PSYCHOPHYSIOLOGICAL RESPONSES OF HYPERACTIVE CHILDREN IN ANTICIPATION OF NOXIOUS AND NON-NOXIOUS STIMULI

by

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Gray's (1975, 1976) two-process learning theory is comprised of two synergistically operating systems which influence behavior and arousal. The behavioral inhibition system (BIS) is responsible for inhibiting (stopping) behaviors in response to punishment and extinction conditions while the behavioral activation system (BAS) is responsible for eliciting behavior in response to signals of reward. Fowles (1980) suggested that electrodermal activity is strongly associated with BIS activation while heart rate is strongly associated with BAS activation. Skin conductance and heart rate were presumed to measure activity in these two systems, respectively.

Psychophysiological research on hyperactive children indicated that they did not differ from normal children in resting levels of heart rate or skin conductance measures. Hyperactive children did, however, demonstrate smaller electrodermal responses than normal children to signal and nonsignal tones. This electrodermal hyporesponsiveness suggested that hyperactive children might be deficient in their BIS which might explain their impulsive behaviors and attentional problems.

The present study was designed to determine if hyperactive children showed deficits in their BIS by compairing their heart rate and skin conductance responses in anticipation of noxious and non-noxious auditory stimuli with that of nonhyperactive children. A countdown procedure (Hare, Frazelle, & Cox, 1878) was used to mark the anticipatory period and direct subjects' attention toward the coming stimuli. If hyperactive subjects were deficit in their BIS then they should show less skin conductance increase during the anticipatory period than nonhyperactive subjects. No differences were expected in HR responses.

Results indicated that no differences existed between hyperactive and nonhyperactive children in resting SC levels. Significant differences between hyperactive and nonhyperactive children were found in the SC trends across the anticipatory periods. Hyperactive children showed greater initial increases in SC in anticipation of the noxious stimulus than nonhyperactive children however, SC leveled off about 1/3 of the way across the anticipatory period. No differences in the HR trends for the noxious or non-noxious stimuli were found between the two groups. These results indicated that hyperactive children in this study did not appear to be deficit in their BIS.

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CHAPTER I

INTRODUCTION

Hyperactivity is one of the most significant and common childhood referral problems presented to psychologists, counselors, and physicians. Approximately 30 to 50% of children evaluated demonstrate symptoms of hyperactivity (Safer & Allen, 1977; Wender, 1971). Prevalence estimates of elementary school children experiencing childhood hyperactivity indicate that about 1% to 6% of all children are hyperactive (Lambert, Sandoval, & Sassone, 1978) and hyperactivity appears to be 4 to 10 times more common among males (American Psychiatric Association [APA], 1980; Cantwell, 1975; Ross & Ross, 1982; Stewart & Olds, 1973, Werner, Bierman, French, Simonian, Connor, Smith, & Campbell, 1968).

Descriptive and diagnostic terms commonly used to classify "hyperactivity" include: Attention Deficit Disorder with Hyperactivity, Hyperkinetic Reaction of Childhood, Hyperkinetic Syndrome, Hyperactive Child Syndrome, and Minimal Brain Dysfunction. The lack of common terminology and consensus on diagnostic criteria has made it difficult, if not impossible, to compare and replicate studies (Ross & Ross, 1982).

There is much dissent over whether hyperactivity is a clinical syndrome (viz., consistent symptom pattern and treatment response) or a set of behavioral complaints (Conners & Wells, 1986; Ross & Ross, 1982); however, most researchers and clinicians seem to agree on the frequently cited primary and secondary symptoms and exclusionary criteria (Ross & Ross, 1982). Primary symptoms of hyperactivity include developmentally inappropriate inattention, impulsive behavior, overactive or restless behaviors which are not goal directed, short attention span, and emotional lability; all of which occur in multiple situations (APA, 1980; Cantwell, 1975; Conners & Wells, 1986; Ross & Ross, 1982). Secondary characteristics of hyperactivity include aggression, poor response to discipline, low frustration tolerance, poor anger control, and poor academic performance (APA, 1980; Cantwell, 1975; Ross & Ross, 1982). Exclusionary criteria in diagnosing hyperactivity include mental retardation, psychoses (e.g., schizophrenia), affective disorders (e.g., mania), severe sensory defects, and neurological diseases (APA, 1980; Ross & Ross, 1982). Most researchers in the field believe hyperactive children belong to a heterogeneous group which could be further subdivided into subgroups.

Definition of Terms

Ross and Ross (1982) stated that the lack of common terminology and consensus on diagnostic criteria has made it difficult, if not impossible, to compare and replicate studies. It is thus desirable to use the most common definition in order to maximize the comparability of the present study to past and future studies. In the study of hyperactivity, many different terms have been used to classify the disorder but there seems to be considerable agreement on the following characteristics: developmentally inappropriate (a) impulsivity, (b) inattention, and (c) restless, overactive behaviors which are not goal directed (Conners & Wells, 1986; Ross & Ross, 1982).

These characteristics of hyperactivity are the primary symptoms outlined as criteria for Attention Deficit Disorder with Hyperactivity (ADD-H) in the third edition of the Diagnostic and statistical manual of mental disorders (DSM-III) (APA, 1980). It is interesting to note that

DSM-III lists two active subtypes of ADD--314.01 Attention Deficit Disorder with Hyperactivity and 314.00 Attention Deficit Disorder without Hyperactivity--yet "it is not known whether they are two forms of a single disorder or represent two distinct disorders" (APA, 1980, p. 41). The essential features (viz., inattention and impulsivity) of both active ADD subtypes are the same and the difference between the two is the presence or absence of hyperactivity (viz., restless, overactive behaviors). A third ADD presented--314.80 Attention Deficit Disorder, Residual Type--is reserved for individuals who once met the criteria for ADD-H but for whom no signs of hyperactivity are currently present. Such individuals continue to show attentional deficits and impulsivity which impair social or occupational functioning (APA, 1980). Routh (1983) stated that "whatever the faults of the DSM-III diagnostic criteria may prove to be, they are at least more explicit than any previous consensual criteria have been" (p. 130) and the use of these criteria will allow comparison with other studies utilizing the same definition.

In the present study, hyperactivity was conceptualized as attentional and impulsive behavior problems defined by DSM-III (APA, 1980) which span the entire development of the individual. The operational definition of hyperactivity was a child who exhibits developmentally inappropriate inattention, impulsivity, or restless, overactive nongoal related behaviors with an onset before age seven, with a minimum duration of six months, and not due to Schizophrenia, Affective Disorders, or Severe or Profound Mental Retardation. Hyperactive children in the present study were diagnosed by and under the medical care of pediatricians at a local clinic.

Throughout the present study references to psychophysiological variables are made. The two variables which were important in this study are heart rate (HR) which is expressed in beats per minute (bpm) and electrodermal activity (EDA) which is expressed either in ohm or micromho units. An ohm (a skin resistance measure) and a micromho (a skin conductance measure) are mathematical inverses. In the psychophysiological literature, the term electrodermal activity refers to the electrical conductivity of the skin due to activity of sweat glands. Electrodermal activity is a general term which is used to refer to several measurement procedures which include skin resistance level (SRL), skin resistance response (SRR), skin conductance response (SCR), and skin conductance level (SCL).

Statement of the Problem

Several clinical features demonstrated by psychopaths include: impulsiveness, lack of anxiety, poor frustration tolerance, poor anger control, and intolerance of discipline; clinical features also demonstrated by hyperactive children (APA, 1980; Coleman, Butcher, & Carson, 1980; Satterfield, 1978). There is strong evidence that there is a higher incidence of future antisocial behaviors <u>predictive</u> of psychopathy among hyperactive children (Cantwell, 1975; Gittelman, Mannuzza, Shenker, & Bonagura, 1986; Hechtman, Weiss, & Perlman, 1984; Huessy, Metoyer, & Townsend, 1973; Mendelson, Johnson, & Stewart, 1971; Robins, 1974, 1978; Ross & Ross, 1982; Satterfield et al., 1982; Weiss, Minde, Werry, Douglas, & Nemeth, 1971).

In the study of psychopathy, researchers have been interested in identifying the constitutional differences between psychopaths and nonpsychopaths in the search for possible causes of the psychopathic personality. A major line of research (Hare, 1970, 1978) has focused on the psychophysiological correlates of anxiety and arousal in order to investigate why psychopaths appear to be fearless or unaroused by noxious stimuli, free from anxiety, impulsive, and fail to learn from past experiences. Lykken (1957) and Schmauk (1970) found psychopaths demonstrated lower skin conductance responses in the anticipation of electric shocks and poor passive avoidance learning. Lykken (1957) concluded that the poor passive avoidance learning in psychopaths was a result of insufficient anxiety elicited by the noxious stimulus. Schachter and Latane (1964) found psychopaths to be insufficiently aroused to learn an avoidance (of shock) task as well as nonpsychopaths, yet when artificially aroused with adrenalin which mimics activity of the sympathetic nervous system, psychopaths learned the task better than nonpsychopaths.

Fowles (1980) reviewed Gray's (1975) two-process learning theory and discussed its implications for the clinical features of psychopathy and psychophysiological research. Gray considers his two-factor learning theory (Gray, 1975) to be a descendant of Eysenck's (1970) personality theory (Gray, 1976). Gray (1976) believed that impulsivity and anxiety were better constructs than neuroticism and introversion--extraversion (Eysenck, 1970) in the causal influences of behavior. Anxiety was conceptualized as increasing sensitivity to signals of punishment while impulsivity was seen as increasing sensitivity to signals of reward (Gray, 1976). The Hullian concept of drive which is characteristic of Eysenck's (1970) theory was replaced with the notion of incentive (positive or negative) in the elicitation or inhibition of behaviors (Gray, 1976).

Gray's two-process learning theory (Gray, 1975, 1976) is comprised of two synergistically operating systems which influence behavior and arousal: the behavioral inhibition system and the behavioral activation system. The behavioral inhibition system (BIS) is responsible for inhibiting (stopping) behaviors in response to punishment and extinction (Gray's frustrative nonreward) conditions. The BIS is activated by novel stimuli, punishment conditioned stimuli, and nonreward conditioned stimuli (Gray, 1976). The BIS inhibits ongoing behavior when it receives signals of punishment or when expected reward is not obtained. Fear, anxiety, and frustration are terms which describe the emotional content of BIS activation (Gray, 1976). The BIS is considered to be a substrate for anxiety as it is responsive to noxious or aversive stimuli and its activity and efficiency is impaired by antianxiety drugs (viz., alcohol, barbiturates, minor tranquilizers) (Fowles, 1980; Gray, 1975, 1976). The behavioral activation system (BAS) is responsible for eliciting behavior in response to signals of reward. The BAS is activated by reward conditioned stimuli and nonpunishment conditioned stimuli (Gray, 1975). Gray's theory is presented in greater detail in Chapter II.

In discussing the implications of Gray's theory for psychophysiological variables (viz., heart rate [HR] and electrodermal activity [EDA]), Fowles (1980) suggested that research indicated BAS activity is strongly associated with heart rate (HR) while BIS activity is strongly associated with electrodermal activity (EDA). These two psychophysiological variables (HR and EDA) were thus presumed to measure the activation of the BAS and BIS, respectively.

Fowles (1980) theorized that psychopaths are deficient in their BIS which accounts not only for the clinical features of impulsivity, lack of anxiety, failure to learn from past punishments, and strong reward-seeking behaviors but also accounts for the psychophysiological data which indicates psychopaths (a) are hyporesponsive in EDA in anticipation of noxious stimului (electric shocks and loud noises) (Hare, 1965a, 1965b; Hare & Craigen, 1974; Hare, Frazelle, & Cox, 1978, Hare & Quinn, 1971; Lykken, 1957), (b) show poor classical conditioning with noxious stimuli (Hare, 1978), but (c) demonstrate normal HR (BAS) responses (Hare & Craigen, 1974; Hare et al., 1978; Hare & Quinn, 1971). Interestingly, psychopaths and nonpsychopaths did not differ in their tonic (resting) HR or EDA (Hare, 1978). Similar results (EDA hyporesponsiveness) were also found among juvenile delinquents rated high in antisocial behavior (Borkovec, 1970; Fox & Lippert, 1963; Siddle, Nicole, & Foggitt, 1973).

Psychophysiological research with hyperactive children has also searched for the constitutional differences between hyperactive and nonhyperactive children. A review of psychophysiological research conducted on hyperactive children (Hastings & Barkley, 1978) and more recent research suggested that hyperactive children do not differ from nonhyperactive children in (a) resting HR (Barkley & Jackson, 1977; Boydstun, Ackerman, Stevens, Clements, Peters, & Dykman, 1968; Delamater, Lahey, & Drake, 1981; Dykman, Ackerman, Oglesby, & Holcomb, 1982; Ferguson, Simpson, & Trites, 1976; Zahn, Abate, Little, & Wender, 1975) or (b) resting EDA level (Boydston et al., 1968; Cohen & Douglas, 1972; Conners, 1975; Delamater et al., 1981; Dykman et al., 1982; Ferguson et al., 1976; Firestone & Douglas, 1975; Montagu, 1975; Spring, Greenberg, Scott, & Hopwood, 1974; Zahn et al., 1975). Some subgroups of hyperactive children have demonstrated lower resting EDA than nonhyperactive children (Satterfield, Atoian, Brashears, Burleigh, & Dawson, 1974; Satterfield, Cantwell, Lesser, & Podosin, 1972; Satterfield & Dawson, 1971). Differences in specific EDA in response to experimentally manipulated stimuli (viz., signal and nonsignal tones) have been found in that hyperactive children seem to have significantly smaller EDA responses to the tones than nonhyperactive children (Boydstun et al., 1968; Cohen & Douglas, 1972; Conners, 1975; Delamater & Lahey, 1983; Firestone & Douglas, 1975; Satterfield & Dawson, 1971; Spring et al., 1974; Zahn et al., 1975). These studies suggested that hyperactive children evidence electrodermal hyporesponsiveness to stimuli, a similar phenomenon demonstrated by psychopaths.

