses can be elicited by a wide
range of factors such as interest, motivation, surprise, arousal and cognitions. These factors may account for the differences found between groups in electrodermal activity during non-stressful tasks. There is increasing support for the hypothesis that subject-experimenter-situational interactions have important implications for electrodermal response (Christie, 1975). Psychopathic subjects may be relatively unaffected by the novelty or uncertainty of the experimental situation, or may differ in the sorts of expectancies and attitudes held, or they may be insufficiently motivated to engage in the type of cognitive processing that leads to an increase in SC. Other criminals may become aroused during simple tasks because of a desire to do well, to please the experimenter, or because they are worried about what may happen. Even when aversive stimuli are involved psychopaths may be unmotivated to assess the threat of aversiveness or may fail to use cognitive processes to cope with the threat. Although several interesting theoretical accounts have been advanced for the psychopath's low level of tonic and NSP activity (Hare and Quinn, 1971; Hare and Craigen, 1974), it is important to remember that the differences found have been typically very small, and may be of little practical significance.

In an early study, Lykken (1957) found that psychopaths were poor electrodermal conditioners to electrical shock. Subsequent research has supported the finding that signals associated with impending shock or loud tones elicit less
electrodermal activity in psychopaths than others. (see review by Hare, 1978). The relatively small increases in ED activity shown by psychopaths in anticipation of an aversive stimulus is consistent with the hypothesis that these cues produce little anticipatory fear (Hare, 1965). There is some evidence that psychopaths are electrodermally hyporesponsive to aversive stimuli presented without warning (Hare, 1972; Mathis, 1970). However, several studies have found no significant differences in SC responses between psychopaths and other inmates with unsignalled tones ranging from 80 to 120 db (Hare, 1975; Hare, Frazelle, and Cox, 1978).

While there is good evidence that psychopaths exhibit little electrodermal activity in anticipation of an aversive stressor, the situation with cardiac activity is different. For example, Hare and Quinn (1971) reported no difference between subjects in the acquisition of a conditioned cardiac response. Hare and Craigen (1974) and Hare, Frazelle and Cox (1978) found that psychopaths displayed significantly larger cardiac accelerations in anticipation of an unpleasant stimuli than did nonpsychopaths. These findings indicate that psychopaths were more autonomicly aroused by an impending aversive event, whereas the electrodermal data just reviewed indicates the reverse.

In order to reconcile the dissociation between electrodermal and cardiac responses, Hare (1978) has used Lacey's (1967; Lacey and Lacey, 1974) hypothesis concerning
cardiac changes and sensory 'intake' and 'rejection'. According to this theory, cardiac responses reflect the way sensory input is modulated. Lacey (1967) argued that cardiac deceleration which is accompanied by decreased pressure in baroreceptors in the carotid sinus is associated with increased cortical arousal and 'sensory intake'. Cardiac acceleration is associated with increased pressure in the carotid sinus which is associated with a decrease in cortical arousal and 'sensory-rejection'. Hare (1978) suggests that the anticipatory cardiac accelerations displayed by the psychopath may reflect an attempt to actively cope with the situation, which, via the hypothesized 'sensory rejection process', attenuates the impact of the aversive stimulus and inhibits fear arousal. The lack of electrodermal response suggests that this coping response is successful in psychopaths. Hare concludes that "as a result, situations that have great emotional impact for most people may be of relatively little consequence to psychopaths, simply because the latter are better able to attenuate the aversive sensory input and to reduce anticipatory fear" (p. 137).
B. AVOIDANCE LEARNING IN PSYCHOPATHS

1. Passive Avoidance Learning

Passive avoidance involves the inhibition of a response or behavior to avoid punishment. The psychopath's apparent difficulty in learning through punishment and his lack of concern for future events have generated research examining the psychopath's performance in tasks mediated by fear or anxiety.

Much of the early research in avoidance learning interpreted the findings in terms of Mowrer's (1947) two-process theory of avoidance learning (see also modified cognitive version by Seligman and Johnson, 1973). Mowrer postulated two stages in learning to avoid punishment. In the first stage, cues (behavior and situational) associated with punishment acquire the capacity, through classical conditioning, to elicit conditioned fear responses. The second stage consists of reinforcement, by fear reduction, of responses that remove the individual from the fear-producing cues. Punishment can be avoided by making some other response (active avoidance) or by inhibiting the response (passive avoidance). In response to criticism of his theory (Solomon, Kamin, and Wynne, 1953), Mowrer (1960) added the concept of safety signals. These signals are associated with the termination of aversive events, and informs the individual of pleasant events (or lack of aversive events), and are capable of motivating behavior.
At the experimental level, the finding that psychopaths show significantly less electrodermal activity in anticipation of an aversive UCS suggests that they may also display an avoidance "deficit". There is some empirical evidence that suggests that psychopaths do indeed display a deficit in passive avoidance learning.

Lykken (1957), studied passive avoidance conditioning in male and female primary and "neurotic" psychopaths (defined by Cleckley's criteria) and in a group of college and high school students (control group). The subject's task was a mental maze consisting of four levers at each of 20 choice-points. Each choice-point had one correct response and three incorrect responses, one of which was punished by shock. The subject's "manifest" task was to learn the correct sequence of responses. The "latent" task was to avoid the shocked incorrect responses at each choice-point. The results indicated that there were no between group differences on the manifest task, i.e. all subjects learned their way through the maze equally well. However, on the latent task, the primary psychopaths showed the least passive avoidance to the shocked responses.

Several other researchers have used modifications of the mental maze to study avoidance learning in psychopaths. Schachter and Latane (1964) replicated Lykken's study with primary and neurotic psychopaths (Cleckley criteria) and controls under placebo (saline) and epinephrine conditions. When given a placebo, primary psychopaths performed poorly on the
latent task. However, when given epinephrine, the primary psychopaths showed no deficit in passive avoidance.

These studies provide some support for the widely held clinical assumption that psychopaths are deficient in learning to inhibit a punished response. All of the above studies have used shock as the aversive stimuli. In contrast to the above findings, different conclusion were reached when a different type of aversive stimuli was used. Schmauk (1970), using primarily Minnesota Multiphasic Personality Inventory (MMPI) criteria to classify subjects, administered a mental maze task identical to Lykken's, but varied the type of aversive stimuli given. Three types of stimuli were used to punish incorrect responses; shock, loss of money and verbal disapproval. Under the shock and verbal disapproval conditions, primary psychopaths showed a deficit in passive avoidance and reported that they were not aware of the association between the lever pressed and the aversive stimuli. However, the control subjects were aware of this contingency and learned to passively avoid these aversive stimuli. When the punishment consisted of loss of money there were no group differences in avoidance and all groups were aware of the lever-punishment contingency, indicating that psychopaths can learn to avoid a punished response under certain conditions. Schmauk (1970) concluded:

The single most important result of the experiment is, it seems, this finding that primary
sociopaths can learn to avoid punishment as well as normals if the punishment is genuinely experienced as noxious or distressing. This is not to say that the punishment must be excessively severe in order to be effective, but rather that it must be highly selective and properly selected (p. 334).

The above finding emphasizes the important distinction between learning and performance. The psychopathic subjects in the above studies may have been capable of forming the association between the lever and the appropriate response (in this case passive avoidance), but due to lack of motivation or other reasons, did not perform the response.

A partial explanation for the failure of psychopaths to avoid certain aversive stimuli may be that the stimuli used are not aversive to them. In all of the above studies, except for Lykken who used a set level of punishment, the shock level was set individually at a self-reported "painful" level. None of these levels differed significantly among the groups. Hare and Thorvaldson (1970) reported that psychopaths significantly increased their tolerance level for shock when incentives (cigarettes) were offered for doing so.

Neuman and Kosson (1986) argue that the psychopath's adequate passive avoidance to monetary punishment can be explained by the procedural differences in Schmuk's study. In
the monetary punishment condition, the avoidance contingency was made more salient and this may have increased the psychopath's attention to, and learning of, the punishment contingency. Neuman and Kosson examined passive avoidance learning in psychopaths assessed using Hare's Psychopathy Checklist. In a successive go/ nogo discrimination task in which subjects were rewarded (poker chips worth 10 cents each) for responding to correct cues (S+) and punished (loss of a poker chip) for responding to incorrect cues (S-), psychopaths made significantly more passive avoidance errors (the number of times subjects failed to inhibit a response to $S^-$) than nonpsychopaths. These findings have also been reported using "psychopathic" juvenile delinquents (Neuman, Widom, and Nathan, 1985).

There are several limitations to the above-noted studies. A major problem is that in several of these studies the psychopathic group likely contained few subjects who would meet the clinical/behavioral criteria for psychopathy. For example, in the Neuman et al. (1986) and Schmauk (1970) studies, MMPI scores were used to classify subjects. In a recent study comparing assessment procedures, Hare (1985) found that self-report measures (such as the MMPI) correlated weakly with clinical-behavioral measures of psychopathy and were poor at discriminating psychopaths from other criminals.

Another limitation is that several of these studies lacked an important control group. In the Lykken (1957) and Schmauk
(1970) studies "neurotic" psychopaths and noncriminal controls were used. The neurotic psychopath is a confusing group, since its members usually meet most of the criteria to be classified as a psychopath, except that they score high on an anxiety test. Noncriminals may differ in unknown ways from the criminals in the psychopathic group because of the effects of incarceration. A necessary control group when studying psychopaths is a nonpsychopathic criminal group.

There are also several methodological problems with these studies. No study has counter-balanced the order of punished responses. Not have any of the early studies reported whether their avoidance ratios differed significantly from chance levels. Finally, since none of these studies have statistically analyzed changes in passive avoidance over time, it it not possible to know whether the rate of response acquisition differed between groups.

Despite these limitations, it is clear that psychopaths, under some conditions, do show a deficit in passive avoidance performance. Contradictory data found when the loss of money is used as the aversive stimulus questions the generalizability of this finding. More research is required to determine the effects of different types of punishment on psychopaths passive avoidance performance.
2. Active Avoidance in Psychopaths

The psychopath's deficit in conditioned or anticipatory fear has been used to explain the psychopath's deficiency in passive avoidance performance (Hare, 1970; Hare, 1978). The problem with this interpretation is that if psychopaths have a deficit in responding to conditioned fear stimuli than one would predict that they would also exhibit a deficit in active avoidance. However, there is evidence (Gray, 1975; Bolles, 1972) that active avoidance is to a large extent reinforced by the attainment of stimuli associated with non-punishment (safety signals). If this view of active avoidance is correct, no deficit in psychopaths performance would be expected in active avoidance. The few studies that have examined active avoidance behaviors in psychopaths have obtained some what conflicting results.

Active avoidance refers to the performance of a response in order to avoid punishment. In one study Chesno and Kilmann (1975) examined subject's passive and active avoidance under conditions of high (95 db) and low (35 db) ambient noise. The aversive stimulus was electrical shock for responding incorrectly. The psychopaths displayed poor active avoidance when the level of background stimulation was low, but displayed effective active and passive avoidance under high stimulation levels. Chesno and Kilmann suggested that the previous finding of poor passive avoidance conditioning in psychopaths could be
an artifact of the long, boring and unstimulating nature of the mental maze task. They argued that their findings supported an under-arousal theory of psychopathy. Under conditions of low stimulation psychopaths seek to increase their "arousal" by stimulating themselves; however, as the background simulation level increases, their need for further sensory input is reduced.