In terms of Gray's theory, hyperactive children may have deficits in their BIS which would impair their ability to inhibit overt behaviors. Such a conceptualization resembles Satterfield's (1978) theory of hyperactivity which proposes low Central Nervous System (CNS) arousal combined with insufficient inhibitory control over behavior.

Psychophysiological studies of hyperactivity which found hyperactive children showing reduced electrodermal activity provided data to suggest that hyperactive children may be deficient in their BIS. Such a conceptualizaton could help explain the psychophysiological data on hyperactivity as it has for psychopathy. A deficient BIS would suggest greater relative input from the BAS which would result in the appearance of impulsive overt behaviors. Also, a deficient BIS could help to explain the attentional problems seen in hyperactive children. Raskin (1973) wrote that studies investigating individual differences in vigilance tasks requiring sustained attention found that better vigilance performance was associated with higher skin conductance (SC). This was interpreted that better vigilance was the result of the individual's general level of arousal. Raskin (1973) also cited research which found fewer false detections of signals among individuals who had higher EDA. Rosenthal and Allen (1978) presented research which suggested that hyperactive children are poor at vigilance and reaction time tasks which require sustained attention.

EDA hyporesponsiveness to signal and nonsignal tones seen among hyperactive children is similar to the reduced anticipatory EDA to noxious stimuli found in psychopaths, however, it is not known what differential psychophysiological effects a noxious stimulus would produce in hyperactive children. Anticipation of a noxious stimulus which is anxiety (the trait associated with the BIS) producing should result in increases in EDA. Fowles (1980) suggested that under the same conditions, HR would be expected to remain relatively stable as input into the BIS should have no "direct implications for HR" (Fowles, 1980, p. 96). The present study used Gray's (1975, 1976) two-process learning theory to hypothesize relationships among psychophysiological responses (HR and EDA) of hyperactive and nonhyperactive children in anticipation of noxious and non-noxious stimului. If hyperactive children are deficient in their BIS, then hyperactive children should show electrodermal hyporesponsiveness (reduced EDA) in anticipation of a noxious stimulus when compared to nonhyperactive children. No differences would be expected between hyperactive and nonhyperactive children in HR. A deficient BIS could help explain the impulse control and attentional problems seen among hyperactive children.

Purpose of the Study

The purpose of the present study was to examine psychophysiological responses (viz., HR and SCL) of hyperactive and nonhyperactive children in their anticipation of the presentation of noxious and non-noxious stimului, in order to determine if hyperactive children show EDA hyporesponsiveness. If hyperactive children show reduced SCL in anticipation of a noxious stimulus in comparison to nonhyperactive children, then evidence would suggest they may be deficient in their BIS. A similar method used to investigate psychophysiological responses of psychopaths in anticipation of a noxious stimulus (Hare et al., 1978) was used to examine potential psychophysiological differences between hyperactive and nonhyperactive children. Hare et al. (1978) used a loud auditory stimulus to invoke anticipatory skin conductance responses in anticipation of the stimulus presentation.

Sroufe (1975) recommended deriving hypotheses from a model or theory when conducting research and this should "be more fruitful than a continued accumulation of empirical findings" (p. 16). Indeed, conducting research without a theoretical base can be blind and may not contribute meaningfully to science. In the present study, a theory which has been applied to adult psychopathy (Fowles, 1980; Gray, 1975, 1976) is extended to another domain to possibly explain why hyperactive children show impulsive behaviors and attentional problems. As in psychopathy, a deficient BIS could help explain the clinical features and psychophysiological data of hyperactivity.

Such a parsimonious theory (Gray, 1975) could help account for some of the behavioral characteristics of childhood hyperactivity as well as psychopathy. It could also account for the efficacy of stimulant medication in the treatment of hyperactivity. The effects of stimulant medications in hyperactive children seem to increase the hyperactive child's arousal and stimulation of the nervous system (Hastings & Barkley, 1978); contrary to the "paradoxical" effect once thought. Stimulant medications seem to increase inhibitory control over motor behaviors and allow children to be more goal directed in their behavior (Satterfield et al., 1972). Hyperactive children who showed lower EDA (Satterfield et al., 1972) or who were less responsive in specific EDA (Ferguson, Simpson, & Trites, 1976) evidenced better stimulant drug response than children with greater EDA responsiveness. Gray's (1975, 1976) theory may also provide clear constructs for the mechanism of hyperactivity.

The present study was designed to determine if hyperactive children demonstrated psychophysiological responses indicative of a deficient BIS (viz., EDA hyporesponsiveness). If hyperactive children are deficit in their BIS, then they should demonstrate EDA hyporesponsiveness in anticipation of the presentation of a noxious stimulus.

Questions for Hypotheses

The present study was designed to answer the following research questions in order to investigate if hyperactive children differ from nonhyperactive children on psychophysiological measures linked to Gray's (1975, 1976) two-factor learning theory.

1. Do hyperactive children differ from nonhyperactive children in their resting skin conductance level?

2. Do hyperactive children differ from nonhyperactive children in their resting heart rate?

3. Do hyperactive children differ from nonhyperactive children in their skin conductance levels in anticipation of a noxious stimulus?

4. Do hyperactive children differ from nonhyperactive children in their skin conductance levels in anticipation of a non-noxious stimulus?

5. Do hyperactive children differ from nonhyperactive children in their heart rate response in anticipation of a noxious stimulus?

6. Do hyperactive children differ from nonhyperactive children in their heart rate response in anticipation of a non-noxious stimulus?

By answering these research questions and relating the results to Gray's (1975, 1976) two-process learning theory, it will be possible to investigate if hyperactive children possess deficient behavioral inhibition systems (BIS). If hyperactive children show deficits in their BIS, differences in EDA in anticipation of a noxious stimulus should be evident with hyperactives showing EDA hyporesponsiveness (reduced SCL). Hyperactive and nonhyperactive children were not expected to differ in their HR responses in anticipation of the noxious stimulus. Investigation of the anticipation of a non-noxious as well as a noxious stimulus should help to identify if hyperactive children differ from nonhyperactive children in anticipation of stimuli in general.

Significance of the Study

There is no doubt that hyperactivity is among the most prevalent behavioral problems of childhood. The present study was designed to examine the differential heart rate and skin conductance level changes in anticipation of noxious and non-noxious stimului in a sample of hyperactive and nonhyperactive children. The findings should be of great importance to professionals in psychology, education, and medicine, since each of these disciplines is confronted and concerned with hyperactive children. In utilizing Gray's (1975, 1976) theory to test some theoretical notions about hyperactive children this study will contribute to the literature and knowledge about the psychophysiology of hyperactive children.

Also of importance are constitutional differences which may be the primary contributor in the manifestation of hyperactivity. It is likely that such constitutional differences interact with the environment to produce hyperactive or aggressive behaviors and knowledge of such psychophysiological differences may ultimately aid in better identification, treatment, and prevention of this and other behavior disorders.

The following chapter provides a review of the literature related to the research questions addressed in the present study. The third chapter describes the method used to investigate and answer the research questions as well as the selection of subjects and the instruments used in data collection. The fourth chapter presents the results of the study based on the data collected and the statistical analyses used. Chapter five provides a discussion of the results and conclusions of the present study.

CHAPTER II

REVIEW OF RELATED LITERATURE

The present review of the related literature is presented in two main sections in order to integrate (a) the theoretical foundations and background (viz., Gray's two-factor learning theory and related psychophysiological studies of psychopaths) and (b) psychophysiological studies of hyperactive children as they relate to Gray's two-factor learning theory (viz., heart rate and electrodermal activity).

Theoretical Foundation and Background

Gray's theory and research has integrated constructs of learning theory and personality theory with physiological research on learning and drug effects in the search for a physiological basis of personality (Gray, 1975, 1976; Gray & Smith, 1969). Gray's two-factor learning theory provided the theoretical foundation for the present study. Gray (1976) considered his theory to be a descendant and modification of Eysenck's (1970) personality theory. Therefore, it is appropriate to compare and contrast Gray and Eysenck in order to better familiarize the reader with the salient aspects of Gray.

Eysenck's theory of personality is based on the assumption that individuals differ in (a) autonomic nervous system (ANS) reactivity and (b) the degree to which they develop conditioned responses (Eysenck, 1970; Hall & Lindsey, 1978). These individual differences are expressed along personality dimensions of _introversion--extraversion_ and _neuroticism--stability_. Eysenck added a third dimension or axis to his theory which he termed _psychoticism_ (Eysenck, 1970) but this dimension did not seem relevant in the present study. Conditionability is the underlying trait along the introversion--extraversion dimension. Individuals who form conditioned responses easily tend to display introverted behavior; whereas individuals who do not form conditioned responses easily tend to demonstrate extraverted behavior (Eysenck, 1970; Eysenck & Rachman, 1965;). The underlying trait along the neuroticism--stability dimension is autonomic reactivity. Individuals with a high degree of ANS reactivity seem to be susceptible to neurotic disorders given certain environmental conditions (Eysenck, 1970; Eysenck & Rachman, 1965).

In the case where individuals are both highly conditionable and autonomically reactive (introverted neurotic [dysthymic]) excessively strong conditioned fears or guilt reactions, phobias, obsessions and compulsions, and anxiety states are likely to develop. In individuals low in conditionability (extraverted neurotic [psychopath]) there is a failure to develop conditioned fear or guilt reactions necessary for inhibition of antisocial impulses which results in lying, stealing, sexual delinquency, and aggressive behavior.

Both personality dimensions in Eysenck's (1970) theory have underlying physiological systems. The autonomic nervous system and central brain structures (viz., limbic system and hypothalamus) which control the ANS, provide the physiological substrate for emotionality (Eysenck, 1970; Eysenck & Rachman, 1965) which is seen as the fundamental psychological process of neuroticism. Highly neurotic individuals appear to be more easily aroused and show ANS responses of greatly increased heart rate, sweating, and vascular changes to unconditioned punishers and to conditioned stimuli. This is believed to constitute the unconditioned emotional response and conditioned fear and guilt reactions seen in neurotics. The ascending reticular activating system (ARAS) provided the physiological substrate for arousability (Eysenck, 1970; Eysenck & Rachman, 1965) which was seen as the underlying psychological process of introversion. Introverts were believed to be more arousable due to more ARAS impulses sent to the cerebral cortex.

Gray's theory is similar to Eysenck in many respects but is radically different in others. Gray (1976) modified Eysenck's theory by rotating (in two-dimensional space) the neuroticism and introversion axes 45 degrees and renamed the factors impulsivity and anxiety (see Figure 1, p. 17). It was anxiety and impulsivity which Gray (1976) believed to be the causal influences of behavior. Anxiety in Gray's theory was conceptualized as an increasing sensitivity to signals of punishment while impulsivity was seen as the increasing sensitivity to signals of reward. Gray (1976) replaced Eysenck's notion of conditionability with a fearlessness postulate which states that the greater the degree of trait anxiety, the greater the sensitivity or reactivity to punishment signals and situations.

In describing the characteristics of Eysenck's introversion and neuroticism constructs in terms of his own theory, Gray (1976) suggested that introversion was characterized by an increased sensitivity to punishment relative to rewards while neuroticism was characterized by increased sensitivity to both punishment and rewards. Gray (1976) preferred the concept of incentive (positive or negative) in the activation (elicitation) or inhibition of behavior rather than the Hullian concept of drive which is characteristic of Eysenck's (1970) theory.

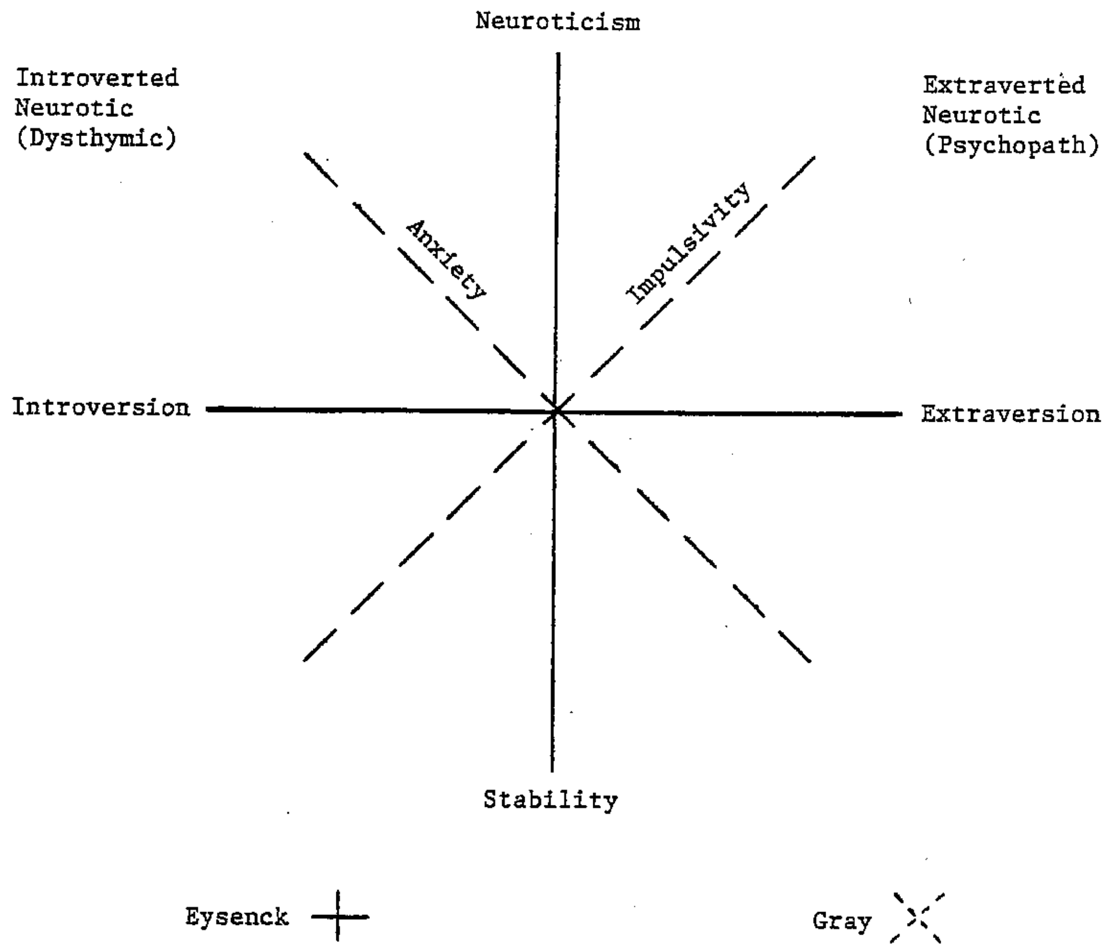

Figure 1. Gray's (1976) theory compared and superimposed with Eysenck's (1970) personality theory (adapted from Gray, 1976).

Gray and Eysenck have both developed theories which attempt to account for normal as well as pathological behavior and both believe constitutional or physiological characteristics of the individual play a major role in the development and maintenance of behavior. Both view personality development as an interaction between physiological or constitutional characteristics and environmental factors of learning. Gray's theory has received some recent attention in the literature as Fowles (1980) reviewed and integrated psychophysiological research on animal learning using Gray's (1975, 1976) theory. Fowles later utilized Gray's theory to explain the psychophysiological data and clinical features of psychopathy. The following section will discuss and explicate the characteristics of Gray's two-factor learning theory and how it relates to psychopathy.

Gray's Two-Factor Learning Theory

Gray's theory, like many of the traditional learning theories, is based, to a large degree, on animal learning studies. Gray (1982) indicated that his theory was formulated exclusively from animal experiments. Gray's theory and writing has dealt primarily with anxiety but has been applied to the psychophysiological literature and to psychophysiological data obtained with psychopaths (Fowles, 1980) and has implications for hyperactivity, which is the subject of the present study. The implications for hyperactivity will be spelled out later.

Gray's two-process theory of learning (Gray, 1975, 1976; Gray & Smith, 1969) is comprised of two antagonistic systems which influence (a) arousal and (b) whether overt behavior is activated (elicited) or inhibited. The two systems were thus named the <u>behavioral inhibition system</u> (BIS) and the <u>behavioral activation system</u> (BAS). The block diagram of the arousal-decision model created by Gray and Smith (1969, reprinted in Gray, 1975, p. 361) is presented in Figure 2 (p. 21) to facilitate an understanding of the interacting components in Gray's theory.

<u>The Behavioral Inhibition System</u>. The behavioral inhibition system (BIS) is the system which is responsible for inhibiting (stopping) ongoing behaviors due to extinction (i.e., Gray's frustrative nonreward) and punishment situations. The BIS is activated by three types of stimuli: (a) novel stimuli, (b) punishment conditioned stimuli, and (c) nonreward conditioned stimuli. Two other stimuli were tentatively included. These included (d) intense stimuli and (e) aggressive or dominance signals from social interactions (Gray, 1976). These are the stimuli which Gray suggests cause the inhibition (termination) of innate, classically conditioned, or instrumentally conditioned behavior. Because of its responsiveness to noxious or aversive (punishment) stimuli, the BIS is considered to be a substrate for anxiety. Gray (1975, 1976) provided an extensive review of literature and data base for the BIS.

Other evidence for suggesting the BIS is the substrate for anxiety is that BIS functioning is impaired by anti-anxiety drugs (Gray, 1975, 1976, 1982). Alcohol, barbiturates, and cannabis are said to have an "extraverting" effect on behavior. While alcohol, amytal, and other anti-anxiety drugs do not seem to affect learning in reward or escape situations, they do impair learning to suppress (inhibit) responses followed by punishment or extinction (frustrative nonreward) conditions (Gray, 1976).

Put simply, the BIS inhibits ongoing behavior when it receives signals of punishment or when expected reward is not presented. The BIS inhibits rather than energizes overt behavior. However, it also provides positive input into the arousal system. The emotional content of BIS activation can be described by such terms as anxiety, fear, and frustration (Gray, 1976). Output from the BIS include inhibition of behavior, increased arousal, and increased attention (Gray, 1982).

The Behavioral Activation System. The behavioral activation system (BAS) is the system responsible for eliciting behavior in response to positive incentives (rewards). The BAS appears to be a reward seeking system while at the same time mediating escape behaviors and active avoidance; both of which require activation of overt behavior. Stimuli which activate the BAS include (a) reward conditioned stimuli and (b) nonpunishment conditioned stimuli (Gray, 1975). Reward conditioned stimuli signal the organism to "approach" (perform some behavior) in order to obtain the reward. Nonpunishment conditioned stimuli signal the organism to "actively avoid" or escape so that the punisher will not be presented. The BAS, like the BIS, also has positive input into the arousal system.

The Arousal-Decision Model. The arousal-decision model developed by Gray and Smith (1969, reprinted in Gray, 1975, p. 361) is presented in Figure 2 (p. 21). Ri (reward conditioned stimuli) and Pi (punishment conditioned stimuli) represent inputs into the reward and punishment mechanisms, respectively. Both the reward (Rew) and punishment (Pun) mechanisms "are in competition for control of the motor apparatus," and the decision mechanism (D.M.) chooses between them and issues the command for behavior (B.Com.) (Gray & Smith, 1969, p. 248). Behavior commands from the reward side of the model are approach, in response to conditioned stimuli of reward; or escape, in response to conditioned stimuli signaling nonpunishment. The behavior command from the punishment side of the model is stop in response to punishment conditioned stimuli or nonreward conditioned stimuli. Thus, behavior is "activated" (elicited) on the reward side and behavior is "inhibited" on the punishment side. After the actual behavior (or lack of it) acts on the environment, the behavioral consequences (B.Cons.) provide feedback through comparators (Comp.) which compare actual reward or punishment with that expected. Output from these comparators become new inputs into the reward or punishment mechanisms.

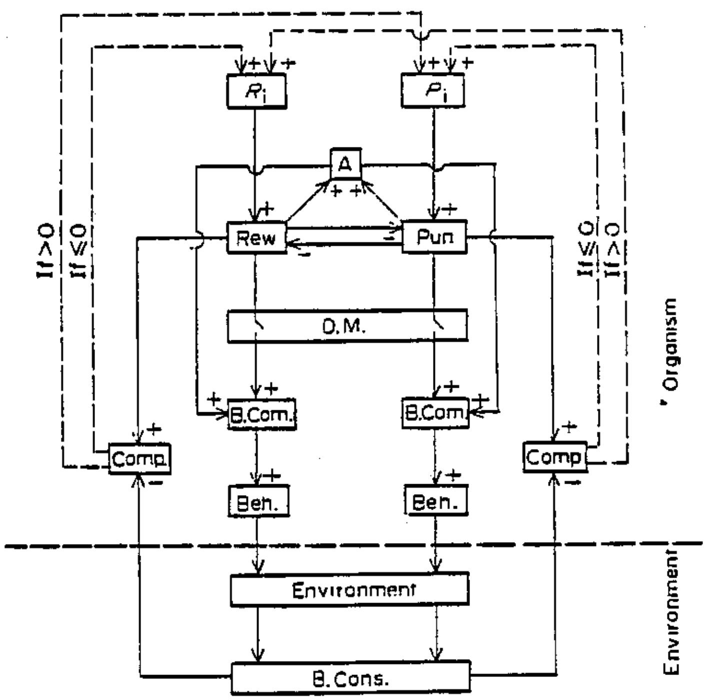

Figure 2. Gray and Smith's (1969) block diagram of the arousal-decision model (reprinted in Gray, 1975, p. 361).

The BIS and BAS actually refer to the total systems which include the punishment (Pun) mechanism and its three outputs and the reward (Rew) mechanism and its three outputs, respectively. Both the BIS and BAS have positive input into the general arousal mechanism (A) which Gray proposes is the ascending reticular activating system (ARAS) (Gray & Smith, 1969). While references are made to possible brain structures and systems which may provide substrates, Gray's theory is a psychological theory (Gray, 1982).

Fowles' Application of Gray's Theory

In a review article, Fowles (1980) discussed the implications of Gray's two-factor learning theory for psychophysiological measures (viz., heart rate [HR] and electrodermal activity [EDA]) and psychopathy. While Gray used the term arousal to refer to a specific mechanism in the arousal-decision model, which has a proposed physiological basis (viz., ARAS); Fowles suggested that "all three components of his [Gray's] model contain elements of what has traditionally been called arousal" (Fowles, 1980, p. 90). Fowles agreed with Gray in that the arousal mechanism is presumed to be associated with the ARAS. However, both the BIS and BAS possess characteristics of arousal and while the three systems of Gray's model "function in an integrated manner, there is also some specificity to each" (Fowles, 1980, p. 90). Fowles cited Lacey's (1967) review which indicated that "arousal" was not a unidimensional trait often expressed as the Yerkes-Dodson inverted U function of behavioral efficiency and arousal, but, multiple arousal systems were likely present.

In reviewing the literature on the experimental data on HR, Fowles found HR to be strongly associated with BAS activation. Although there was a high correlation between HR and activation of behavior, there was some evidence that incentive effects and somatic activity appear to be distinct (Fowles, 1980). HR was seen as reflecting "the incentive effects mediated by the BAS" (Fowles, 1980, p. 93) as the BAS was primarily responsive to rewards. HR, it was concluded, appeared to be a better index of BAS activation than somatic activity.

Fowles' review also presented data indicating that EDA increases in response to threats of punishment or noxious stimuli (viz., punishment conditioned stimuli) and perhaps extinction (nonreward conditioned stimuli); whereas HR does not. Activation of the BIS and EDA increases are also seen with novel stimuli. A number of EDA measurement paradigms have shown responsiveness to threats of punishment or noxious stimuli. Nonspecific fluctuations, the number of electrodermal responses recorded during a set time period, have been shown to increase in response to threats of physical punishment. Specific electrodermal response (EDR) amplitudes are "proportional to the 'emotionality' or 'attention getting' value of the eliciting stimuli" (Fowles, 1980, p. 95). Geer (1966) and Wilson (1967) found EDR increases to fear eliciting stimuli. Electric shock and white noise have been used a great deal and produce reliable EDR. Fowles (1980) discussed results of a study (Roberts, 1974) which demonstrated conditioned fear stimuli increased EDR independently of HR and somatic activity.

Generally speaking, the orienting response (OR) also shows increases in skin conductance and decreases in HR to the presentation of novel stimuli (Andreassi, 1980; Fowles, 1980). More specifically, the orienting response (OR) for HR is a triphasic response whereby HR is characterized by initial deceleration followed by acceleration followed by deceleration (Andreassi, 1980). When a stimulus is aversive, a defensive response (DR) (Andreassi, 1980; Graham & Slaby, 1973; Raskin, Kotses, & Bever, 1969) occurs for HR where a biphasic HR response shows initial acceleration followed by deceleration. For novel stimuli, directional fractionaton of HR and EDA is characteristic of the OR where HR shows a triphasic (cubic function) response of cardiac deceleration, acceleration, deceleration while EDA shows an increase then decrease. Fowles (1980) concluded that punishment conditioned stimuli (aversive stimuli) yield EDA increases (i.e., nonspecific fluctuations, EDR amplitude, and orienting responses). The directional fractionation for HR and EDA to aversive stimuli then changes and HR is then characterized by a biphasic response of cardiac acceleration followed by deceleration.

In situations where passive avoidance (behavioral inhibition) is not effective or is not a possible response, subjects may attempt to escape or actively avoid the presentation of an aversive stimulus and this behavior is mediated by the BAS (Fowles, 1980). In this situation both EDA and HR would be expected to increase (Fowles, 1980). If an aversive stimulus is presented and the individual is unable to escape or actively avoid the stimulus presentation, then the HR and EDA directional fractionation shows EDA increases while HR remains stable or decreases (Elliott, 1969; cited in Fowles, 1980).