Several studies have failed to find any active avoidance deficit in psychopaths. In the Neuman and Kosson (1986) study described earlier, no difference between psychopaths and nonpsychopaths in active avoidance errors was found. Persons and Brunnings (1966) looked at a form of active avoidance in psychopaths, defined by high Pd scores on the MMPI. The subject's task was to draw a line of a specific length, while blindfolded, in order to avoid electric shock. When verbal feedback about their performance and punishment was given, psychopaths displayed "superior" avoidance learning compared to the controls and were slower to extinguish the response. Though sparse, the available evidence suggests that psychopaths have little difficulty in laboratory tasks involving active avoidance.
C. DISINHIBITION THEORIES OF PSYCHOPATHY

The above results suggest that psychopaths may display some sort of performance deficit in passive avoidance conditioning. There is considerable theoretical and empirical evidence indicating that passive avoidance is a distinct and independent form of learning. Razran (1971) observed that organisms too primitive to be classically conditioned or to respond to reinforcement, displayed what he called "aversive inhibitory conditioning". In this type of conditioning, it is not the acquisition of a new response that occurs but an inhibition of behavior. Razran concluded that aversive inhibitory conditioning was an association mechanism of learning what not to do.

Gray (1975, 1982) has developed a model that provides substantial physiological and behavioral evidence that passive avoidance learning is mediated by a different complex of neuronal systems from those that mediate classical conditioning, instrumental learning, active avoidance and escape learning.

According to Gray, the neural substrate of anxiety is the behavioral inhibition system (BIS). Anxiety is assumed to be the state that is elicited in response to threats of punishment or by exposure to a novel environment. The BIS is thought to mediate the behavioral effects of four classes of stimuli; conditioned stimuli associated with punishment (CS-PUN), conditioned stimuli associated with frustrative non-reward (CS-REW), novel stimuli, and innate fear stimuli. The BIS responds
to all of these inputs by suppressing ongoing behavior, increasing the level of arousal and by increasing attention to the environment. Gray's model also postulates the existence of two other systems, the Behavioral Approach system (BAS), which mediates the behavioral effects of stimuli paired with positive reinforcement (reward and non-punishment), and a "fight-flight" system, which mediates the effect of punishment and non-reward. The development of the BIS has been primarily based on examining the behavioral effects of anti-anxiety drugs. Gray assumes that it is possible to infer the nature of anxiety from the reactions to drugs that reduce anxiety (Gray, 1982).

Several investigators have suggested that psychopathy may be related to a dysfunction of some form of inhibition system. Clinically it is possible to see that the psychopath's mixture of impulsiveness, opportunism, callous maximization of personal gain, lack of empathy, lack of feelings of guilt, poor behavioral controls, and lack of long-term plans could be explained within a model which emphasizes the lack of inhibitory controls on behavior. Hare (1970) speculated that the temporal slow-wave activity found in some psychopaths may "... reflect a malfunction of some limbic inhibitory mechanism and that this malfunction makes it difficult to inhibit behavior that is likely to lead to punishment" (p.31). Clinical researchers have also raised the possibility that psychopathy may be associated with some type of inhibition deficit. McCord and McCord (1964) suggest that "... the proclivity for psychopathy found even in
mildly rejected individuals if aggravated by a neural system incompatible with inhibition, develops into the psychopathic syndrome (p. 54).

Trasler (1978; Siddle and Trasler, 1981) emphasized the importance of the interaction between the psychopath and his social environment. One of the psychopath's most salient features is his insusceptibility to social influences. Trasler further argued that the psychopath is under socialized; "[he]...has not learned the inhibitions, the moral scruples, and awareness of social obligations which regulate relationships with others" (p. 284).

Trasler bases much of his theory on the process of internalization on the work of Aronfreed. According to Aronfreed and Reber (1965) internalization is the shift from external to intrinsic cues over the control of behavior. This shift results in the inhibition of certain behaviors being controlled by cues independent of the situation. According to Aronfreed and Reber, passive avoidance learning is the central mechanism of internalization. They emphasize the importance of conditioned aversive stimuli in the process of internalization.

The notion that an individual's behavior can be controlled both by the immediate environmental contingencies and by internalized controls suggests that perhaps psychopaths suffer from an imbalance between situational and intrinsic controls over their behavior. The hypothesis is supported by several lines of evidence. The effect of immediate incentives on the
behavior of psychopaths has frequently been noted. Grant (1977) concluded that for psychopaths "the appeal of the moment is strong enough to block out all thought of consequences" (p. 48). Also, according to Hare (1965), one of the more striking things about the psychopath is what he calls his "short-range hedonism --- a tendency to satisfy immediate needs even at the risk of experiencing severe discomfort in the future". The psychopath's impulsivity, callousness, and irresponsibility can be readily explained in a model in which his behavior is controlled by situational factors.

Results from experimental research also support this hypothesis. Psychopaths do not differ from others in their performance of simple learning tasks (Fairweather, 1954; Persons and Bruning, 1966) nor do they differ when the reinforcement is immediate and rewarding (Doctor and Craine, 1971; Hare, 1966; Hetherington and Klinger, 1964). Psychopaths were also found to persist in a response learned under continuous reinforcement once extinction had begun, in contrast to nonpsychopaths; the opposite was the case with a response learned under partial reinforcement (Ross and Dooby, 1973). Painting (1961) found that psychopaths did well in a two-choice partial reinforcement procedure when performance was based on the immediate previous trial. But, they performed poorly when the correct response on any given trial was determined by what had been correct two trials away.

If internalized controls are acquired via passive avoidance
learning, and if this type of learning is a distinct process (Gray, 1982), then perhaps Trasler's (1978) hypothesis that psychopath's behavior is due to an absence of internal inhibitions of socially-proscribed behavior is correct. Psychopaths could lack internal inhibitions due to a defect in the septo-hippocampal system, the system that Gray (1975) suggests underlies passive avoidance learning. This model implies that defective social training which fails to provide for the conditions necessary for the acquisition of internalized inhibitory responses may also result in a person who is wholly responsive to situational cues. The postulation of a physiological defect may be unnecessary.

More recently Fowles (1980) proposed a three arousal model of psychopathy. This model is also based on Gray's (1975, 1982) work on the hypothesized Behavioral Inhibition System (BIS) and Behavioral Activation System (BAS). Fowles discussed the association between BIS and psychopathy from a psychophysiological point of view. He presented evidence suggesting that a psychophysiological correlate of BAS is heart rate acceleration, while BIS activation is reflected by changes in electrodermal activity. Fowles' attempted to explain psychopathy by suggesting that psychopaths are characterized by a weak or deficient BIS. He presented clinical, behavioral and psychophysiological support for his hypothesis.

Clinically, Fowles argued that some of the major characteristics of the psychopath can be explained by a weak
BIS. Firstly, the psychopath's absence of anxiety in the presence of normally threatening stimuli, and his inability to inhibit behaviors in the face of threats of punishment should result in impulsive behavior seen in psychopaths. Secondly, an inability to learn from past punishment will result in trouble with society. Thirdly, once a person is caught in some transgression, a weak BIS will accommodate more unsocialized active avoidance responses (e.g. lying, assault). Fourthly, any contribution that punishment makes to normal socialization will be minimized, resulting in a strong tendency towards undersocialization. Finally, a weak BIS would predict a low tolerance for alcohol, which is a commonly reported clinical finding in psychopaths.

Behaviorally, a weak BIS and a normal BAS would explain the psychopath's poor passive avoidance behavior and his apparent normal active avoidance.

At the psychophysiological level, assuming that the BIS is associated with electrodermal activity and the BAS with HR activity, a weak BIS would explain the finding that psychopaths are electrodermally hyporesponsive to cues signalling an aversive event while the cardiovascular system appears normally or over reactive to such cues. Additional support for Fowles' theory comes from examining the psychopath's response to novel stimuli. If psychopaths have a weak BIS they should display weak responses to novelty. This prediction is generally supported by the skin conductance data (Hare, 1978).
There are some problems with Fowles' hypothesis. Clinically it does not explain some of the other important characteristics of the psychopath, such as his "poverty in interpersonal relationships". Fowles' admits that "given the quite normal BAS there is no inherent reason why strong personal relationships should not develop". Fowles' theory makes specific predictions with respect to electrodermal and HR activity. If EDA is limited to BIS activation, then one would expect that cues associated with reward should not elicit EDR, although Fowles' notes that "it is not necessarily being argued that EDA responds only to stimuli which activate the BIS". Concerning HR, psychopaths should show normal HR responses to cues signalling reward.

There has been only one experimental study examining the acquisition of conditioned reward responses in psychopaths (Hare and Quinn, 1971). In the study subjects were presented with three different tones each 10 seconds long. One tone was followed by an electric shock (CS-PUN), another followed by a slide of a nude female (CS-REW), and a third by nothing (CS-NEU). Consistent with previously discussed studies, psychopaths gave smaller anticipatory EDRs to the CS followed by shock than did nonpsychopaths. Nonpsychopaths gave smaller EDRs to the CS-REW than to the CS-PUN, suggesting that CS-REW (or at least pictures of nude females) are not particularly effective stimuli for electrodermal conditioning. Psychopaths showed no electrodermal response to the CS-REW. There were no between group differences in cardiac responses to either the CS-REW or
the CS-PUN. For the CS-REW a slight cardiac deceleration developed over the trials for both groups.

In contrast to the above findings, Fowles' model predicts that incentive effects should result in HR increases. Fowles (1983) and Elliot (1969) have demonstrated that when money is used as an incentive, reliable HR increases are found. One possible explanation for the different HR findings between these studies is that the rewards used in the above study may not have been effective reinforcers. However, Hare and Quinn (1971), demonstrated that pictures of nude females were in fact adequate reinforcers of instrumental responding in psychopaths.

The application of Gray's model to psychophysiology and to psychopathy is particularly interesting, since it provides a model that explains much of the psychopath's psychophysiological and clinical characteristics.
D. THE CONTINGENT NEGATIVE VARIATION

A measure of electroencephalogy (EEG) commonly used in research is the event-related potential (ERP). It is named thus because it is time-locked to an evoking stimulus. An ERP is obtained by averaging together EEG from many stimulus presentations. The ERP is described by Donchin, Ritter, and McCallum (1978) as "... a sequence of serially activated processes (labelled components) that are manifested on the scalp as distinct positive - negative fluctuations" (p.351). ERP components have been divided into two categories, exogeneous and endogeneous. Any stimulus will elicit a sequence of ERP components that begins shortly after stimulus onset and last for a quarter of a second. These components are affected by the physical parameters of the evoking stimulus and the general state of the subject. The components are considered to be exogenous since they represent the functioning of lower brain structures and are evoked by events extrinsic to the nervous system. By contrast, endogeneous components are often elicited in the absence of external stimulation and are associated with perceptual, cognitive, and motor processes. These components are affected by the subject's prior experience, intentions and decisions and are modulated by task parameters.

Of particular interest in this study is the contingent negative variation (CNV). The term CNV describes a slow negative potential shift which develops during a warned foreperiod prior
to an anticipated event, such as a motor or mental task. Over two decades of research have been devoted to the functional significance of the CNV, but due to the variety of terminology, paradigms, and theoretical frameworks used, several different hypotheses have emerged.

Walter, Cooper, Aldridge, McCallum, and Winter (1964) were the first to observe slow negative brain potentials. In their classic paradigm, the first stimulus (S1) served as a warning signal, while the second stimulus (S2) required a motor response. They found a negative potential shift which started shortly after S1 and reached a maximum prior to S2. Upon the delivery of S2 and performance of the motor response, the slow negative shift usually returned to baseline. Walter and his co-workers considered the CNV as a measure of expectancy related to the subjective probability of a stimulus occurrence. However, later studies suggest that the CNV does not exclusively represent expectancy. Leifer, Otto, Hart and Huff (1978) found that when subjects had to predict which of four different S2's would occur, the more difficult the prediction the larger the CNV.

There have been several theories that have viewed the CNV in terms of nonassociative concepts rather than an association between stimuli. For example, Irwin, Knott, McAdam, and Rebert (1966; Rebert, McAdam, Knott, and Irwin, 1967) suggested that the CNV reflects motivational determinants. This hypothesis was supported by Knott and Tecce (1978) who found larger CNV
amplitudes 1) in anticipation of a response to S2 compared to no response, 2) in anticipation of a noxious event compared to a nonaversive event, 3) in anticipation of near-threshold compared to easily discriminable stimuli, and 4) in anticipation of stimuli that require greater muscular effort for the same response. Rebet et al. (1967) concluded that the CNV was "an index of cerebral changes related to a general state of the organism". McAdam (1969) provided support for this drive state hypothesis by comparing the latency of the late somatosensory ERP components during a baseline state and in a CNV paradigm. Under the latter condition he found shorter latencies and concluded that the CNV was accompanied by an increase in CNV excitability.

It has been found that the amplitude of the CNV is reduced by the presentation of extraneous stimulation such as conversation and reading (Walter, 1964), irrelevant tones or pictures (McCallum and Walter, 1968), when a secondary task is given, such as memorizing letters (Teece, 1970), and performing mental arithmetic (Teece and Hamilton, 1973). On the basis of these studies, Teece (1972) concluded that the CNV is related to two separate but related processes; attention and arousal. He hypothesized that the amplitude of the CNV increases with increased attention. And that the CNV is related non-linearly (inverted U function) to arousal. Thus at moderate levels of arousal a large CNV is found, but at higher levels of arousal smaller amplitudes are found.
Several other lines of evidence support this distraction hypothesis. Particular support comes from heart rate data. Heart rate increases are accompanied by reduction in CNV amplitude. Drug effects parallel the effects found with the heart rate data. Stimulant drugs which increased subjective alertness also produced larger CNV amplitudes. Sedatives tended to decrease CNV amplitudes. The "rebound effect" is the unusually large CNV found when subjects are given a series of no distraction trials after a series of distraction trials. This effect is believed to reflect the "relief" experienced to easy tasks after difficult tasks and the change from divided to undivided attention (Teece, Yrchuk, Meinbresse, Dessonville, and Cole, 1980).

The relation between CNV and cortical state (arousal/attentiveness) in humans has recently been investigated by Fenwick, Bushman, Horward, Perry, and Gamble (1979) and by Timsit-Berthier, Audibert, and Moeglen (1978). Both experiments utilized the classical click-flash paradigm using a short ISI (1.5 sec). In the Fenwick study they compared the effects of an 100% oxygen condition to varying doses of nitrous oxide (10 to 40 % mixture). The oxygen control condition was presented at the start (pre-drug) and at the end of the experimental session. Nitrous oxide produced a dose-dependent reduction in amplitude of the N100 evoked potential to S1 and a significant dose-dependent increase in RT. The drug also produced subjective reports of lowered alertness and a high degree of subjective distraction. According to Teece's model, since both arousal and
attention appeared to have decreased due to the drug, a reduction in CNV would be expected. However, there were no significant effects of drug dose on the CNV amplitude. These results are difficult to evaluate since the studies all used a short ISI, which makes it impossible to discriminate between the early and late waves of the CNV.

There has been much debate on the extent that the CNV can be regarded as an unitary phenomenon. Most of the early research used short inter-stimulus intervals (ISI) between 1 and 2 seconds. However, when the ISI is extended to 3 to 4 seconds the CNV consists of two distinct negative peaks (see Figure 1). The first negative wave (early CNV) reaches its maximum during the first several seconds after S1 and is maximal over the frontal-central region. The second negative wave peaks just before or at S2 and is maximal over the central region. Recent evidence suggests that the 'early' negative wave reflects the physical properties and functional processing of S1. The early CNV amplitude varies as a function of S1 intensity - greater amplitude for louder sounds (Loveless and Sanford, 1974); the sensory modality of S1 - larger amplitude for auditory S1 versus a visual S1 (Gaillard, 1978; Ritter, Rotkin, Vaughan, 1980); and stimulus duration - greater amplitudes for longer durations (Klorman and Bentsen, 1975). Gaillard (1978; Rohrbaugh and Gaillard, 1983) has shown that the amplitude of the early CNV is also sensitive to the psychological significance of S1. The early CNV appears to be affected by the following properties of
Figure 1. Idealized CNV illustrating the early and late CNV components and ERPs to S1.
S1: informative vs. non-informative (Gaillard, 1978), the relevance of the information (Kok, 1978), and the level of discrimination difficulty and the amount of attention paid to the stimulus (Simons and Lang, 1976; Squires, Donchin, Herning, McCarthy, 1977).

The early CNV has also been associated with orienting processes and is often referred to as the O-wave. Sokolov (1963) was the first to note the link between slow negative waves and the orienting response. In reviewing the animal literature relating slow negative shifts with stimulation, Sokolov concluded that the wave "may play a role in the mechanism of EEG activation or participate in the fixation of traces. This shift is a component of the orienting reflex" (p. 553). More recent evidence of the link between the O wave and the OR has been reviewed by Rohrbaugh and Gaillard (1983). Although Donchin, Ritter, and McCallum (1978) noted that the early wave differs in a number of ways from what one would theoretically expect from a component that relates to the orienting process.

Several researchers have noted the strong relation between the late CNV and motor preparation (Loveless, 1977, 1979; Simons et al., 1979; Gaillard, 1977, 1978; Rohrbaugh and Gaillard, 1983). However, earlier slow wave experiments with short interval stimulus intervals (1.5 sec) reported a cortical negativity preceding the second stimulus in the absence of response requirements (Donchin, Gerbrandt, Leifer, and Tucker, 1972). Cohen (1974) argued that this anticipatory negativity
could be elicited by the expectancy of interesting material and that a "motor response is not necessary for a CNV...". However, because of the short interval stimulus paradigms used the early and late components of the CNV were obscured. Gaillard (1978) did a series of studies with a long ISI (4 sec), testing to see whether the late CNV primarily reflected expectancy or motor preparation. He found that the late component was more pronounced when a motor response was required as compared to a discrimination task. There were no significant differences between easy and difficult discriminations in the amplitude of the late component. However, when a response deadline was included in the discrimination task, there was an increase in CNV amplitude under a speed response condition than under an accuracy condition.

Similar findings have been found in several other studies (Naatanen, Gaillard, and Mantysalo, 1980). One study examined the effects of probability of the occurrence of S2 under three conditions, speed, accuracy, and detection. In the detection condition the reaction response was delayed for one second. The study replicated other studies in which large differences in late CNV amplitude were found between speed and detection conditions (Peters, Knott and Hamilton, 1976). Also, larger amplitudes were found for the speed than for the accuracy condition. The S2 probability had no effect on the amplitude of the late component. Gaillard (1977) concluded: "The results of the present study suggest strongly that the late CNV is
contingent on a motor response and is mainly determined by the level of motor preparation" (p. 127). The amplitude of the late CNV is positively related to the muscular effort required (Low and McSherry, 1968; Rebert, Berry and Merlo, 1976). The different amplitudes in CNV are not due to differences in muscle tension during ISI. Papakostopoulos and Jones (1980) found no differences in CNV amplitudes when different levels of isometric force were required during the ISI. From his studies, Gaillard (1978) concluded that the late CNV reflects preparation for optimal, effective motor responses.

Several researchers have noted the similarity in form and topographical distribution between the late CNV and the readiness potential (RP). The RP is a negative shift which precedes voluntary self-paced movements. It can be interpreted as "probably representing a preparatory process in the dendritic network of those cortical areas involved in the intended movement" (Deecke, Grozinger, and Kornhuber, 1976, p. 99). Although typically obtained during different tasks and with different averaging methods, Gaillard (1978) views the CNV and RP as being generated by the same neurophysiological substrate. Rohrbaugh, Syndulko, Sanquist, and Lindsley (1980) have provided evidence that the RP constitutes a major component of the late CNV. They synthesized CNV wave forms by adding together separately obtained wave forms from unpaired stimuli and from self-paced RT tasks. This synthetic CNV corresponded closely to CNV's obtained in the classic CNV paradigm.
However, a number of studies have indicated that there may also be a non-motoric late wave. In these studies the S1 conveyed task relevant information to the subject that a motor response was not required (Donchin, Gerbarandt, Leifer, and Tucker, 1982; Klorman and Ryan, 1980; Donald, 1973).

Cooper, McCallum, and Papakostopoulos (1979) draw a distinction between two modes of cerebral processing. The first mode is called "scopeutic" and is necessary for planned actions. The individual is selectively involved with his environment. This mode is associated with the presence of slow potentials (CNV). The second mode, termed 'categoric' processing, is automatic and mechanical; the response is pre-determined. If there is an unexpected change in this automatic processing the scopeutic mode of processing will take over. The 'categoric' mode is supposedly associated with the absence of slow potentials. A change from 'categoric' to 'scopeutic' processing is indicated by a reduction in slow potential amplitude. Empirical research is required in establish the existence of these two modes, and to determine under what conditions the transition from one mode to another occurs.

A similar dichotomy is made by cognitive psychologists, for example, Schneider, Dumais and Shiffrin (1980) have postulated differences between automatic and controlled processing. Automatic processing is effortless and involuntary, in contrast to controlled processing which is regulated by the subject. Some support for this model comes from habituation studies. Walter
(1964), in a classical aversive eye-lid conditioning paradigm, reported that the CNV amplitude peaked after a maximum of 20 trials and then declined. McAdam (1966) examined the development of the CNV during learning of a temporal interval and found that, while time estimation errors decreased from the early to middle phase, the CNV rose to a peak in the middle phase and then declined. Rockstroh et al. (1982) also found that across repetitive trials the amplitude of the early CNV decreases. The early CNV is considered as part of the orienting response (Loveless, 1979) and a reduction in its amplitude has been attributed to habituation.