Fowles' review has provided some interesting insights into Gray's theory, but most importantly, Fowles has provided psychophysiological variables (viz., HR and EDA) which correspond to and "measure" BAS and BIS activity, respectively. After reviewing the psychophysiological literature and spelling out the implications of Gray's theory, Fowles (1980) applied Gray's theory to the research and clinical aspects of psychopathic behavior. Fowles suggested that psychopaths manifest a weak or deficient BIS which, at the clinical level, could account for the psychopath's lack of anxiety when presented with normally threatening stimuli and inability to inhibit behavior or "learn" in punishment or extinction situations. Anxiety is believed to be the mediator of punishment effectiveness in the internalization of behavioral inhibition

(Miller, 1948, 1951; Mowrer, 1939, 1940). Another clinical feature of psychopathy merits mentioning and it is the low tolerance for alcohol (Cleckley, 1976), cannabis, and barbiturates. Alcohol, cannabis, and barbiturates have been shown to decrease the efficency of the BIS (Gray, 1976) and in the case of an already weak or deficient BIS hypothesized by Fowles (1980), such drugs would have profound behavioral effects by "narcotizing inhibitory processes" (Cleckley, 1976, p. 356).

With respect to anxiety, punishment, and avoidance learning, Lykken (1957) found psychopaths showed both lower skin conductance responses in the anticipation of an electric shock and poor passive avoidance (behavioral inhibition) learning. Lykken concluded that psychopaths demonstrated insufficient anxiety to learn to avoid electric shock. Schachter and Latane (1964) and Schmauk (1970) also found psychopaths to be insufficiently aroused and performed poorly in avoidance of shocks learning situations. Schachter and Latane (1964) and Chesno and Kilmann (1975) found that by artificially arousing psychopaths they could improve their avoidance learning.

Hare's (1978) review of electrodermal and cardiovascular correlates of psychopathy indicated that psychopaths show poor classical conditioning with noxious unconditioned stimuli. Psychopaths also showed smaller increases in skin conductance level and smaller nonspecific skin conductance fluctuations in anticipation of noxious stimuli (Hare, 1965a, 1965b; Hare & Craigen, 1974; Hare, Frazelle, & Cox, 1978; Hare & Quinn, 1971; Lykken, 1957). Hare suggested that small increases in electrodermal activity in response to noxious stimuli is a pattern among psychopaths which indicates that "relatively little fear is elicited" to noxious stimuli (Hare, 1978, pp. 136-137).

Psychopaths, however, did not differ from nonpsychopaths in their HR responses to noxious stimuli (Hare & Craigen, 1974; Hare et al., 1978; Hare & Quinn, 1971). No differences were found between psychopaths and nonpsychopaths in resting HR (Hare, 1978). With regard to resting skin conductance levels, most studies show no differences between psychopaths and nonpsychopaths.

Although no direct connection or comparison is being made between psychopathy and hyperactivity, methods and procedures utilized in the study of psychopathy appear to be useful in the examination of psychophysiological characteristics of hyperactive children which may be linked to BAS and BIS constructs. There appears to be sufficient data supporting the BAS and BIS constructs to warrant utilization of similar procedures in the study of other populations. The next section will discuss the psychophysiological studies conducted with hyperactive children and the possible implications for Gray's theory.

HR and EDA Correlates of Hyperactivity

As previously discussed, heart rate (HR) appears to be associated with the BAS while electrodermal activity (EDA) appears to be associated with the BIS. In examining hyperactivity via constructs of Gray's two-factor learning theory (1975) it is necessary to review the psychophysiological correlates of hyperactivity as they relate to Gray's theory. This section provides a review of the psychophysiological research involving HR and EDA (i.e., galvanic skin response, skin conductance level, skin conductance response) of hyperactive children.

Psychophysiological studies of autonomic arousal in hyperactive children have focused on several measurement paradigms. These include tonic or resting autonomic levels, spontaneous fluctuations or nonspecific autonomic responses not attributable to experimentally presented stimuli, and specific autonomic responses to experimentally presented stimuli. Review of psychophysiological studies of autonomic functioning of hyperactive children is presented in relation to these measurement procedures. Depending on the theoretical orientation of the researchers and era of the research, hyperactivity may also have been termed minimal brain dysfunction, hyperkinesis, or attention deficit disorder with hyperactivity. As mentioned in Chapter I, these terms are often used interchangeably to classify "hyperactive" children.

Tonic/Resting Autonomic Levels

Resting Heart Rate (HR). Six of the seven studies which examined the resting heart rate (HR) of hyperactive and normal children found no differences between the two groups. Boydstun, Ackerman, Stevens, Clements, Peters, and Dykman (1968) detected no resting HR differences between 26 minimal brain dysfunction (MBD) and 26 normal children. Zahn, Abate, Little, and Wender (1975) found no differences between 54 MBD and 54 normal children in average heart rate. Barkley and Jackson's (1977) study of hyperkinetic children also failed to find differences between hyperkinetic ($n = 12$) and normal ($n = 12$) children. In a study of 21 hyperactive and 15 nonhyperactive children (Delamater, Lahey, & Drake, 1981), no differences in resting HR were found. Dykman, Ackerman, Oglesby, and Holcomb's (1982) study of 10 hyperactive, 10 reading disordered, 10 hyperactive and reading disordered, and 10 normal control children yielded no resting HR differences. In a study of good versus poor methylphenidate responders and a control group of reading disabled children, Ferguson, Simpson, and Trites (1976) found no group differences in resting HR. Finally, in a study of 27 hyperkinetic and 23 normal children; Ballard, Boileau, Sleator, Massey, and Sprague (1976) were the only investigators to find hyperkinetic children to have higher average resting HR than normal children.

Resting Skin Conductance Level (SCL). The majority of studies investigating resting skin conductance level (SCL) in hyperactive and normal children have found that, like HR, there were no differences between the two groups (Boydstun et al., 1968; Cohen & Douglas, 1972; Conners, 1975; Delamater et al., 1981; Dykman et al., 1982; Firestone & Douglas, 1972; Montagu, 1975; Spring, Greenberg, Scott, & Hopwood, 1974; and Zahn et al., 1975). Also, Ferguson et al. (1976) found no group differences in resting SCL among good or poor methylphenidate responders or reading disabled children. One study found hyperactive children (n = 24) to have significantly lower resting SCL than normal children (Satterfield & Dawson, 1971) while another (Satterfield, Atoian, Brashears, Burleigh, & Dawson, 1974) found 18 MBD children to have higher resting SCL than 18 normal children. Satterfield, et al. (1974) suggested that the measurement procedure and experimental conditions during the measurement make these two studies difficult to compare. In yet another study (Satterfield, Cantwell, Lesser, & Podosin, 1972), differences between hyperactive children were found. In this study, Satterfield, et al. (1972) found a group of "best" responders to methylphenidate (n = 6) had significantly lower SCL (M = 16.7 micromho) than 11 normal children (M = 20.0 micromho) and a group of "worst" responders to methylphenidate (n = 5) had higher SCL (M = 24.4) than normal children. Overall, it appears that hyperactive children do not seem to differ from normal children in resting SCL, however, some studies have found subgroup differences.

Nonspecific Autonomic Responses

Studies of nonspecific autonomic responses have examined galvanic skin response (GSR) in the absence of experimentally presented stimuli, but which are thought to be responses to ambient stimuli or internal stimulation within the individual. Satterfield and Dawson's (1971) study of 24 hyperactive and 12 normal children yielded no significant differences between the groups in the number of 1 mm changes during a 10 minute peroid or total conductance change. They did find a significant increase in nonspecific GSR in the group of hyperactive children who were given dextroamphetamine. Spring et al. (1974) also found no differences in nonspecific GSR between 18 hyperactive and 20 normal children. Moreover, Spring et al. (1974) also found hyperactive children on stimulant medication (methylphenidate) had greater nonspecific GSR than those off medication. In a study of 52 MBD and 54 normal children, Zahn et al. (1975) found no group differences in the frequency or amplitude of nonspecific GSR but they did find significantly longer rise and fall times in the resistance changes. GSR outside the 4 second post stimulus period were considered spontaneous or nonspecific. Conners' (1975) study of 31 hyperactive, 19 neurotic, and 18 normal children yielded no differences in the frequency of nonspecific GSR (activation in the absense of stimuli). Barkley and Jackson (1977) found no differences in the mean frequency or mean amplitude of "spontaneous" GSR between 12 hyperkinetic and 12 normal children. Finally, Delamater et al. (1981) also found no differences in the frequency of nonspecific skin conductance responses between 21 (18 male, 3 female) hyperactive and 15 (13 male, 2 female) children.

In summary, all studies reviewed found no differences between hyperactive and normal children in spontaneous or nonspecific GSR.

Specific Autonomic Responses

Specific Heart Rate (HR) Changes. Sroufe, Sonies, West, and Wright (1973) studied the HR deceleration in 21 MBD and 17 normal children on a five second fixed-foreperiod reaction time (RT) task. In such a case, a warning stimulus (tone) is sounded and five seconds later the signal stimulus (light) signals the subject to press the key as fast as possible. Sroufe et al. (1973) found the MBD children to show significantly smaller HR deceleration than normal children. Dykman et al. (1982) also found hyperactive children to have less consistent HR deceleration than normal controls. Zahn et al. (1975) also found smaller HR decelerations in MBD children in a three second fixed-foreperiod RT task. However, there were no differences between the 52 MBD children and 54 normal children in HR deceleration in the 10 second fixed-foreperiod RT task. In this study, the foreperiod was initiated by the child by pushing down the key and the RT task was to release the key. Boydstun et al. (1968) also found no differences in HR deceleration to "reward" tones in a tone discrimination task between MBD (n = 26) and normal (n = 26) children. Ferguson et al. (1976) found no group differences in HR among good and poor methylphenidate responders and reading disabled controls during the RT tasks.

Specific Electrodermal Responses (EDR). Boydstun et al. (1968) found their 26 MBD children to elicit significantly smaller GSR in response to "reward" tones in a tone discrimination task. Spring et al. (1974) also found hyperactive children to have smaller GSR amplitudes and faster habituation to a series of nonsignal tones than normal children. Cohen and Douglas (1972) found hyperactive children to have smaller GSR to the first tone (orienting response), quicker habituation to nonsignal tones, and reduced GSR amplitudes from the nonsignal to signal condition. Hyperactive children appeared to be less sensitive than controls to changes in the task demands. Normal children were also more efficient in their performance; showing faster RT. Satterfield and Dawson (1971) also found hyperactive children demonstrate significantly smaller GSR to the first pair of tones than normal children. Their tentative interpretation was that hyperactive children demonstrate lower reticular activating system (RAS) arousal and that RAS activity is increased by stimulant medications which would increase GSR (arousal) and decrease the need for motor activity as a means of stimulation. Zahn et al. (1975) found their 52 MBD (32 male, 10 female) children to have fewer, smaller, and slower GSR than normal children (29 male, 25 female) in response to signal and nonsignal tones in a RT task. Firestone and Douglas (1975) also found hyperactive children to have fewer skin conductance responses than normal children in response to the warning stimulus in their RT task. Firestone and Douglas suggested that the hyperactive children did not use the warning stimulus effectively and also showed significantly slower RT than controls. Firestone and Douglas also observed that hyperactive children were also unable to inhibit their responses as shown by their false starts, interstimulus responses, and more redundant responses. Conners'

(1975) study of hyperkinetic, neurotic, and normal children indicated that hyperactive children showed significantly smaller GSR than normal and neurotic children in response to tones. Hyperkinetic children also showed less rapid habituation and no amplitude or latency differences between "response" and "nonresponse" tones. Hyperkinetic children, it seemed, showed little difference between autonomic responses when inhibiting versus responding (Conners, 1975). Conners observed that inhibiting responses were more difficult (required more effort) for hyperkinetic children. Conners also found ratings of anxiety to be positively related to skin conductance.

One recent study found no differences between hyperactive (18 male, 3 female) and nonhyperactive (13 male, 2 female) learning disabled students in skin conductance responses (SCR), SCR amplitude, and SCR latency during a tone discrimination task (Delamater et al., 1981). However, these two groups were quite homogeneous as both groups were rated high on both the conduct problem and tension anxiety factors of a commonly used rating scale of behavior problems and comparison to the other studies is difficult. Delamater and Lahey (1983) later reanalyzed the data from the Delamater et al. (1981) study and found that when the learning disabled students were subgrouped according to ratings of tension anxiety and conduct problems, children rated high in conduct problems showed smaller skin conductance responses and anxiety produced a moderating effect. They also found that when the hyperactive sample was examined separately, SCL was lower in hyperactive children with high ratings of conduct problems than hyperactive children rated with low conduct problems.

Another recent study (Dykman et al., 1982) found no differences between hyperactive, reading disabled, hyperactive and reading disabled, and normal controls in SCL during a visual search task in which children could earn pennies for selecting the reward stimulus. This combined with the HR increases during reward conditions led Dykman et al. (1982) to conclude that HR was more sensitive to the experimental conditions than was SCL, an effect which is attributable to incentive characteristics of the procedure.

Summary

Results from the research reviewed indicated that hyperactive children do not seem to differ from normal children in resting or tonic levels of HR or EDA. Thus, hyperactive children do not appear to be underaroused or overaroused in resting levels of autonomic functioning. These studies do suggest that hyperactive children are electrodermally hyporesponsive to stimuli in their environment, showing fewer, smaller, and slower GSR than normal children. Hyperactive children also seem to habituate to stimuli faster than normal children.

General Summary

Gray's two-process learning theory (1975), a descendant and modification of Eysenck's (1970) personality theory (Gray, 1976), is comprised of two antagonistic systems which influence arousal and behavior. The behavioral inhibition system (BIS) is responsible for inhibiting behavior in extinction and punishment situations. The behavioral activation system (BAS) is responsible for eliciting behavior in response to rewards and in mediating escape behaviors. The BIS is considered a substrate for anxiety (Gray, 1976) and is measured by electrodermal activity (EDA) (Fowles, 1980) while the BAS is considered a substrate for impulsivity (Gray, 1976) and is measured by heart rate (HR) (Fowles, 1980).