Several studies have been done to test the influences of different S2 qualities on the amplitude of the CNV. In these experiments, subjects hear 2 different tones which predict which of two different events will occur at S2. In a study by Rockstroh et al. (1982), one S2 was of a weak tone (65 db) the other an aversive tone (110 db). No motor response to S2 was required. There was a larger early and late CNV in anticipation of the aversive S2. As the aversiveness of the stimuli increased (ie, if electric shock was used as S2) the amplitude of both the early and late CNV also increased. The finding that the quality of S2 affects the CNV is also supported by Simons et al. (1979), who show that positive consequences affect CNV amplitudes. The study consisted of one S1 that signaled that a high interest slide would appear (nude females), while another tone signaled that a low interest slide would appear (household object). The
late CNV was larger prior to the high interest condition than to
the low interest condition.

The results from experiments with phobics provide
additional support that the CNV is sensitive to anticipation of
affective stimulation. Barbas et al. (1978; Dubrovsky and
Dongier, 1978; Klorman and Ryan, 1980) compared the amplitude of
the CNV during phobicgenic and neutral conditions. The results
found that the affective quality of the anticipated event, both
negative and positive, was related to the amplitude of the CNV.
Other studies have investigated task difficulty to CNV
amplitude. Birbaumer et al. (1981), examined the effect of easy
and difficult arithmetic problems, signaled by two different S1.
He found the early and late CNV to be larger in preparation for
the difficult task. In summary, it would appear the amplitude of
the early CNV is sensitive to the anticipation of affective
stimulation.
E. THE CONTINGENT NEGATIVE VARIATION AND PSYCHOPATHY

The application of ERP's to psychopathology has been guided by two goals. The first goal is to develop objective diagnostic indications of specific disorders. The second goal is to uncover the neurophysiological functions associated with the disorder. (Shagrass, Ornitz, Sutton, and Tueting, 1978). The goal to obtain objective indices of psychopathology has not been reached after more than two decades of research. Callaway (1979, p. 517) suggests that the reason for this lack of success is that; "... the research for correlations between diagnosis and ERP is a very poor approach, not because the ERP are weak, but because psychiatric diagnosis is such a shoddy thing." The further goal of ERP research is to provide some understanding of possible underlying disturbances in brain function. However, as several reviews have pointed out (Roth, Horvath, Pfefferbaum, Tinklenberg, Mezzich, and Kopell, 1979; Shagrass et al., 1978), the reported variability of ERP responses, both within and between patients and controls, may have little to do with the particular psychological disorder. The ERP variability may possibly be explained by individual variability, such as differences in psychological state, diagnostic criterion, or by differences in methodology, such as scoring and labelling of ERP components. Rather than report that an ERP component is larger or smaller in a pathological group as compared to normals, researchers should examine ERPs in the context of the experimental conditions which produced them.
It is commonly assumed that antisocial individuals are characterized by reduced CNV amplitudes. This assumption that a CNV - antisocial relation exists has led to such statements as "Antisocial psychopaths, for example, consistently have rather small CNV's" (Hassett, 1978, p. 125) appearing in psychophysiological textbooks. In Walters' et al. (1964) initial description of the CNV, they reported that psychopathic patients showed little or no CNV. In a second study by this group (Walter, 1966) they found that recidivist delinquents "do not seem capable of producing more than a trace of a CNV, even with active social support and encouragement " (p. 21). A third study by McCallum (1973) found prison psychopaths to have significantly lower amplitudes than a normal non-prison control group. All of the above studies used short ISI. There have been 5 studies which have measured the CNV in various antisocial groups which have failed to support the above findings. Three of these studies (Paty, Benezech, Eschapasse and Noel, 1978; Syndulko, Parker, Iris, Maltzman, Ziskind, 1975; Raine and Venables, 1986) found no significant differences in CNV amplitudes in XXY and XYY "psychopaths", imprisoned psychopaths, and non-institutionalized antisocial adolescents. In two other studies patients in a forensic hospital, larger CNV's were found in patients that had high MMPI Pd and Ma scores (Fenton, Fenwick, Ferguson, and Lam, 1978) and in extroverted patients with an anti-social diagnosis (Howard, Fenton, and Fenwick, 1982).
Although several methodological and conceptual weaknesses exist in all of these studies, they suggest that no consistent relation exists between CNV and antisocial personality.

The major problem with these studies arise from the differing populations used and the variety of diagnostic criteria used to assess psychopathy. The two studies which used criteria based on Cleckley's conception (Raine and Venables, 1986; Syndulko et al., 1975) both reported no significant differences in CNV. Another methodological problem is the lack of appropriate control groups. McCallum (1973), who reported a significantly lower CNV in prison psychopaths, only used a normal control group, thus not controlling for the effect of institutionalization. The homogeneity of the psychopathic group in this study is also suspect, since three of its members were female psychiatric patients, and little information was given on the diagnostic procedure. Another problem is the unknown portion of the psychopathic group that was on medication. The two studies that found larger CNVs in anti-social patients used normal controls 5 years younger than the experimental group and schizophrenics. These studies found no CNV amplitude differences between anti-social and normal controls, but reported differences between the schizophrenic control group and anti-socials. However, schizophrenics have been shown to have smaller CNVs relative to controls (Abrabran, McCallum, and Gourlay, 1976; Timsit-Berthier, Delaunoy, Koninckx, and Rousseau, 1973) and consequently the larger CNV found in the antisocials
relative to the schizophrenics may be due to the reduced CNV in the latter group.

Much of the theoretical interpretation of these findings has been based on Walters (1966) who originally thought that the CNV reflected a cortical correlate of association learning. On this basis Walters postulated that the lack of CNV in recidivist delinquents reflected an inability to learn from experience. Both Syndulko and McCallum support this theoretical position. Howard et al. (1982), however, has more recently adopted a strongly Pavlovian approach based on the concepts of expectancy and excitability/inhibitory association processes. The classic CNV paradigm however, is not a conditioning paradigm. In this paradigm the subject does not have to learn the contingencies between S1 - S2 - motor responding since these contingencies are usually clearly explained before the experiment begins. Typically the subject is tested to ensure that he fully understands the relation. There is no clinical literature to suggest that psychopaths cannot form associations, and thus one should not predict any differences between psychopaths and controls in a classic CNV paradigm. All the above studies, except Syndulko's, used a nonaversive S2. Syndulko et al. (1975) found that older psychopaths (M = 35) unlike younger psychopaths (M = 21) or staff controls (M = 28) failed to show a larger CNV to a loud tone (95 db) relative to a weak tone (70 db).

A study by Howard et al. (1982) examined the effect of positive and negative reinforcers delivered at S2 on the CNV
amplitude. The subject population were patients from a special psychiatric hospital divided into a schizophrenic and a personality disorder group. Seven out of 10 subjects in the personality disordered (PD) group were classified as having a 'psychopathic disorder' under the 1959 Mental Health Act (MHA) and were referred to as the psychopathic group by Howard et al. The MHA defined PD as "a persistent disorder or disability of the mind (whether or not including subnormality of intelligence) which results in abnormally aggressive or seriously irresponsible conduct on the part of the patient". There were no between group differences in the Pd scale of the MMPI or an any of the MMPI derived scales of impulsiveness, sociability, anxiety or extraversion. The majority of patients in the schizophrenic group were on medication (7 out of 10) and 2 of the psychopaths were on medication. A control group, matched for age and sex, consisted of 10 subjects selected from the nursing staff. The study examined the CNV in response to cues signalling rewarding (slides of nude females), aversive (110 db tone), and neutral (blank slide) events. A 3.5 second ISI was used. Neither of the two psychiatric groups displayed differences in CNV between the reinforcement conditions. There were no significant differences found between the "psychopathic group" and the control group on any of the conditions. Control subjects gave the largest CNV to cues signalling the reward. Schizophrenics gave significantly smaller CNVs than controls in anticipation of reward indicating, according to these authors, that these
patients were deficient in their expectancy for reward outcome. The authors then combined the patient groups and divided them into two groups based on high and low impulsivity scores. The high impulsivity group gave low amplitude CNV in anticipation of reward, similar to the schizophrenic group. Because the authors considered impulsivity to be the defining characteristic of psychopathy, they argued that psychopaths and schizophrenics are both undersensitive to cues signalling reward. Since schizophrenics have also been reported to be poor electrodermal conditioners (Ax, Bamford, Beckett, Fretz, and Gottlieb, 1970) in anticipation of aversive events, the authors conclude that their results support Ax and Lloyd's (1978) hypothesis of a motivational deficit common to both schizophrenics and psychopaths. This conclusion is incompatible with Fowles (1980) model, which predicts psychopaths should be relatively unresponsive to cues signalling punishment but not to cues signalling reward. However, due to the lack of proper diagnostic assessment, and the failure to control for medication effects the conclusions drawn by Howard et al. (1982) may have little to do with psychopathy.

In summary, the studies reviewed in this section provide no evidence that psychopaths are characterized by reduced or absent CNV's. Since psychopaths appear to have a deficit related to emotional processing, future research should concentrate on examining the relationship between CNV and psychopathy within experiments with emotional processing requirements.
F. PURPOSE OF PROPOSED EXPERIMENT

There is considerable evidence from studies examining anticipatory electrodermal responses to cues signalling punishment (electrical shock and tones) that psychopaths are electrodermally hyporesponsive to these cues (see review Hare, 1978). The importance of the type of reinforcer used has been shown in Schmauk's (1970) study in which psychopaths learned to avoid punishment passively, if the punishment consisted of loss of money. In this punishment condition psychopaths also displayed the appropriate pattern of electrodermal anticipatory response. The above study suggests that autonomic anticipation deficits in psychopaths may be related to the type of punishment used. The purpose of this study was to determine whether psychopaths show a deficit in electrodermal conditioning to monetary punishment.

Anomalies in the electrodermal system may be a reflection of the particular cognitive and motivational demands placed on the psychopath. Evoked potentials are a much more direct measure of the CNS functioning than measures such as SC and HR and may provide valuable convergent evidence of cognitive and motivational effects on psychopaths' behavior. This study was designed to measure slow cortical potentials in psychopaths in a motivationally significant task. There has been little research examining incentive effects on slow wave activity, and no
research looking at slow wave potentials in a well-defined group of psychopaths in anticipation of reward and punishment. Therefore, the present research was designed to assess the effects of the warning signals reinforcement value on psychopath's and nonpsychopath's CNV amplitude. The use of a long ISI will allow for the separation between early and late components of the CNV and permit separate analysis of the functional significance of these components.

The design of the present study also permitted the examination of cortical evoked potentials following the warning signal. Recent research has related the amplitude of the P300 to the warning stimulus and to the early CNV (Kok, 1978; Rohrbaugh, Syndulko, and Lindsley, 1978; Squires et al., 1977). In addition, this study will provide further data on the recent reports of enhanced P300 amplitudes in psychopaths (Raine, 1986; Raine and Venables, 1986).

In the present study psychopaths and nonpsychopaths were exposed to repeated presentations of three different tones which were paired with monetary gain, monetary loss, or no reinforcement. It was hypothesized that if psychopaths have a deficit in their BIS they would display little anticipatory electrodermal response in anticipation of loss of money. Nonpsychopaths were expected to show the largest anticipatory electrodermal response proceeding punishment reinforcement. No differences were expected in reaction time responses between groups or across the reinforcement conditions. Although there is
still debate over the functional interpretation of the CNV, research has demonstrated that this waveform is sensitive to positive and negative qualities of an anticipated event. It was predicted that nonpsychopaths would show larger amplitude early CNVs for the reward and punishment conditions as compared to the neutral condition. Previous research has found that psychopaths display little ED activity preceding an aversive stimuli. As a result of this deficit it was predicted that psychopaths would show reduced CNV amplitudes compared to nonpsychopaths in the punishment condition. Alternatively, if psychopaths are capable of giving normal responses under the appropriate reinforcement conditions, then no group differences in early CNV amplitudes and SC responding should occur. It was further predicted that if the late CNV represents motor preparation there should be no differences between the groups or across reinforcement conditions.
III. METHODS

A. SUBJECTS

Subjects were male inmates drawn from the inmate population of a medium security institution. Institutional file information and a semi-structured interview were used to complete a Psychopathy Checklist (Hare, 1980) for each inmate. This checklist, based on Cleckley's (1976) conception of psychopathy, is reliable and valid. For example, a recent psychometric analysis of the checklist (Schroeder, Schroeder, and Hare, 1983) yielded reliabilities (inter- and intrarater correlations, alpha coefficients) of .82 to .93 and a generalizability coefficient of .90. In the present study the interrater reliability for the 15 subjects who had two ratings done was .86. Volunteers were selected if they were between 18 and 45 years of age, were free of known neurological impairments and had normal hearing.

Data were collected on 29 subjects. However the EEG data from 3 of the subjects could not be scored because of excessive blinking. Data from 2 other subjects were dropped due to technical errors in data acquisition, leaving 24 subjects. A cutoff score for group membership was 32. Subjects scoring above this were assigned to the psychopathic group (Group P), while those scoring below 32 were assigned to the nonpsychopathic group (Group NP). The total mean checklist score for this sample
was 27.50 (SD = 9.02), a value that is virtually the same as that obtained with several much larger samples of inmates. Group P scores ranged from 32 to 38. Group NP scores ranged from 14 to 28. There were 12 subjects in each group. The subjects in the P group ranged from 18 to 41 years of age. Subjects in the NP group ranged from 18 to 30 years of age. There were no significant group differences in age or education. Table I presents background characteristics on the subjects in each group.

Subjects were paid $6.00 for participating, plus whatever money they made in the experiment. All had participated in an earlier EEG experiment but were naive to the hypothesis being tested.

B. PHYSIOLOGICAL RECORDING

A 16-channel Beckman type R-711 polygraph was used to obtain recordings of electroencephalographic (EEG) activity, eye movements (EOG), skin conductance (SC) and heart rate (HR). An additional channel was used to record stimulus presentation. EEG was recorded from frontal (Fz), central (Cz) and parietal (Pz) sites, referenced to linked ears (A1, A2). Signals were obtained via Beckman silver-silver chloride electrodes and recorded with Beckman type 9806A A.C. couplers with band filters set to produce a low pass 3 db cutoff at 30 Hz and a high pass cutoff at .01 Hz; the EEG couplers were modified to produce a 14.75
TABLE I

Group Comparisons on Age, Education, Anxiety and APD Diagnosis

<table>
<thead>
<tr>
<th>Group</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checklist*</td>
<td>24.0</td>
<td>36.0</td>
</tr>
<tr>
<td>Age*</td>
<td>24.8</td>
<td>25.2</td>
</tr>
<tr>
<td>Education*</td>
<td>9.5</td>
<td>8.8</td>
</tr>
<tr>
<td>Anxiety* (Speilberger)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>40.3</td>
<td>38.2</td>
</tr>
<tr>
<td>Trait</td>
<td>45.6</td>
<td>40.3</td>
</tr>
<tr>
<td>DSM-III - APD (percent of group)</td>
<td>33%</td>
<td>93%</td>
</tr>
</tbody>
</table>

* group means
second time constant. All sites were cleaned thoroughly with Redux electrode paste and abraded lightly with a blunt needle. The electrodes were attached to the scalp using collodion, and Medi-trace EEG gel acted as the electrolyte. Electrical impedances were measured at all sites at the beginning and end of the experiment and they never exceeded 5 kohms.

EOG was recorded via Beckman miniature electrodes placed on the supra-orbital ridge and the outer canthus of the right eye; the couplers and time constant were the same as those used for EEG.

EEG and EOG were digitized on-line at 256 Hz by a Compaq micro-computer and were stored on a Compaq hard disk for off-line analysis. A 50 microvolt calibration signal was recorded on each channel for subsequent amplitude measurements. Reaction times were calculated to the nearest millisecond for each trial and stored on the hard disk. Data were transferred to Scotch magnetic tape cartridges for permanent storage.

C. STIMULUS PRESENTATION

Stimuli presentation and the inter-stimulus interval were controlled by a Compaq microcomputer. The procedure involved a classical forewarned reaction time paradigm, in which the subject received a warning stimulus (S1) followed by an imperative stimulus (S2), to which he made a motor response. He received one of three types of reinforcement, each of which was
signalled by the pitch of tones used as S1. One tone signalled monetary gain (Reward condition), another monetary loss (Punishment condition), and a third signalled that no reinforcement would occur (Neutral condition). Each tone was presented binaurally through stereo headphones. The frequencies of S1 were, 200, 900, 1600 Hz, all 75db intensity, duration 100 msec. S1 was followed 6 seconds later by S2 consisting of a 75 db, 1300 Hz tone that lasted for 100 msec. The middle frequency tone (900 Hz) always predicted the neutral outcome. The outcome associated with the high (1600 Hz) and low (300 Hz) tones was randomized between groups. The inter-trial interval was varied between 10 and 15 seconds. The order of the trials was pseudo-randomized, such that no more than 2 trials of the same type followed each other. There were 25 trials per condition. The tones were generated by a generator built by the UBC Psychology Department. A Sony tape recorder was used to provide white noise at 60 db throughout the experiment in order to mask out background noises.

C. PROCEDURE

Testing was carried out in an empty tier in the institution. Due to the location of the study no soundproofing or electrical shielding was available. The white noise masked the majority of sounds, but did not control for loud random noises such as cell doors being closed or the occasional yelling
of inmates in the halls or on other tiers. It was not possible to control the for the use of coffee, tea, cigarettes, medication or street drugs prior to the experiment, although subjects were asked at the end of the experiment to indicate how long ago they had used any of the above. Only one subject, from Group P, reported using a street drug within 6 hours of the experiment. There were 2 experimenters present, the author plus either a male or female assistant.

The inmate was initially given a brief description of the experiment and the recordings to be taken and then asked to read and sign a consent form. Electrodes were attached and impedances measured. Once the electrodes were connected he was asked to fill out the Spielberger State-Trait Anxiety Inventory (Speilberger, Gorsuch, and Lushene, 1970). Resting EEG was taken for 10 seconds with eyes open and 10 seconds with eyes closed. The inmate was then given detailed instructions (Appendix B) on the task requirements. He was told to press a button, placed directly in front of him, as quickly as possible to S2 regardless of the condition. In order to motivate him the level of reinforcement was contingent on the his reaction time to S2. Since money is not permitted in the prison, poker chips were used to represent money (white chips representing 25 cents and blue chips representing 10 cents). In the reward condition, he was given a chip representing either 25 cents or 10 cents. Reaction time thresholds were calculated by the procedure explained below. An inmate who responded quicker then his
threshold received a 25 cents chip, otherwise he received a 10 cent chip. In the punishment condition, he lost 10 cents if he responded faster than his threshold, and lost 25 cents if he responded slower. In the neutral condition, he neither gained nor lost any money. At the beginning of the experiment, the inmate was given a pile of chips representing $6.00. He was told that he could keep whatever money he made in the experiment. The minimum amount of money made was $2.25, and the maximum amount was $9.75.

In order to determine individual RT threshold, each inmate was given 20 trials in which he was asked to respond as quickly as possible to a single tone. The RT threshold subsequently used for each subject was set at the 75th quartile of his distribution of RT scores.

Each subject was given practice at identifying the three tones used as S1. He was asked to identify the tones as high, medium, and low and to say which condition the tones predicted. Practice was given until he correctly identified the tone-outcome association for each condition twice in a row. An index card with the tone-outcome association was left on the table in front of him throughout the experiment. Reaction time responses were made with the dominant hand.

On each trial the subject heard the S1, followed 6 seconds by S2. His task was to press a response button placed in front of him as quickly as possible. Following this one of three lights lit up (see Figure 2). The lights were placed on the wall
Figure 2. Stimulus paradigm.
directly in front of the subject (1.2 meters away). A red light represented the punishment condition, a green represented the reward condition, and a yellow represented the neutral condition. He was told that once the light had gone off he should look down to see how much money the assistant had given or taken away. The trials were presented in blocks of 15. A 2 to 3 minute rest period was given between each block of trials. In order to reduce EEG artifacts, the subject was instructed not to move around, to keep his eyes fixated towards the lights, and to minimize his blinking during the trial.

During the rest periods the subject was again reminded not to blink during the trials, and was again told about the tone-outcome associations. At the end of the experiment another resting period of 10 seconds of eyes open and closed was given. The electrodes were removed and the subject was given a post-experimental questionnaire (see Appendix C), in which he was asked to rate his reactions during the experiment. The experiment lasted approximately 2 hours.
D. DATA ANALYSIS

All EEG measures were referenced to a blink-free baseline obtained during the one second period prior to S1 onset.

i. Slow Cortical Potentials

Because of the relatively long inter-stimulus interval used, several trials were contaminated by eyeblinks. Trials contaminated by vertical eye movements of more than 50 microvolts and trials with vertex EEG amplitudes that exceeded 100 microvolts were excluded from further data analysis. The total number of trials per average ranged from 11 to 25. Since the averaged amplitude of a waveform is dependent on the number of trials used to obtain it, the number of trials in each group and condition were analyzed. No significant differences between groups or across conditions were found. Grand averages time-locked to S1 onset and spanning 6 seconds were made for each group in each condition. Visual inspection of these averages indicated that the task requirements elicited a two component slow wave response. The first component will be referred to as the early CNV and the second component as the late CNV. Individual averages at Cz in each condition were smoothed using a 3 Hz phaseless digital filter. The approximate location of the maximal early CNV was identified. The early CNV was scored as the averaged amplitude 1000 to 1200 msec post S1. The late CNV was scored as the averaged amplitude 200 msec prior to S2.
ii. Auditory Evoked Potentials

Grand averages auditory evoked potentials (AEP) at Cz were calculated in response to S1. Individual averages were then smoothed with a 20 Hz phaseless digital filter to facilitate peak identification. The N100 was identified as the maximum negative wave between 80 and 200 msec post S1. The P300 was identified as the maximum positive wave between 250 and 500 msec post S1. Both amplitudes and latencies of the N100 and P300 were scored for each subject.

iii. Skin Conductance

A skin conductance response was defined as the difference (in umhos) between the mean SC 5 seconds pre-stimulus (S1) and the maximal SC reached during the 6 second anticipatory interval. Any response which was greater than .05 μmhos was measured. Those subjects who failed to show any SC response of greater than .05 μmhos to the tones in the practice session were described as nonresponders and were not included in the analyses. Three nonpsychopaths were nonresponders and two psychopaths were nonresponders. One subject's data were lost due to technical problems with the SC coupler. This subject was from the psychopathic group. The response on the first trial was not included, since it was felt that it represented an orienting
response to the initial tone rather than an anticipatory response. In order to examine changes in SC over the trials, the SC was averaged across two blocks of trials. Block one consisted of the average of the first 13 trials of each condition. Block two consisted of the final 12 trials. Only 12 trials were averaged together in Block one for the Neutral condition since it was the condition presented on trial one.