Fowles (1980) suggested that psychopaths are deficient in their BIS which accounts for the psychophysiological data and clinical features such as the absence of anxiety and failure to learn from experiences. Psychopaths demonstrate a pattern of physiological responding in the anticipation of a noxious stimulus (viz., reduced EDA and normal HR) (Hare, 1978). Such a pattern points to the lack of arousal (anxiety) to "normally" arousing stimuli (shock and loud noise). This reduced arousal seems to be an influence in psychopaths poor avoidance learning (Lykken, 1957; Schachter & Latane, 1964; Schmauk, 1970).

Psychophysiological studies of hyperactive children indicated that although they do not differ from normal children in resting (tonic) levels of HR and EDA, hyperactive children do seem to be hyporesponsive to stimuli (signal and nonsignal tones) in their environment and show fewer, smaller, and slower galvanic skin response (GSR) than normal children (Hastings & Barkley, 1978). This electrodermal hyporesponsiveness may be indicative of BIS deficits. If this is true and if hyperactive children are deficit in their BIS then EDA hyporesponsiveness should be seen in anticipation of noxious stimuli. Hyperactive children would not be expected to differ from nonhyperactive children in HR responses in anticipation of a noxious stimulus if an avoidance response is not possible.

The following chapter presents this study's methods and procedures used to answer questions raised by the review of the literature. Subject selection and instruments used will also be discussed in detail.

CHAPTER III

METHOD

The present study was designed to investigate if psychophysiological differences existed between a group hyperactive and a group of nonhyperactive children in anticipation of noxious and non-noxious stimuli. To assure that the subject's rights, privacy, welfare, and civil liberties were protected, the Carbondale Committee for Research Involving Human Subjects reviewed and approved the protocols and procedures used in this study. This research also conforms to the ethical standards of the American Psychological Association (APA, 1981). Psychophysiological data (viz., heart rate and electrodermal activity) was collected to answer following research questions.

1. Do hyperactive children differ from nonhyperactive children in their resting skin conductance level?

2. Do hyperactive children differ from nonhyperactive children in their resting heart rate?

3. Do hyperactive children differ from nonhyperactive children in their skin conductance levels in anticipation of a noxious stimulus?

4. Do hyperactive children differ from nonhyperactive children in their skin conductance levels in anticipation of a non-noxious stimulus?

5. Do hyperactive children differ from nonhyperactive children in their heart rate response in anticipation of a noxious stimulus?

6. Do hyperactive children differ from nonhyperactive children in their heart rate response in anticipation of a non-noxious stimulus?

In answering these research questions and relating the results to Gray's (1975, 1976) two-process learning theory, it was possible to investigate if hyperactive children possess deficient behavioral inhibition systems (BIS). If hyperactive children demonstrated lower SCL in anticipation of the noxious stimulus then there would be evidence to suggest that hyperactive children possess deficits in their BIS. No differences in HR responses were expected between hyperactive and nonhyperactive subjects. Investigation of the anticipation of a non-noxious as well as a noxious stimulus helped to identify if hyperactive children differ from nonhyperactive children in anticipation of auditory stimuli in general.

Subjects

A sample of hyperactive children between the ages of 7 and 12 was obtained by soliciting volunteers from among four local pediatricians' caseloads. The pediatricians, all of whom practice in a major local clinic, sent a copy of the solicitation letter and informed consent form (see Appendix A and C) to the parents of each diagnosed hyperactive child under their care. This letter explained the salient features of the study and provided an informed consent form necessary for participation in the study. Parents consenting to their child's participation returned the signed consent form to the pediatrician. Of the 35 letters and consent forms sent, 14 were returned and considered for the study. Three subjects were lost when their parents withdrew from the study due to scheduling difficulties and time conflicts. One additional subject was eliminated from the subject pool because of a diagnosis of sensory-neural hearing loss which may have made the loud auditory stimulus harmful.

The resulting sample ($\underline{n}$ = 10) of hyperactive children consisted of seven males and three females. The mean age of the hyperactive group was

9 years, 10 months and all subjects were Caucasian.

To control for stimulant medication effects on psychophysiological measures, hyperactive children were required to be off their medication for at least 48 hours prior to the study. Because data in this study were collected during the summer months, when children were out of school, it was a time when hyperactive children were normally taken off their stimulant medications. The 48 hour time frame was used in the Delamater and Lahey (1983) and Douglas, Barr, O'Neill, and Britton (1986) studies and was considered to be sufficient time to minimize stimulant drug effects. All subjects but two were off their stimulant medication for the summer and the remaining two were reported to have met the above criteria.

Nonhyperactive subjects were obtained in a similar fashion. A similar letter and consent form (see Appendix B and C) was sent home with children between the ages of 7 and 12 who attended a local elementary school. This letter also explained the salient aspects of the study and provided an informed consent form necessary for participation in the study. Those parents consenting to allow their children to participate returned the signed informed consent to their children's school. An insuffecent number of consent forms were initially returned and parents who did volunteer by returning signed consent forms were called to recommend potential volunteers. Telephone solicitation was then used to identify parents willing to consent to their child's participation in the study.

The nonhyperactive sample ($\underline{n}$ = 16) consisted of nine males and seven females with a mean age of 9 years, 3 months. As with the hyperactive sample, all nonhyperactive subjects were Caucasian.

Apparatus

A Lafayette Model 76102 Data Graph System polygraph and a Grass Model 7 Polygraph was used to collect the psychophysiological data. Bipolar skin conductance (SC) was directly measured and recorded by passing a constant voltage of .5V (Lykken & Venables, 1971) through Coulbourn T19-91 Ag/AgCl (silver/silver chloride) cup electrodes and amplified by a Lafayette Model 76441 SC amplifier. Johnson & Johnson K-Y Lubricating Jelly was used as the electrolyte. These electrodes were attached using four double-sided adhesive disks; one for each electrode and one for each finger. Electrodes were attached in a bipolar manner to the distal phalanges of the second and third fingers (index and middle fingers, respectively) on the non-lateral hand and secured with surgical adhesive tape. Laterality was assessed by asking the child which hand they used in writing. Skin conductance was expressed in micromho units.

Heart rate was obtained by passing electrocardiogram (ECG) impulses through a Lafayette Model 76403 Cardiotachometer. ECG impulses were measured by a Grass 7P5A pre-amplifier and output into the cardiotachometer by a Grass 70AC D.C. driver amplifier of the Grass Model 7 Polygraph. Heart rate was expressed in beats per minute (bpm) units. Electrodes were placed on the left medial malleolus of the tibia (ankle bone) and on the right dorsal side of the neck just below the hair line in an attempt to minimize movement artifacts. A ground electrode was placed on the left lateral malleolus of the fibula to eliminate interference signals. Coulbourn electrode jelly was used as the electrolyte and electrodes were secured using double-sided adhesive disks.

A Beltone Model 10-D Audiometer and headphones was used to present the noxious and non-noxious auditory stimuli binaurally. A Sharp RD-664AV cassette tape recorder was used to present the taped instructions and countdown procedures through the audiometer headphones.

All electrical apparatus was tested for electrical isolation by Todd Cottle, an electrical engineer at Southern Illinois University, in order to assure reliable and safe operation of all equipment directly connected to the subjects. The psychophysiological equipment was tested 5 days prior to the start of the study.

Procedure

Hyperactive and nonhyperactive children who participated in the study were brought to the Southern Illinois University Psychology Department by their parent(s) for the psychophysiological measurement session. After greeting the parent(s) and child, the experimenter escorted them to a nearby lounge and described the experimental procedures. They were told that the experimenter was interested in seeing how the child physically reacted in a resting session and in response to a soft and loud tone. The attachment of electrodes for measurement of heart rate and finger sweating was also be explained. The parent(s) and child were reminded of their right to withdraw from the study at any time without prejudice. The experimenter then escorted the child to a nearby washroom where the child was asked to wash their hands with warm water. The child was then taken to the psychophysiology laboratory for psychophysiological recording. All subjects were seen in individual sessions which lasted 30 minutes.

The children were again told that the experimenter was interested in how their body physically reacted in a resting session and to the presentation of a soft and loud tone; and in order to do that it was necessary to attach some wires and electrodes. Children were reassured that they would not be harmed and if they had any questions about what was going on they should feel free to ask. While the electrodes were being prepaired and attached, their function (measurement of sweating or heart rate) was explained. All children were told that they could terminate their participation in the experiment at any time without penalty.

No special preparation of the skin was necessary for the attachment of the heart rate electrodes; however, the distal phalanges of the second and third finger were specially prepared for the attachment of the skin conductance electrodes. Cotton balls and 70% isopropyl alcohol were used to clean the surface of the skin where the skin conductance electrodes were to be placed. After the surface was wiped dry, K-Y jelly was applied to the surface of the skin and then removed lightly with gause pads. The double-sided adhesive disks and the electrodes were then attached.

The psychophysiological recording occured with the child sitting in a reclining chair set in a semi-reclined position. After the electrodes were attached and the audiometer headphones were affixed upon the child's head, the child was asked to "sit quietly and relax for awhile." They were also told to keep their hands and legs still in order to minimize potential movement artifacts due to fingers pressing on the electrodes or leg movements. The measurement sesson was conducted with the child sitting alone in the experimental chamber which was quiet and contained only the child, the chair, and a table. Tape recorded instructions instructed the child that directions would be heard through the headphones and that they should not move their arms or feet. They were also told to "sit quietly and relax for a few minutes." The resting period lasted 3 minutes. Refer to Appendix D and E for transcripts of the taped instructions for the two stimulus condition presentation orders.

Following the resting period, tape recorded instructions for each of two stimulus intensity conditions (loud and soft) were presented to the child through the audiometer headphones. Hyperactive and nonhyperactive children were randomly assigned to one of the counterbalanced stimulus condition presentation orders (soft/loud or loud/soft) to control for potential order effects. A table of random numbers (Dayton, 1970, pp. 379-383) was used to assign subjects to the presentation order.

In the noxious stimulus (loud tone) condition, children were told that the experimenter "will count slowly from 1 to 5. After the number 5, you will hear a loud tone and this is what it sounds like." The noxious stimulus was presented so the child could experience the characteristics of the tone. The interval between the numbers 1 through 5 was 3 seconds for a total trial length of 12 seconds. The anticipatory period was the 12, one-second intervals prior to the presentation of the tone. Three trials were given where a 1000 Hz tone was presented binaurally at 100 dB (SPL) for a 1 second duration immediately following the count of "five." A 1 minute recovery period separated the three anticipatory trials.

While Hare et al. (1978) used a 120 dB, 1000 Hz tone with psychopathic prisoners in Canada, this was judged to be too noxious and potentially harmful to the children's ears. In consulting with a local clinical audiologist (D. Newcom, personal communication, March 25, 1987) it was determined that a 1 second long, 1000 Hz tone at 100 dB (SPL), should be sufficiently noxious yet not harmful to children's ears and hearing. Katz (1978) presented a table of permissible noise exposure levels and durations which are recommended in the Occupational Safety and Health Act. Noise at 100 dB (SPL) can be endured for 2 hours with no harmful effects. Audiologists frequently use tones ranging from 80 dB (SPL) to 110 dB (SPL) in testing for the acoustic reflex (contraction of the stapedial muscle and tensor tympani which protect the hearing apparatus during exposure to loud noises in order to prevent noise induced hearing loss [D. Newcom, personal communication, March 25, 1987]). Katz (1978) suggested that "115 dB is the absolute maximum level to which anyone should be exposed" (p. 66). The 1000 Hz tone at 100 dB (SPL) was considered to be within the limits of safety.

In the non-noxious (soft tone) condition, children were again told that the experimenter will "count slowly from 1 to 5. After the number 5 you will hear a soft tone and this is what it sounds like." The non-noxious stimulus was presented for one second so the child could experience the characteristics of the soft tone. The interval between the numbers 1 through 5 was 3 seconds for a total trial length of 12 seconds. The anticipatory period was again the 12 one second intervals prior to the presentation of the tone. Three trials were given where a 1000 Hz tone was presented binaurally at 60 dB (SPL) for a 1 second duration immediately following the count of "five." A 1 minute recovery period separated the three anticipatory trials.

In both the soft (60 dB) and loud (100 dB) stimulus conditions, subjects were told that the stimulus would occur at a specific point in time. This was done to facilitate the anticipatory electrodermal and heart rate responses as in the Hare et al. (1978) study, rather than using a classical conditioning paradigm. However, in the Hare et al. (1978) study the aversive stimulus was not presented prior to the experimental trials (as was done in the present study) so the subjects did not "know" the characteristics of the stimulus until after the first trial. It was thought in the present study that facilitation of the anticipatory SCL increases could be achieved by presenting the stimulus to the subjects prior to the three trials.

The experimental procedure of the present study did not allow the subjects an opportunity to actively avoid (escape) the presentation of the stimuli (barring termination of participation). Thus, it was expected that there should be increases in SCL and decreases or no changes in HR in anticipation of the noxious stimulus (Fowles, 1980).

Following the psychophysiological recording, the child and parent(s) were thanked for their participation and the child received a healthful food snack to reward their participation. The parent(s) were told that a follow-up letter summarizing the study's results and implications would be sent at the conclusion of the study but that individual data would remain anonymous. Any questions regarding the procedure were answered during this debriefing.

The following chapter presents the results of this study in relation to the research questions examined.

Data Analyses

Resting levels of HR and SC were obtained during the final minute of the resting period. Both HR and SCL were measured continuously and averaged across the 60, one-second intervals of the final minute. These mean resting levels were subjected to *t* tests for the difference between means for independent samples to determine if differences existed between hyperactive and nonhyperactive children in their resting or tonic HR and SC levels. The .05 level of significance was used in all statistical decisions.

Anticipatory HR data were expressed and analyzed in beats per minute (bpm) while SCL data were expressed and analyzed in micromho units. Venables and Christie (1973) stated that "SC data appear to be fairly normally distributed, and in view of the general robustness of normal parametric statistics, transformation (to log SC) usually appears to be unnecessary" (p. 93). Examination of the distribution of SCL data indicated that a log conversion would not produce a more normal distribution in this case and raw SCL data were used in all analyses. Movement artifacts were responsible for creating missing data relative to HR; however, only 6 observations of a total 1872 were lost. Analyses of HR were based on 1866 total observations. No SCL artifacts were generated so data analyses were based on the total 1872 observations.

Anticipatory HR and SCL data were subjected to 2 X 2 X 12 analyses of variance with the factors being Group (hyperactive vs. nonhyperactive), Condition (100 dB vs. 60 dB tone), and Time (12 one second anticipatory intervals prior to tone). Data from trials 1 through 3 for both the 60 dB and 100 dB tone conditions were pooled to yield the most stable estimates of anticipatory responses. Anticipatory HR and SCL responses were also subjected to trend analyses using orthogonal-polynomials (linear, quadratic, and cubic functions) for the Time factor and its interactions with other variables (viz., Group and Condition) (Dayton, 1970).

Trend analyses using orthogonal-polynomials involved raising the independant variable Time to certain powers to explain its relationship to the dependant variables HR and SCL. Linear relationships are expressed in a straight line whereas quadratic relationships are expressed as a curved line with one bend in the curve. Cubic relationships are expressed as curved lines with two bends in the curve. Dayton (1970) suggested that it is seldom necessary to go beyond third degree polynomials (cubic) as the relationship becomes too complex to be meaningful.

CHAPTER IV

RESULTS

The purpose of the present study was to investigate psychophysiological responses (viz., SCL and HR) of hyperactive and nonhyperactive children during a resting session and in anticipation of noxious and non-noxious stimuli in order to determine if the two groups differed. Data are presented which answer research questions concerning group differences in resting or tonic levels of HR and SCL and anticipatory HR and SCL responses in anticipation of 60 dB and 100 dB tones.

Resting/Tonic Autonomic Levels

Skin Conductance Level (SCL)

Research Question 1 asked: Do hyperactive children differ from nonhyperactive children in their resting skin conductance level? Comparison of resting SCL data during the final minute of the resting period indicated that hyperactive children (M = 5.30 micromho, SD = 1.58) and nonhyperactive children (M = 6.63 micromho, SD = 2.54) did not differ significantly in their resting SCL, $t(24) = 1.481$.

Heart Rate (HR)

Research Question 2 asked: Do hyperactive children differ from nonhyperactive children in their resting heart rate? Differences in resting HR between hyperactive and nonhyperactive children were statistically significant, $t(24) = 2.513$, $p < .02$. Hyperactive children in this study possessed significantly lower HR ($\underline{M}$ = 76.7 bpm, $\underline{SD}$ = 10.24) than nonhyperactive children ($\underline{M}$ = 87.38 bpm, $\underline{SD}$ = 10.67) during the final minute of the resting session.

Anticipatory Autonomic Responses

Skin Conductance Level (SCL)

Research Question 3 asked: Do hyperactive children differ from nonhyperactive children in their skin conductance levels in anticipation of a noxious stimulus. Research Question 4 asked: Do hyperactive children differ from nonhyperactive children in their skin conductance levels in anticipation of a non-noxious stimulus. Table 1 (p. 48) summarizes the Group X Condition X Time analysis of variance and orthogonal-polynomial contrasts (Dayton, 1970) used to test the differences in trends across Time. These analyses provided answers to these two research questions regarding anticipatory SCL responses.

Research questions 3 and 4 were answered by testing for significance the interaction between Group (hyperactive vs. nonhyperactive), Condition (60 dB vs. 100 dB tone), and the trends across Time (12, one-second anticipatory intervals before the tone). Although the global interaction did not reach significance, a specific orthogonal-polynomial contrast indicated that there was a significant difference in the quadratic trends across the anticipatory period between the two groups in the 60 dB and 100 dB conditions, $\underline{F}(1, 264) = 5.81$, $\underline{p} < .05$. No significant interactions between Group and Condition were found with respect to the linear or cubic trends across Time.

TABLE 1

SUMMARY TABLE FOR GROUP X CONDITION X TIME ANALYSIS OF VARIANCE AND ORTHOGONAL-POLYNOMIAL CONTRASTS (LINEAR, QUADRATIC, AND CUBIC FUNCTIONS) OF TIME AND THEIR INTERACTIONS WITH GROUP AND CONDITION FOR ANTICIPATORY SKIN CONDUCTANCE LEVEL (SCL)

Source	df	SS	MS	F	p
Group	1	612.917	612.917	1.27	.2704
Error	24	11558.986	481.624		
Condition	1	169.502	169.502	6.47	.0178
Group X Condition	1	64.801	64.801	2.47	.1288
Error	24	628.561	26.190		
Time	11	20.238	1.840	11.37	.0001
Linear	1	8.028	8.028	49.56	<.01
Quadratic	1	10.196	10.196	62.94	<.01
Cubic	1	.181	.181	1.12	ns
Error	264	42.704	.162		
Group X Time	11	3.083	.280	1.73	.0664
Linear	1	2.780	2.780	17.16	<.01
Quadratic	1	.162	.162	1.00	ns
Cubic	1	.071	.071	.44	ns
Error	264	42.704	.162		
Condition X Time	11	2.605	.237	2.76	.0021
Linear	1	1.918	1.918	22.30	<.01
Quadratic	1	.560	.560	6.51	<.05
Cubic	1	.061	.061	.71	ns
Error	264	22.647	.086		
Group X Condition X Time	11	.829	.075	.88	.5621
Linear	1	.002	.002	.02	ns
Quadratic	1	.500	.500	5.81	<.05
Cubic	1	.000	.000	.00	ns
Error	264	22.647	.086		

Note. Orthogonal-polynomial coefficients were obtained from Table B-11 (Dayton, 1970, p. 426).

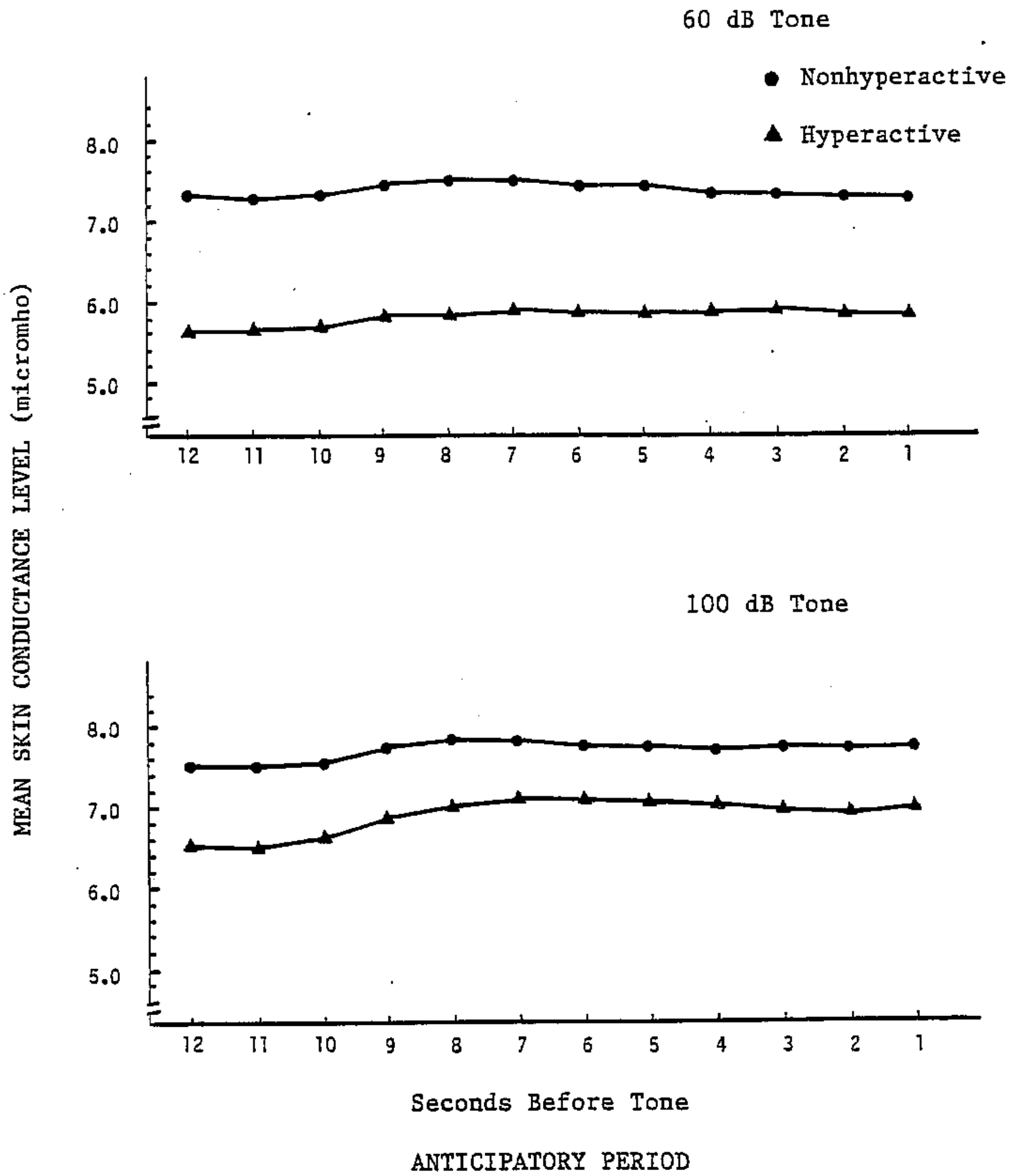

Figure 3. Skin conductance level (SCL) as a function of anticipatory period between hyperactive and nonhyperactive children for the 60 dB and 100 dB tones.

Figure 3 (p. 49) presents SCL trends across the 12 one second anticipatory intervals for hyperactive and nonhyperactive children in the 60 dB and 100 dB conditons. From inspection of Figure 3, it appeared that hyperactive children demonstrated a greater initial increase and later decreases in SCL than nonhyperactive children in the 100 dB conditions whereas the nonhyperactive children seemed to show a greater initial increase and later decrease in SCL in the 60 dB conditions than hyperactive children.

Significant differences were found in the linear trends of SCL across the anticipatory period for hyperactive and nonhyperactive children, $\underline{F}(1, 264) = 17.16$, $\underline{p} \leq .01$. Differences between the hyperactive and nonhyperactive children in the quadratic and cubic trends across the anticipatory period were not significant. Figure 4 (p. 51) presents the SCL trends across the anticipatory period for the hyperactive and nonhyperactive children. It appeared that there was a more linear SCL trend across the anticipatory period for the nonhyperactive children than for the hyperactive children.

Significant differences were also found in the linear SCL trends across time between the two stimulus conditions (60 dB vs. 100 dB), $\underline{F}(1, 264) = 22.30$, $\underline{p} < .01$. Differences in the quadratic SCL trends between the two stimulus conditions were also significant, $\underline{F}(1, 264) = 6.51$, $\underline{p} < .05$. The trend across the anticipatory period appeared to be more linear in the 60 dB condition than in the 100 dB condition whereas the trend across time appeared to be more quadratic for the 100 dB condition than in the 60 dB condition (see Figure 5, p. 51). The quadratic trend appeared to be characterized by an initial increase in SCL followed by a general leveling off or slight decrease.

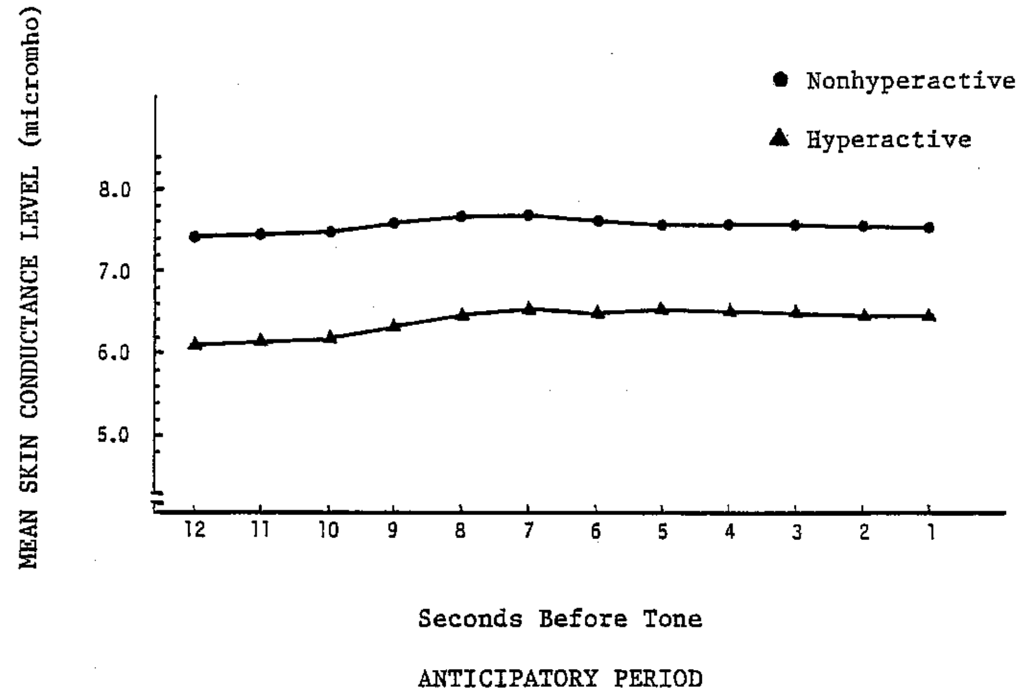

Figure 4. Skin conductance level (SCL) as a function of anticipatory period for hyperactive and nonhyperactive children.