IV. RESULTS

A. Performance Data

1) Reaction Time (RT) Data

The mean RT threshold was set at the beginning of the experiment was somewhat faster for Group P (M = 232.16 ms; SD = 54.63), than for Group NP (M = 255.75 ms; SD = 73.99); but this difference was not statistically significant. Reaction time distributions for each group in each condition tended to be positively skewed. Prior to the analysis of variance (ANOVA) F tests for the homogeneity of covariance matrices (Barlett's test) were made between groups at each condition. None reached statistical significance at the .05 probability level. F tests for symmetry (Anderson, 1958) were computed, one for each error term in the analysis of variance for which there was more than one degree of freedom for a within factor. None of these reached
<table>
<thead>
<tr>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>268.6 (71.3)</td>
<td>237.0 (54.9)</td>
</tr>
<tr>
<td>Reward</td>
<td>251.3 (76.1)</td>
<td>227.6 (60.7)</td>
</tr>
<tr>
<td>Punishment</td>
<td>254.1 (83.3)</td>
<td>228.9 (63.7)</td>
</tr>
<tr>
<td>Group Mean</td>
<td>258.0 (75.2)</td>
<td>231.2 (58.3)</td>
</tr>
</tbody>
</table>
significance at the .05 level. Mean RTs were calculated for each subject in each condition and a 2 X 3 (Group X Condition) ANOVA was performed; none of the main effects reached significance at the .05 level. As can be seen in Table II there was a trend for Group P to respond faster across all conditions as compared to Group NP, but this difference was not statistically significant.

2) Error (ER) Rate Data

Errors were calculated as the number of times the subject failed to respond faster than his individually set-RT threshold. Prior to ANOVA, F tests for homogeneity of covariance matrices and symmetry assumptions were tested. Neither F-ratio reached significance at the .05 level. There were no significant differences between groups in the number of errors made. Mean ERs and SDs are presented in Table III. The ER results indicate that psychopaths cannot be distinguished from nonpsychopaths on the basis of their performance. There were no group differences in the amount of money made in the experiment between Group P (M = $6.82) and Group NP (M = $6.90).

B. Evoked Potentials Data

Assumptions regarding the homogeneity of covariance matrices and symmetry assumptions were tested. None of these tests reached significance. Separate 2 X 3 (Group x Condition)
TABLE III

Group Means and Standard Deviations (in parentheses) for Error Rate in Reward and Punishment Conditions

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reward</td>
<td>9.08 (7.21)</td>
<td>9.25 (6.01)</td>
</tr>
<tr>
<td></td>
<td>Punishment</td>
<td>9.75 (6.87)</td>
<td>10.08 (6.58)</td>
</tr>
</tbody>
</table>
TABLE IV

Group Means and Standard Deviations (in parentheses) for N100 Amplitudes (microvolts) Across Reinforcement Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>-11.5 (4.1)</td>
<td>-12.0 (5.5)</td>
</tr>
<tr>
<td>Reward</td>
<td>-11.3 (4.9)</td>
<td>-11.8 (4.5)</td>
</tr>
<tr>
<td>Punishment</td>
<td>-12.8 (4.9)</td>
<td>-13.5 (4.2)</td>
</tr>
<tr>
<td>Group Mean</td>
<td>-11.9 (4.6)</td>
<td>-12.4 (4.7)</td>
</tr>
</tbody>
</table>
TABLE V

Group Means and Standard Deviations (in parentheses) for P300 Amplitudes (microvolts) Across Reinforcement Conditions

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td></td>
<td>6.1 (4.5)</td>
<td>3.2 (5.2)</td>
</tr>
<tr>
<td>Reward</td>
<td></td>
<td>3.6 (4.2)</td>
<td>3.6 (4.5)</td>
</tr>
<tr>
<td>Punishment</td>
<td></td>
<td>4.2 (5.5)</td>
<td>5.0 (6.8)</td>
</tr>
<tr>
<td>Group Mean</td>
<td></td>
<td>4.6 (4.7)</td>
<td>3.9 (5.5)</td>
</tr>
</tbody>
</table>
between-within multivariate analysis of variance (MANOVA) were performed on N100 amplitudes and latencies and on P300 amplitudes and latencies. There were no statistically significant effects involving Groups (P and NP) for either analysis. The only multivariate F to reach significant was for the N100 main effect for condition \( (F(4,19) = 3.63, p < .02) \). Univariate tests on N100 latency and amplitude were significant only for the amplitude of the N100 \( (F(2,44) = 3.88, p < .03) \). Tukey multiple comparisons were made between the means at the .05 level. The N100 amplitude response to the PUN condition was significantly larger when compared to the REW and NEU conditions. Table IV and V present, respectively, the means and SDs for N100 and P300 amplitude.

C. Slow Cortical Potentials

Assumptions regarding the homogeneity of covariance matrices and symmetry were tested with no significant results. The averaged cortical slow wave response curves of each group across the reinforcement conditions during the 6 second anticipatory interval are presented in Figure 3. Figure 4 plots the between group comparisons of averaged slow wave responses for each reinforcement condition. A 2 x 3 (Group X Condition) between-within MANOVA was performed on the early and late components of the CNV. The only multivariate F to reach significance was the main effect for group \( (F(2,21) = 5.02, p < \)
Figure 3. Averaged slow cortical response waves for each group plotted across reinforcement conditions. Stimulus onset occurred at the interval designated as 0. Relative negativity is displayed upward. Curve represents data sampled at every 64 sample points.
Figure 4. Between group comparisons of averaged slow cortical response waves for each reinforcement condition.
Univariate tests on the two dependent variables indicated significance for only the early CNV \( F(1,22) = 6.19, p < .02 \). As seen in Figure 5 this result reflects the tendency for Group P to display greater early negativity to the warning tones across all the conditions. Contrary to predictions the Group X Condition interaction only approached significance \( F(2,44) = 2.79, p > .07 \), indicating that the early CNV did not vary significantly across groups for the three reinforcement conditions. The mean early CNV amplitudes and SD's are presented in Table VI.

As predicted there were no significant effects in the analyses of the late CNV. The univariate F test did not reach significance for the group effect \( F(1,22) = 2.80, p > .10 \) or for the Group X Condition interaction \( F(2,44) = 1.25, p > .30 \). These results are plotted in Figure 6 and means and SD's are presented in Table VII.

D. Skin Conductance Data

Significant results were obtained on tests for homogeneity of covariance matrices and symmetry \( p < .005 \). All p values reported are Greenhouse-Geisser probabilities in which departures from homogeneity of variances is taken into account. A 2 X 2 X 3 (Group x Block X Condition) ANOVA was performed on the mean anticipatory SC responses. There were no significant
Figure 5. Group means for early CNV amplitudes across reinforcement conditions.
TABLE VI

Group Means and Standard Deviations (in parentheses) for Early CNV Amplitudes (microvolts) Across Reinforcement Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>-2.8 (5.2)</td>
<td>-8.1 (3.1)</td>
</tr>
<tr>
<td>Reward</td>
<td>-4.9 (3.8)</td>
<td>-6.3 (4.3)</td>
</tr>
<tr>
<td>Punishment</td>
<td>-4.3 (2.4)</td>
<td>-6.4 (3.5)</td>
</tr>
<tr>
<td>Group Mean</td>
<td>-4.0 (4.3)</td>
<td>-7.0 (3.7)</td>
</tr>
</tbody>
</table>
Figure 6. Group means for late CNV amplitudes across reinforcement conditions.
TABLE VII

Group Means and Standard Deviations (in parentheses) for Late CNV Amplitudes (microvolts) Across Reinforcement Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>0.5 (3.7)</td>
<td>-3.1 (4.1)</td>
</tr>
<tr>
<td>Reward</td>
<td>-1.9 (4.8)</td>
<td>-2.0 (2.7)</td>
</tr>
<tr>
<td>Punishment</td>
<td>-1.4 (2.4)</td>
<td>-3.8 (4.2)</td>
</tr>
<tr>
<td>Group Mean</td>
<td>-0.9 (3.9)</td>
<td>-3.0 (3.7)</td>
</tr>
</tbody>
</table>
group (F(1,16) = 1.13, p > .30), condition (F(1.32,21.19) = 2.60, p > .10) or group by condition interaction effects (F(1.32,21.19) = 1.32, p > .50). The main effect for blocks reached significance (F(1,16) = 4.63, p < .05), indicating that all subjects gave larger responses during the first block. The means and SDs for the anticipatory SC data are presented in Table VIII, and the results are plotted in Figure 7.

Given the small N involved in this study group separation was based on a cutoff of 32 on the Psychopathy Checklist. As a result, group separation was not as wide as it has been in previous research. Hare, Frazelle and Cox (1978) reported that group differences in anticipatory SC responses may only occur when "a very well defined group of primary psychopaths" is obtained.

Further analyses on SC responses were carried out using a more stringent cutoff criterion for group membership. Subjects receiving a checklist score of 35 and above were compared to those receiving a checklist score of 20 and below, resulting in 9 subjects in each group. A 2 X 3 (Group by Condition) repeated measures ANOVA was performed, revealing no significant effects. The pattern of results replicated the findings for the larger groups. The means and SDs for these subjects are presented in Table IX.

Electrodermal responses to the reinforcement were difficult to evaluate for two reasons. First, they occurred after an anticipatory period in which the baseline was changing
Figure 7. Group means for anticipatory SC responses.
TABLE VIII

Group Means and Standard Deviations (in parentheses) for Anticipatory Skin Conductance Responses Across Reinforcement Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>.13 (.14)</td>
<td>.07 (.07)</td>
</tr>
<tr>
<td>Reward</td>
<td>.18 (.33)</td>
<td>.07 (.08)</td>
</tr>
<tr>
<td>Punishment</td>
<td>.21 (.37)</td>
<td>.10 (.14)</td>
</tr>
<tr>
<td>Group Mean</td>
<td>.17 (.29)</td>
<td>.08 (.10)</td>
</tr>
</tbody>
</table>
TABLE IX

Group Means and Standard Deviations (in parentheses) for Extreme Groups for Anticipatory Skin Conductance Responses Across Reinforcement Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Nonpsychopaths</th>
<th>Psychopaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>.16 (.13)</td>
<td>.08 (.11)</td>
</tr>
<tr>
<td>Reward</td>
<td>.32 (.33)</td>
<td>.12 (.14)</td>
</tr>
<tr>
<td>Punishment</td>
<td>.25 (.27)</td>
<td>.08 (.09)</td>
</tr>
<tr>
<td>Group Mean</td>
<td>.24 (.27)</td>
<td>.09 (.11)</td>
</tr>
<tr>
<td>Condition</td>
<td>Nonpsychopaths</td>
<td>Psychopaths</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Neutral</td>
<td>.45 (.55)</td>
<td>.18 (.20)</td>
</tr>
<tr>
<td>Reward</td>
<td>.44 (.62)</td>
<td>.18 (.19)</td>
</tr>
<tr>
<td>Punishment</td>
<td>.53 (.70)</td>
<td>.16 (.13)</td>
</tr>
<tr>
<td>Group Mean</td>
<td>.47 (.62)</td>
<td>.17 (.17)</td>
</tr>
</tbody>
</table>

TABLE X

Group Means and Standard Deviations (in parentheses) for Skin Conductance Responses To Reinforcement Conditions
(cf. Epstein, Boudreau, and Kling, 1975). For this reason the responses were compared to the pre-S1 baseline. The second difficulty was the variable interval between the warning tone and the time the reinforcement was presented. This interval depended on the subject's reaction time and on how fast the assistant gave the reinforcement. When the largest SC response 6 seconds after S2 was used as the response to the reinforcement and the same analysis was performed as with the anticipatory responses, only the main effect for group approached significance ($F(1,16) = 2.13, p > .10$). The means and SDs for the SC response to the reinforcement are presented in Table X.