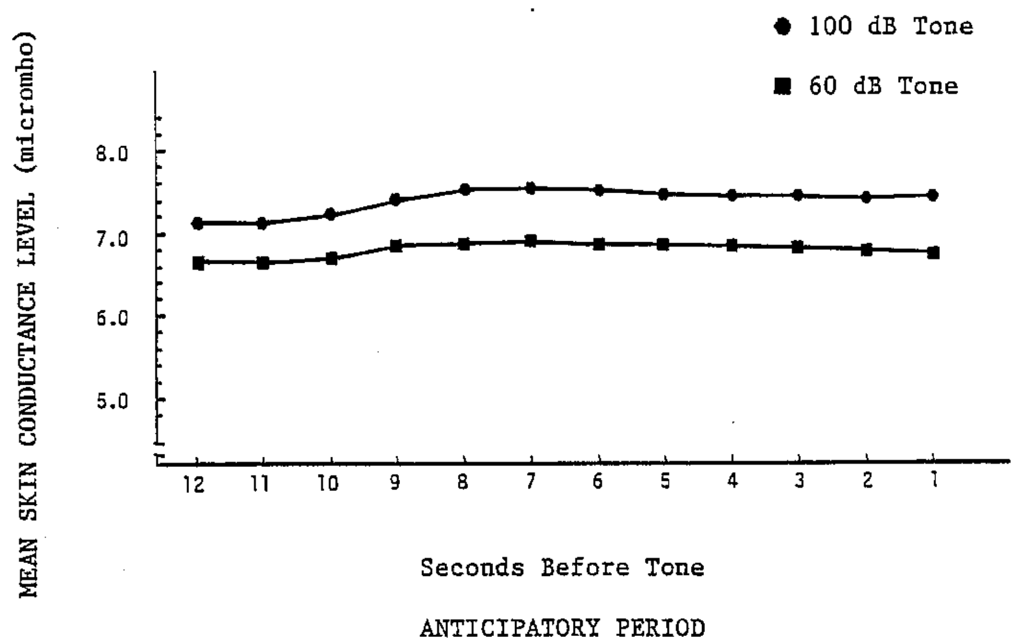

Figure 5. Skin conductance level (SCL) as a function of anticipatory period for the 60 dB and 100 dB tones.

The significant main effect of condition (60 dB vs. 100 dB), $F(1, 24) = 6.47$, $p < .02$, indicated that SCL throughout the anticipatory periods were generally greater (M = 7.40 micromho) during the 100 dB condition than during the 60 dB condition (M = 6.80 micromho). This simple main effect is not particularly meaningful in light of the previous interactions of stimulus condition with Group and Time.

Heart Rate (HR)

Research Question 5 asked: Do hyperactive children differ from nonhyperactive children in their heart rate response in anticipation of a noxious stimulus. Research Question 6 asked: Do hyperactive children differ from nonhyperactive children in their heart rate response in anticipation of a non-noxious stimulus. Table 2 (p. 53) summarizes the Group X Condition X Time analysis of variance and orthogonal-polynomial contrasts used to test the differences in trends across Time. These analyses provided answers to these two research questions regarding anticipatory HR responses.

Research questions 5 and 6 were answered by testing for significance the interaction between Group (hyperactive vs. nonhyperactive), Condition (60 dB vs. 100 dB), and the trends across Time (12 one second anticipatory intervals before the tone). No significant differences were detected in the linear, quadratic, or cubic trends of HR response among hyperactive and nonhyperactive children in the 60 dB or 100 dB conditions. The global interaction between Group, Condition, and Time also failed to reach significance.

TABLE 2

SUMMARY TABLE FOR GROUP X CONDITION X TIME ANALYSIS OF VARIANCE AND ORTHOGONAL-POLYNOMIAL CONTRASTS (LINEAR, QUADRATIC, AND CUBIC FUNCTIONS) OF TIME AND THEIR INTERACTIONS WITH GROUP AND CONDITION FOR ANTICIPATORY HEART RATE (HR)

Source	df	SS	MS	F	p
Group	1	54205.733	54205.733	6.13	.0208
Error	24	212319.246	8846.635		
Condition	1	212.467	212.467	.37	.5493
Group X Condition	1	518.270	518.270	.90	.3523
Error	24	13823.304	575.971		
Time	11	1372.801	124.800	1.86	.0454
Linear	1	42.762	42.762	.64	ns
Quadratic	1	244.756	244.756	3.64	ns
Cubic	1	626.511	626.511	9.32	<.01
Error	264	17755.800	67.257		
Group X Time	11	915.519	83.229	1.24	.2621
Linear	1	314.540	314.540	4.68	<.05
Quadratic	1	346.799	346.799	5.16	<.05
Cubic	1	27.181	27.181	.40	ns
Error	264	17755.800	67.257		
Condition X Time	11	876.747	79.704	1.55	.1136
Linear	1	75.923	75.923	1.48	ns
Quadratic	1	50.969	50.969	.99	ns
Cubic	1	78.580	78.580	1.53	ns
Error	264	13568.347	51.395		
Group X Condition X Time	11	469.422	42.675	.83	.6098
Linear	1	.033	.033	.00	ns
Quadratic	1	31.540	31.540	.61	ns
Cubic	1	67.711	67.711	1.32	ns
Error	264	13568.347	51.395		

Note. Orthogonal-polynomial coefficients obtained from Table B-11 (Dayton, 1970, p. 426).

Significant differences were found in the linear HR trends between the hyperactive and nonhyperactive children, $\underline{F}(1, 264) = 4.68$, $\underline{p} < .05$. The quadratic HR trends between the hyperactive and nonhyperactive children also differed significantly, $\underline{F}(1, 264) = 5.16$, $\underline{p} < .05$. This interaction is presented in Figure 6. The HR trend of nonhyperactive children tended to be more linear than hyperactive children while the HR trend of hyperactive children tended to be more quadratic than nonhyperactive children. The quadratic trend was characterized by a general decrease in HR followed by a general increase.

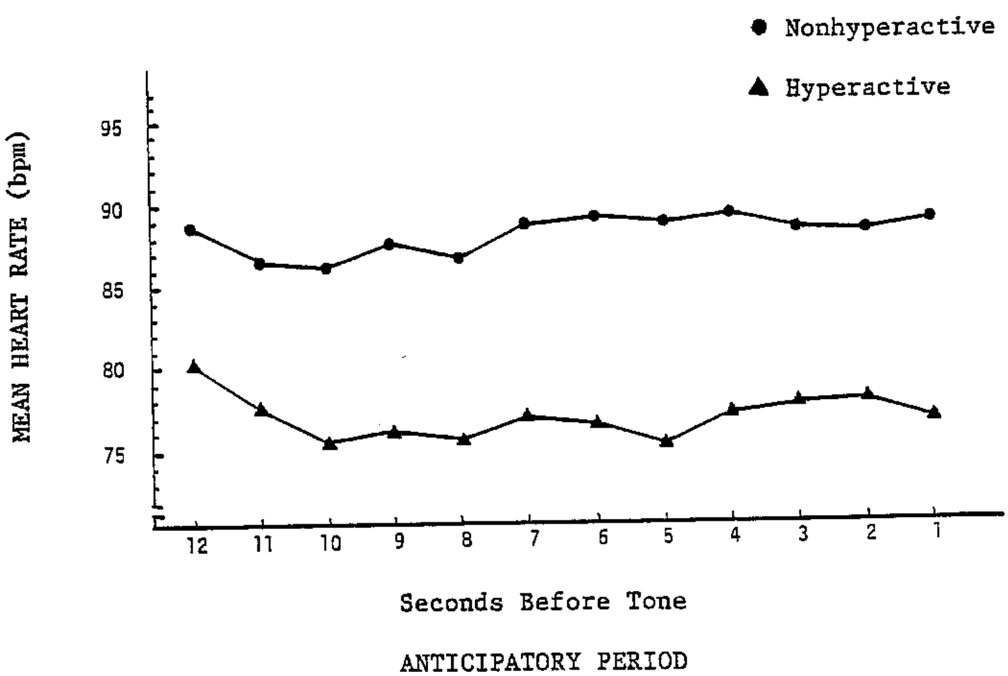

Figure 6. Heart rate (HR) as a function of anticipatory period for hyperactive and nonhyperactive children.

One significant main effect which was identified in the analysis of HR was the generally lower HR throughout the anticipatory period among the hyperactive subjects. Hyperactive children ($\underline{M}$ = 77.03 bpm) had significantly lower HR than nonhyperactive children ($\underline{M}$ = 88.10 bpm), $\underline{F}(1, 24) = 6.13$, $\underline{p} < .02$. This was consistant with the generally lower resting HR among hyperactive subjects in this study.

The following chapter presents a discussion of the results obtained in the present study as they relate to the research questions addressed. Also discussed are the implications, recommendations, and limitations which are suggested by the present study.

CHAPTER V

DISCUSSION AND SUMMARY

Discussion

Results for resting SCL indicated that no significant differences existed between hyperactive and nonhyperactive subjects. This result was consistant with the majority of studies reviewed (Boydstun et al., 1968; Cohen & Douglas, 1972; Conners, 1975; Delamater et al., 1981; Dykman et al., 1982; Firestone & Douglas, 1972; Montagu, 1975; Spring et al., 1974; and Zahn et al., 1975) and supported the view that hyperactive children as a group do not differ from normal children in their resting levels of arousal as measured by skin conductance.

Results obtained for resting HR were quite unusual and in an unexpected direction. Hyperactive children in the present study demonstrated significantly lower resting HR than nonhyperactive children. This was inconsistant with the research presented on resting HR which suggests that no differences exist between hyperactive and normal children (Barkley & Jackson, 1977; Boydstun et al., 1968; Delamater et al., 1981; Dykman et al, 1982; Ferguson et al., 1976; Zahn et al., 1975). Only one study found significant differences in resting HR between hyperactive and normal children and that study found hyperactive children to have higher resting HR than normal children (Ballard et al., 1976). It was difficult to draw conclusions about the differences in resting HR in the present study and it was probably best to assume that it was a unique effect among the samples in the present study.

Anticipatory SCL data provided evidence to suggest that hyperactive children are not deficient in their BIS as they did not show SCL hyporesponsiveness in anticipation of the 100 dB stimulus. Differences between the two groups indicated that hyperactive children demonstrated greater initial increases in SCL and later decreases in the 100 dB condition than nonhyperactive children. However, in the 60 dB condition, hyperactive and nonhyperactive children seemed to show more similar (and stable) SCL trends across the anticipatory period. It appeared that hyperactive children showed greater arousal than nonhyperactive children in the 100 dB condition. This suggests that hyperactive children in the present study may have demonstrated greater BIS activation than nonhyperactive children. This appeared to be quite a discrepant result given the consistancy with which other studies showed hyperactive children to be significantly less responsive on electrodermal activity measures (Boydstun et al., 1968; Cohen & Douglas, 1972; Conners, 1975; Firestone & Douglas, 1975; Satterfield & Dawson, 1971; Spring et al., 1974; Zahn et al., 1975). One possiblity for the discrepant results may be in the utilization of physician diagnosed hyperactive children which tends to include more heterogeneous or nonspecific behavior problems than diagnoses in most research situations where more objective behavior rating methods are typically used (Plomin & Foch, 1981) and subjects are studied at referral. The present sample of hyperactive children may have differed from the nonhyperactive children in levels of anxiety (as well as other traits) which may also have contributed to the greater increases in SCL than nonhyperactive children in anticipation of the noxious stimulus.

The hyperactive children in this study were all prescribed stimulant medications in the treatment of hyperactivity. Even though they were off their medications a minimum of 48 hours before the measurement session (8 were off at least 20 days before) it might be possible that stimulant medications, over time, change the physiological mechanisms underlying the BIS. If this is the case, then it would be imperative that studies such as this one be conducted on children upon referral rather than after stimulant medication treatment had been in effect.

Comparison of anticipatory SCL responses between the 60 dB and 100 dB conditions suggested that the 100 dB tone may not have been sufficiently "noxious" to produce pronounced increases in anticipatory SCL. In general, the 100 dB condition did produce significantly greater increases in SCL across the anticipatory period than the 60 dB tone; but the initial increases appeared to be fairly small and appeared to level off approximately 1/3 of the way across the anticipatory period. There did not appear to be any question that the 100 dB tone was generally more arousing; but there does seem to be a question about its "noxiousness."

Anecdotal data also suggested that the 100 dB tone may not have been noxious enough to produce the expected increases in anticipatory SCL. During the debriefing session, the children were asked to share their perceptions about the loud tone. The overwhelming majority of subjects, hyperactive and nonhyperactive alike, indicated that they had heard louder auditory stimuli than the 100 dB tone. Among the stimuli which were reported to be louder than the "noxious" stimulus were "guns, motorcycles, fire alarms, smoke detecters, cherry bombs/fireworks, loud music played through headphones, rock concerts, and children screeming in their ears." Children today seem to be in contact with a variety of auditory stimuli which appear to be more "noxious" than the 100 dB stimulus used in the present study. If children are frequently exposed to more intense auditory stimuli than the 100 dB tone used in the present study then dramatic increases in anticipatory SCL might not be expected.

Ethical considerations limited the present study to 100 dB intensity as the loudest the 1000 Hz tone could have been applied. Perhaps another frequency tone could be used in the future which may prove to be more noxious. Also, the use of 100 dB white noise as a noxious stimulus may prove to be a better noxious auditory stimulus. Other noxious stimuli (e.g., cold pressor, foul odors, mild electric shock, vaccination injections by physicians) may provide better characteristics in inducing greater increases in SCL; however, there are problems associated with these as well. Another way to help facilitate anticipatory SCL increases might be to provide specific descriptions which exagerate the noxious quality of the stimulus. One such study provided instructions which described the noxious auditory stimulus as a "loud, startling blast of noise" (Hare et al., 1978, p. 166). The present study only stated that a "loud tone" would be heard at a specific point in time.

No differences between hyperactive and nonhyperactive children were found in their HR responses in anticipation of the 60 dB and 100 dB tones. The trends in HR responses across the anticipatory period were essentially the same for hyperactives and nonhyperacives in the 60 dB and 100 dB conditions. This was consistent with the nonsignificant differences in HR responses found in the Boydstun et al. (1968) and Ferguson et al. (1976) studies; however, direct comparison is not possible because of the differences in data collection procedures. The general pattern or trend of HR across the anticipatory period was characterized by an initial decrease in HR followed by a leveling off and then slight increase. This pattern is similar to the HR responses demonstrated in the orienting response (OR). The OR is characterized by a triphasic curve (cubic relationship) in which HR decreases, then increases, and then decreases again (Andreassi, 1980). This is seen in situations where stimuli are presented continuously across the analysis intervals. In the present study the OR appeared in <u>anticipation</u> of the presentation of auditory stimuli.

Directional fractionation of HR and SCL was also seen in anticipation of the noxious stimulus as SCL tended to initially increase and then stabilize while HR tended to initially decrease and then increase. In situations where a noxious or aversive stimulus is experienced and the individual does not have an opportunity to escape or actively avoid the subsequent presentation, SCL tends to increase while HR does not (Elliot, 1969; cited in Fowles, 1980). The procedure in the present study did not allow the children an active avoidance (escape) response (other than terminating their participation) so the directional fractionation of SCL increases and HR decreases was an expected result.

Overall, it appeared that hyperactive children in the present study did not demonstrate characteristics indicitive of a deficient BIS. Quite the contrary, they may have demonstrated greater BIS activation or arousal in the 100 dB condition as indicated by greater initial increases in SCL during the anticipatory period as compared to nonhyperactive children.

The deficient BIS conceptualization among hyperactive children is not supported by the present study. While hyperactive children tend to have difficulties with impulse control, attentional deficits, and overactive, nongoal related behaviors; these do not seem to be related to deficits in the BIS if such a mechanism even exists. Gray's notions, on the surface, appeared to provide some constructs which might have had some implications for hyperactivity yet they were not supported in the present study. Studies which showed consistantly lower EDA among hyperactive children indicate that more research should be conducted to further investigate if Gray's theory has implications for hyperactivity. Such studies might utilize behavior and personality assessments to diagnose hyperactivity upon referral and attempt to subgroup on such variables as anxiety and conduct disorders (aggression).

Further research involving noxious auditory stimuli should consider the use of white noise or other frequencies of tones as the 100 dB 1000 Hz tone used in the present study may not have been sufficiently noxious to produce pronounced SCL increases. Other noxious stimuli (e.g., cold pressor or vaccination injections by a physician) may be more noxious and provide sufficient stimulation to produce and study greater SCL increases.

Summary

Hyperactive and nonhyperactive children did not differ significantly in their resting SCL; a result consistant with the majority of studies investigating SCL differences. While hyperactive children demonstrated significantly lower HR than nonhyperactive children in the present study, this result was inconsistant with the literature on resting HR differences and was considered to be unique to these two samples.

Results of SCL data analyses indicated that hyperactive and nonhyperactive subjects differed in their SCL trends across the anticipatory period in the 60 dB and 100 dB conditons. Hyperactive children tended to show greater initial increases and later decreases in

SCL in the 100 dB condition than nonhyperactive children. Nonhyperactive children tended to show greater increases and later stability in the 60 dB condition than hyperactive children. There was no support for the notion that hyperactive children are deficient in their BIS.

Results for HR data indicated that hyperactive and nonhyperactive children did not differ in their HR trends across the anticipatory period for the 60 dB or 100 dB conditions. The HR trends were characterized by initial HR deceleration followed by HR acceleration; characteristics of the orienting response.

Gray's (1975, 1976) theory does not appear to offer explanations about why hyperactive children demonstrate impulsive behaviors and attentional problems. It was hypothesized that BIS deficits among hyperactive children would help explain the clinical features of hyperactivity. Data from this study failed to support this hypothesis. Further research utilizing different noxious stimuli should be conducted to further test the theoretical notions presented. Other tests of the deficient BIS hypothesis which might be useful would be to compare hyperactive and nonhyperactive children on active (escape) and passive (inhibition) avoidance tasks. If hyperactive children possess a deficient BIS then their passive avoidance should be deficit compared to nonhyperactive children.

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APPENDICES

APPENDIX A

SOLICITATION LETTER TO PARENTS OF HYPERACTIVE CHILDREN

Southern Illinois
University at Carbondale
Carbondale, Illinois 62901

Department of Educational Psychology

May 26, 1987

Dear Parent:

I am a doctoral student in Educational Psychology at Southern Illinois University studying special characteristics of hyperactive children between the ages of 7 and 12. In order to complete this project a number of hyperactive children are needed to participate in a session where measures of heart rate and finger sweating are studied. Measures of these two variables will be taken while the child is resting and when two tones are presented for 1 second. One tone will be soft (60 decibel) and the other will be loud (100 decibel). These tones are frequently used by audiologists in hearing evaluations and will not damage the child's ears or hearing. Participation in this study also requires hyperactive children be off stimulant medication for at least 48 hours before the measurement session. The entire procedure will take no more than 30 minutes and will be conducted during the third and fourth weeks in June.

When the study is completed, a letter presenting the overall results will be sent to all participants. Each child will be given a unique number so that individual names will not be associated with the data. Complete confidentiality is assured and individual data will not be identifiable or reported. Results will be presented on a group (hyperactive vs. nonhyperactive) basis only.

If your child is between 7 and 12 years of age and you are interested in volunteering to participate in this important study, please sign the informed consent form which is attached and return it to your child's physician. Participation is strictly voluntary and you or your child may withdraw consent or refuse to participate at any time without penalty or discrimination. I will contact all volunteers by phone to arrange a convenient date and time for the measurement session and to answer any questions. The deadline for return of the consent form to your physician is June 5, 1987.

If you have any questions, please write or call. The address is Wham 223, Southern Illinois University, Carbondale, Illinois, 62901 and the telephone numbers are 536-7763 (Work) and 529-3907 (Home).

Thank you for your help. Your participation in this study is greatly appreciated.

Sincerely,

Gary L. Canivez, M.S.
Candidate, Doctor of Philosophy

APPENDIX B

SOLICITATION LETTER TO PARENTS OF NONHYPERACTIVE CHILDREN

Southern Illinois
University at Carbondale
Carbondale, Illinois 62901

Department of Educational Psychology

May 26, 1987

Dear Parent:

I am a doctoral student in Educational Psychology at Southern Illinois University studying special characteristics of hyperactive children between the ages of 7 and 12. In order to complete this project a number of nonhyperactive children are needed to participate in a session where measures of heart rate and finger sweating are studied. Measures of these two variables will be taken while the child is resting and when two tones are presented for 1 second. One tone will be soft (60 decibel) and the other will be loud (100 decibel). These tones are frequently used by audiologists in hearing evaluations and will not damage the child's ears or hearing. The entire procedure will take no more than 30 minutes and will be conducted during the third and fourth weeks in June.

When the study is completed, a letter presenting the overall results will be sent to all participants. Each child will be given a unique number so that individual names will not be associated with the data. Complete confidentiality is assured and individual data will not be identifiable or reported. Results will be presented on a group (hyperactive vs. nonhyperactive) basis only.

If your child is between 7 and 12 years of age and you are interested in volunteering to participate in this important study, please sign the informed consent form which is attached and return it to your child's school. Participation is strictly voluntary and you or your child may withdraw consent or refuse to participate at any time without penalty or discrimination. I will contact all volunteers by phone to arrange a convenient date and time for the measurement session. The deadline for return of the consent form to the school is June 1, 1987.

If you have any questions, please write or call. The address is Wham 223, Southern Illinois University, Carbondale, Illinois, 62901 and the telephone numbers are 536-7763 (Work) and 529-3907 (Home).

Thank you for your help. Your participation in this important study is greatly appreciated.

Sincerely,

Gary L. Canivez, M.S.
Candidate, Doctor of Philosophy

APPENDIX C

INFORMED CONSENT FORM

CONSENT FORM

This study is being conducted to investigate the effects of two tones, one soft and one loud, on children's heart rate and finger sweating. The soft (60 decibel) and loud (100 decibel) one second long tones will be presented through earphones of a standard audiometer used in conducting hearing screenings. These tones are frequently used by audiologists in hearing evaluations and will not damage the child's ears or hearing. The entire procedure will take no more than 30 minutes and will be conducted during the third and fourth weeks in June. Each child will be given a unique number so that individual names will not be associated with the data. Complete confidentiality is assured and individual data will not be identifiable or reported. Participation is strictly voluntary and you or your child may withdraw consent or refuse to participate at any time without penalty or discrimination.

This project has been reviewed and approved by the Carbondale Committee for Research Involving Human Subjects. The Committee believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberties, and rights. The Chairperson of the Committee may be reached through the Graduate School, Southern Illinois University at Carbondale, Carbondale, Illinois 62901. The telephone number of the Office is 618/536-7791, ext. 22/55.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that I may withdraw without prejudice at any time.

______________________________ ______________

Parent/Legal Guardian Signature Date

______________________________ ______________

Parent/Legal Guardian Signature Date

____

Telephone Number

Child Information:
Date of Birth: ____________
Sex: M F
Grade: 1 2 3 4 5 6 7

APPENDIX D

TRANSCRIPT OF TAPED INSTRUCTIONS FOR THE SOFT/LOUD TONE PRESENTATION ORDER

Start Tape

Hello! Thank you for coming today to help me in this research project. All instructions and directions will be heard through your headphones. Please do not move your arms or feet. The study will not take long. Remember, do not move your arms or feet. Try to sit quietly and relax for a few minutes.

Stop Tape

3 Minute Resting Period

Start Tape

Good! In a few moments you will hear the experimenter count slowly from 1 to 5. After the number 5 you will hear a soft tone and this is what it sounds like. (Present 60 dB tone) You will have to wait one minute before the start of each counting procedure. Remember, the experimenter will count from 1 to 5 and after the number 5 you will hear the soft tone.

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 60 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 60 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 60 dB Tone)

1 Minute Interval

In a few moments you will hear the experimenter count slowly from 1 to 5. After the number 5 you will hear a loud tone and this is what it sounds like. (Present 100 dB tone) You will have to wait one minute before the start of each counting procedure. Remember, the experimenter will count from 1 to 5 and after the number 5 you will hear the loud tone.

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 100 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 100 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 100 dB Tone)

Stop Tape

APPENDIX E

TRANSCRIPT OF TAPED INSTRUCTIONS FOR THE LOUD/SOFT TONE PRESENTATION ORDER

Start Tape

Hello! Thank you for coming today to help me in this research project. All instructions and directions will be heard through your headphones. Please do not move your arms or feet. The study will not take long. Remember, do not move your arms or feet. Try to sit quietly and relax for a few minutes.

Stop Tape

3 Minute Resting Period

Start Tape

Good! In a few moments you will hear the experimenter count slowly from 1 to 5. After the number 5 you will hear a loud tone and this is what it sounds like. (Present 100 dB tone) You will have to wait one minute before the start of each counting procedure. Remember, the experimenter will count from 1 to 5 and after the number 5 you will hear the loud tone.

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 100 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 100 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 100 dB Tone)

1 Minute Interval

In a few moments you will hear the experimenter count slowly from 1 to 5. After the number 5 you will hear a soft tone and this is what it sounds like. (Present 60 dB tone) You will have to wait one minute before the start of each counting procedure. Remember, the experimenter will count from 1 to 5 and after the number 5 you will hear the soft tone.

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 60 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 60 dB Tone)

1 Minute Interval

1 . . . 2 . . . 3 . . . 4 . . . 5 (Present 60 dB Tone)

Stop Tape

VITA

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Southern Illinois University

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MAJOR PROFESSOR: John J. Cody, Ph.D.

PUBLICATIONS:

Canivez, G. L. (1986). Academic achievement of male and female high school athletes [Summary]. Proceedings of the 18th Annual Convention of the National Association of School Psychologists, 149-150.

Canivez, G. L., & Prichard, K. K. (1986). Motivational distortion scales for the Children's Personality Questionnaire [Summary]. Proceedings of the 18th Annual Convention of the National Association of School Psychologists, 276-277.