E. Anxiety Questionnaire Data

The State-Trait Anxiety Inventory (Speilberger et al., 1970) measures individual differences in anxiety proneness (trait) and the level of state anxiety that is actually experienced in a particular situation. It was used here because normal subjects with high scores on trait anxiety inventories show smaller CNV amplitudes than do those with low scores (Knott and Irwin, 1973). Measures of state and trait anxiety did not differentiate between Groups P and NP. Means for Group P and NP on the state scale were $M = 38.17$ (SD = 9.05) and $M = 40.27$ (5.92) respectively. The means were not significantly different ($t(21) = 1.65, p > .52$). Group NP scored higher on the trait scale, 45.55 (SD = 10.39) than did Group P, 40.25 (SD = 5.31);
however, this difference was not significant $t(21) = 1.56$, $p > .13$. These findings are consistent with the Hare and Cox (1978) and Spielberger, Kling, and O'Hagan (1978) reports of the absence of anxiety state and trait differences between psychopathic and nonpsychopathic criminals.

F. Rating Data

A 2 X 3 (Group by Condition) repeated measures MANOVA was performed on the subjective ratings (one to seven point scale) to the reinforcement conditions. There were no group differences in rating of the conditions. The only multivariate $F$ to reach significance was for the condition effect ($F(12, 9) = 4.88$, $p < .01$). To control for the experiment-wise error rate the significance level for the univariate tests on each of the dependent variables was set at .008 (by the Bonferroni procedure). Univariate tests on each of the six dependent variables indicated highly significant differences across the conditions for the following: Interesting ($p < .0001$), Boring ($p < .0003$), Uneasy ($p < .003$) and Exciting ($p < .0001$). Tukey multiple comparisons were performed between the means with the significance level of .001. As expected the PUN and REW conditions were rated significantly more interesting and exciting as compared to the NEU condition. The NEU condition was rated as significantly more boring. Figure 8 summarizes this effect for the interesting and boring variables.
Figure 8. Mean ratings of interest and boredom to reinforcement conditions collapsed across groups.
Figure 9. Mean ratings of anticipation and eagerness to tones collapsed across groups.
A 2 X 3 (Group by Condition) between-within MANOVA was also performed on the subjective ratings to the tones. Again no group differences were found. The multivariate F for the condition effect was significant \( F(12,8) = 3.26, p < .05 \). Univariate tests on each of the six dependent variables were performed with the significance level set at .008 to control for experiment-wise error rate (by the Bonferroni procedure). Significant results were found for two of the dependent variables: Anticipation \( (p < .001) \) and Eagerness \( (p < .006) \). Tukey multiple comparisons with a significance level of .001 indicated that the PUN and REW differed significantly from the NEU condition. This effect for anticipation and eagerness is shown in Figure 9.

Subjective ratings to the conditions and to the tones associated with reinforcement indicates that all subjects found the REW and PUN conditions significantly more interesting and exciting than the NEU condition.

G. Qualitative Observations

Most of the subjects appeared to find the experimental procedure interesting. Where relevant subject verbalizations and behaviors were recorded throughout the experiment. Several comments and behaviors made by subjects in Group P are of interest. One subject, during a break period, offered to make a deal with the assistant who was handling the reinforcement. He suggested that if the assistant would give him only quarters and
remove only dimes he would split the winnings with the assistant. Another inmate wanted to do the experiment over because he felt he could do even better. A third did not want to take the rest periods, because he enjoyed playing the game. Two subjects tried to cheat on the reaction time task, one by keeping the reaction time button pressed down all the time, and the other by holding it down half-way in order to respond faster. Both of these subjects were from Group P. An interesting comment was written at the end of the post-experimental questionnaire by one of the psychopaths. He wrote "I enjoyed the challenge of the game on a personal level rather than the material gain aspect of the procedure".

Another comment that was made by a number of the subjects was that they found it difficult to discriminate the middle tone from the high and low tone. The middle tone always predicted the neutral condition. However, since no record was made of which subjects made this comment, group comparisons cannot be made.
V. DISCUSSION

This study was designed to examine the psychopath's anticipatory autonomic and electrocortical responses prior to monetary reward and punishment. The results indicate that psychopaths are not deficient in their anticipatory response to this form of reinforcement, a finding that is generally consistent with Schmauk's (1970) study in which psychopaths failed to show a passive avoidance deficit when money was used as the punishment, and with Seigel's (1978) report that psychopaths failed to show any performance deficit with monetary punishment when the probability of punishment was a near certainty.

Before discussing the electrocortical results, the skin conductance data will be reviewed. Generally, the results from the SC measures were less conclusive and more variable than electrocortical findings. Although there were no group differences in anticipatory electrodermal responses, there was a tendency for psychopaths to have smaller SC responses as compared to nonpsychopaths and to show less differential SC activity across the conditions than did the nonpsychopaths. This is in line with the findings described by Hare and Quinn (1971) in which the psychopath's anticipatory SC responses failed to differentiate between tones that preceded electric shock, slides of nude females, and a blank slide. The lack of group differences in SC anticipatory responses is inconsistent with Fowles' hypothesis of a weak BIS in psychopaths.
As expected, nonpsychopaths gave the smallest SC responses to the tone preceding the neutral condition, and the largest to the tone preceding the punishment condition. The small differential SC conditioning in nonpsychopaths may have been due to the task requirements. In each condition subjects were required to prepare for a motor response. Simons et al. (1979) reported that the mere presence of a motor response will enhance SC responding.

Past theoretical formulations have emphasized the psychopath's deficits in anticipatory autonomic activity prior to aversive stimuli (Hare, 1978; Fowles, 1980; Gorenstein and Newmen, 1980). Most of the research has involved "sensitization" types of punishments (Aronfreed, 1968). "Induction" punishments (Aronfreed, 1968) refer to the withdrawal of affection and rewards, the form of punishment used in this experiment. The present results, along with those obtained by Schmauk (1970) suggest that the psychopaths's deficit in autonomic responding may be confined to "sensitization" forms of punishment and that Fowles' BIS hypothesis may have to be modified to apply only to "sensitization" punishments.

The second purpose of this study was to investigate the relation between slow cortical potentials, ERP's, and psychopathy in anticipation of monetary reward and punishment. The N100 results were consistent with those obtained by Jutai and Hare (1983; Jutai, Hare and Connolly, 1985; Raine and Venables, 1986). There were no difference in N100 response of
psychopaths and nonpsychopaths. The N100 is sensitive to fluctuations in central arousal (Khachaturian and Gluck, 1969; Naatanen, 1975). Changes in N100 amplitude have also been associated with selective attention with the N100 being larger in response to stimuli presented in an attended channel than in an unattended channel (Hillyard, 1982). The lack of group differences in N100 amplitude suggests that psychopathy is not associated with abnormal central arousal and that neither group paid more attention than the other to the warning tones. Still, it is noteworthy that for both groups the N100 was larger to the tone associated with monetary loss as compared to the other tones.

The CNV consisted of two negative components, an early wave peaking after the S1, and a second negative wave proceeding the second stimulus. These results are in agreement with the earlier findings of Rohrbaugh et al. (1976) and Gaillard (1978). Group differences in CNV were found only for the early CNV. The late CNV was not influenced as expected, by the different reinforcement conditions. This latter finding supports the hypothesis that the late CNV is a cortical correlate of motor preparation (Naatanen and Merisalo, 1977; Rohrbaugh and Gaillard, 1983).

The CNV has been reported to be sensitive to subjective motivational properties of a stimuli (Irwin et al., 1976). Several studies have reported a larger CNV in anticipation of affective stimuli (Klorman and Ryan, 1980; Simons et al., 1979;
Rockstroh et al., 1982; Dubrovsky and Doniger, 1978). Although, the Group by Condition interaction failed to reach significance (p > .07) this finding warrants further comment. As expected nonpsychopath's early CNV amplitudes were larger when the S1 was associated with the positive and negative reinforcement conditions than with the neutral condition. In contrast, psychopath's early CNV did not differentiate between the reinforcement conditions and the neutral condition. This finding may be explained by Cleckley's (1976) postulated semantic deficit in psychopaths; a deficit in which there is a dissociation between thought and affect. In a recent ERP experiment, Williamson (1986) reported that psychopaths failed to show differential RT and ERP responding to emotional and non-emotional words. She interpreted this finding as indicating that psychopaths do not differentiate between affective components of language. Although, this study was not examining language processing, it did involve affective processing. Thus, psychopaths lack of differentiation across reinforcement conditions, is consistent with the hypothesis that they fail to discriminate between neutral and affective events. It also suggests that psychopaths fail to attach the appropriate motivational significance to events of differing affective value.

Another possible explanation for psychopath's larger early CNV in the neutral condition as compared to nonpsychopaths comes from evidence that the early CNV amplitude is affected by the
level of discrimination difficulty (Simons and Lang, 1976). Enhanced negativity is found when the stimuli are difficult to discriminate. If psychopaths found it difficult to discriminate the middle tone, which was associated with the neutral condition, from the other tones, then a larger early CNV to this tone would be expected. Several of the subjects did mention this problem, although it was not recorded which group they were from.

Previous data indicate that the early CNV is sensitive to attentional factors (Rohrbaugh et al. 1978). Tecce (1972) reported that the CNV relates to the mobilization of an attentive set throughout the foreperiod. One interpretation of the larger early CNV observed in psychopaths is based on the recent research on selective attention. There is some reason to believe that psychopaths have a heightened ability to attend to stimuli or events that interest them (Hare, 1982; Yochelson and Samenow, 1976). Jutai and Hare (1983) found no group differences in amplitude of N100 responses to a tone in a passive attention task. However, the psychopaths gave smaller N100 response to these same tones during a task in which they were instructed to selectively attend to a video game task. This result was interpreted as indicating that psychopaths were able to allocate a relatively large proportion of their attentional resources to the interesting video game. In a second study, Jutai, Hare and Connolly (1986) recorded N100, P300 and slow positive wave (SPW) to phonemic stimuli presented alone or during a video game task.
There were no group differences in N100 or P300, but the psychopaths displayed a larger SPW amplitude to the phonemic stimuli during the video task. Jutai et al. (1986) interpreted their results as indicating that psychopaths may have difficulty in allocating their attentional and processing resources between the competing demands of two tasks, when task demands are relatively heavy. In another study, Hare (1982) reported a pattern of reduced electrodermal nonspecific fluctuations, when listening to a comedian prior to an aversive tone. Hare interpreted his data as indicating a reduced conflict and arousal in psychopaths and a heightened ability to focus their attention and to screen out aversive stimuli.

Although it did not deal with psychopathic subjects, one study is of particular interest at this point. Raine and Venables (1986) measured P300 and CNV amplitudes in two samples of antisocial adolescents during a classical forewarned reaction time experiment. In both samples the antisocial adolescents had significantly larger P300 amplitudes in response to the warning stimuli than did the prosocial subjects. This paradigm was assumed to be of interest to the subjects since it was the only one in a long series that involved a response by the subject.

A recent experiment (Raine, 1986) designed specifically to test the psychopath's selective attention measured P300 amplitudes in response to a target digit presented visually. Psychopaths showed greater amplitude P300 and a more sustained SPW in response to the target stimuli.
Assuming that the task in this study was interesting to the psychopaths, the large CNV response could represent the psychopath's enhanced attention to task demands. A possible measure of motivational difference between groups was reaction times. Interestingly, the psychopaths did show a trend to faster reaction times during the experiment, suggesting that they were highly motivated to perform the task. Informal observations of the comments of the subjects suggested that the psychopaths did find this task challenging and exciting.

The P300 is elicited to stimulus events that are unpredicted or that require some type of response or judgment (Wood, McCarthy, Squires, Vaughan, McCallum, 1984). All stimuli in this experiment elicited a P300 response, but the P300 results did not systematically relate to the reinforcement conditions nor did they vary as a function of group. This finding is not consistent with Raine's (1986; Raine and Venables, 1986) report that P300 amplitudes were larger in psychopaths than in nonpsychopaths. However, Jutai et al. (1986) reported no differences in P300 amplitude in their selective attention task. Klorman and Ryan (1980) also found a disassociation of P300 and CNV amplitude. The CNV was sensitive to the affective stimulation given at the end of the foreperiod, whereas the P300 was not. The lack of P300 amplitude differences in this study could be due to the fact that the recordings were taken at the vertex rather than over the parietal cortex. The P300 amplitudes are typically maximal over the parietal cortex.
(Hillyard, Courchesne, Krausz and Picton, 1976; Rohbraugh, Syndulko, and Lindsley, 1976). Further analysis of the P300 at Pz may provide evidence that supports the previous findings. Another possible explanation is that although the CNV and the P300 differ with regard to their spatial centers (frontal vs parietal) and peak latency (1000 vs 300 msec), they will tend to contaminate each other by partially cancelling each other because of their inverse polarity (Gaillard, 1978).

While the present findings may be related to group differences in the allocation of attentional resources, it is also possible that the findings reflect group differences in the response to distraction. Several studies have demonstrated that the CNV amplitude is reduced by many types of distraction presented during the foreperiod (Teece and Scheff, 1969; Tecce, Savignano-Bowman, and Meinbresse, 1976) including white noise (Plooij-van Gorsel and Janssen, 1980). Conceivably the nonpsychopaths were more distracted by the white noise than were the psychopaths. Thus, it is possible that the higher amplitude CNV shown by the psychopaths could be explained by the depressed CNV amplitudes in the nonpsychopaths.

In conclusion, this study, taken together with past findings, provides additional support that the autonomic differences between psychopaths and nonpsychopaths are task-specific. Psychopaths may demonstrate autonomic and performance deficits in tasks which are physically threatening and monotonous, but they show no impairment when they find the task
motivating and interesting. The electrocortical results support the view advanced by Jutai and Hare (1983; Raine, 1986) that psychopaths are particularly proficient at selectively attending to task-relevant events of interest. Systematic investigations of ERP's in psychopaths in anticipation and processing of a variety of sensory and emotional stimuli are needed, with concurrent measurements of autonomically controlled and electrocortical measures in order to provide much needed convergent information on the psychophysiology of psychopathy.
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Tecce, J. J. Contingent negative variation (CNV) and


APPENDIX A

Cleckley's criteria for psychopathy

1. Superficial charm and good intelligence.
2. Absence of delusions and other signs of irrational thinking.
3. Absence of 'nervousness' or psychoneurotic manifestations.
4. Unreliability.
5. Untruthfulness and insincerity.
6. Lack of remorse or shame.
7. Inadequately motivated antisocial behavior.
8. Poor judgement and failure to learn by experience.
10. General poverty in major affective reactions.
11. Specific loss of insight.
12. Unresponsiveness in general interpersonal relations.
13. Fantastic and uninviting behavioral with drink and sometimes without.
14. Suicide rarely carried out.
15. Sex life impersonal, trivial and poorly integrated.
16. Failure to follow any life plan.
APPENDIX B

Subject Instructions

You will be hearing one of three tones, about 6 seconds later you will hear another tone, when you hear the second tone press this RT button as quickly as you can. One tone will be followed by you losing money, another by you gaining money and a third tone will be followed by nothing. After you have pressed this button one of the three lights will come on. If the tone you first heard was the punishment tone than the red light will come on, it the first tone was the reward tone the green light will come on. And if the first tone was the neutral tone the yellow light will come on. After the light has gone off the assistant will either remove or give you a chip. For the reward condition you will be given either a 25 or 10 cent chip depending on how fast you pressed the button. So for the reward condition, if you press the button fast you can get a 25 cent chip otherwise you will get a 10 cent chip. For the punishment condition, you will either lose a 25 or a 10 cent chip. You will only lose a 10 cent chip if you press the button quickly otherwise you will lose a 25 cent chip. So for the reward condition if you press quickly you will get a 25 cent chip and if you press fast for the punishment condition you will lose only a 10 cent chip. For the neutral condition, no chips will be given or taken away. Here is a pile of chips that represent $6.00. The white chips represent 25 cents and the blue chips represent 10 cents. You will be given $6.00 for participating in the experiment plus you will get however much you make in the experiment. The maximum amount of money you can get is $6.00 plus $9.75 in the experiment, which equals $15.75. The least amount of money you will get is $6.00 plus $2.25 in the experiment, which equals $8.25.

Remember that when you hear the low/high tone you know that you will lose money, when you hear the low/high tone you know that you will gain money, and when you hear the middle tone you know that you will neither gain or lose.
POST EXPERIMENTAL QUESTIONNAIRE

Date__________ Subject __________

1) Which tone (high, medium, low) was followed by:
   a) loss of money ____________
   b) nothing ________________
   c) gaining money ____________

2) Which of the following statements best describes your state during the experiment... (check one)
   (1) Feeling active and vital; alert; wide awake ____
   (2) Functioning at a high level; but not at peak; able to concentrate ______
   (3) Relaxed; awake; not at full alertness; responsive ____________
   (4) A little foggy; not at peak; let down ______
   (5) Fogginess; beginning to lose interest in remaining awake, slowed down ______
   (6) Sleepiness; prefer to be lying down; fighting sleep ______
   (7) Almost asleep; lost struggle to remain awake ______

3) Please indicate your general reaction when you lost money by placing a check mark in the appropriate place on each scale.

TENSE
   very little: ___:____:____:____:____:____:____:very much

INTERESTED
   very little: ___:____:____:____:____:____:____:very much

BORED
   very little: ___:____:____:____:____:____:____:very much
4) Please indicate your general reaction when you gained money by placing a check mark in the appropriate place on each scale.

TENSE
very little: __:__:__:__:__:__:__:__:very much

INTERESTED
very little: __:__:__:__:__:__:__:__:very much

BORED
very little: __:__:__:__:__:__:__:__:very much

UNEASY
very little: __:__:__:__:__:__:__:__:very much

UNCOMFORTABLE
very little: __:__:__:__:__:__:__:__:very much

EXCITED
very little: __:__:__:__:__:__:__:__:very much

5) Please indicate your general reaction when nothing followed the tones by placing a check mark in the appropriate place on each scale.

TENSE
very little: __:__:__:__:__:__:__:__:very much

INTERESTED
very little: __:__:__:__:__:__:__:__:very much

BORED
very little: __:__:__:__:__:__:__:__:very much

UNEASY
very little: __:__:__:__:__:__:__:__:very much

UNCOMFORTABLE
very little: __:__:__:__:__:__:__:__:very much

EXCITED
very little: __:__:__:__:__:__:__:__:very much
6) Did you feel anxious at any point in this experiment?

7) Please indicate your general reactions during the interval, between the two tones, while you waited for the experimenter to remove money.

ANTICIPATION
very little:___:___:___:___:___:___:very much
UNEASINESS
very little:___:___:___:___:___:___:very much
EAGERNESS
very little:___:___:___:___:___:___:very much
Boredom
very little:___:___:___:___:___:___:very much
DISCOMFORT
very little:___:___:___:___:___:___:very much
NERVOUSNESS
very little:___:___:___:___:___:___:very much
APPREHENSION
very little:___:___:___:___:___:___:very much
SLEEPY
very little:___:___:___:___:___:___:very much
8) Please indicate your general reactions during the interval, between the two tones, while you waited for the experimenter to give you money.

ANTICIPATION
very little:___:___:___:___:___:___:___:
very much

UNEASINESS
very little:___:___:___:___:___:___:___:
very much

EAGERNESS
very little:___:___:___:___:___:___:___:
very much

BOREDOM
very little:___:___:___:___:___:___:___:
very much

DISCOMFORT
very little:___:___:___:___:___:___:___:
very much

NERVOUSNESS
very little:___:___:___:___:___:___:___:
very much

APPREHENSION
very little:___:___:___:___:___:___:___:
very much

SLEEPY
very little:___:___:___:___:___:___:___:
very much

9) Please indicate your general reactions during the interval, between the two tones, while you waited for nothing to occur.

ANTICIPATION
very little:___:___:___:___:___:___:___:
very much

UNEASINESS
very little:___:___:___:___:___:___:___:
very much

EAGERNESS
very little:___:___:___:___:___:___:___:
very much

BOREDOM
very little:___:___:___:___:___:___:___:
very much

DISCOMFORT
very little:___:___:___:___:___:___:___:
very much
NERVOUSNESS

APPREHENSION

SLEEPY

10) In the last 24 hours, do any of the following apply to you? (please check)
   a) drunk anything with caffeine (coffee, tea, coke): ______
      if so how long ago (hours): __________
   b) taken any medications (aspirin, anti-biotics, cold medicine): ______
      if so how long ago (hours): __________
   c) taken any non-medication drugs: ______
      if so how long ago (hours): __________
   d) drunk any alcohol: ______
      if so how long ago (hours): __________

NOTE: The above question will be used only to help the experimenter score your physiological responses.

Did you try very hard to push the button as quickly as you could?

   Yes: ______
   Somewhat: ______
   No: ______