Cerebral Asymmetry in Psychopaths:

A Behavioural and Electrocortical Investigation

by

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Abstract

Researchers studying forensic psychopathology have been searching for biological explanations for the socially costly and puzzling disorder, psychopathy. This dissertation attempts to replicate and expand upon previous findings that psychopaths have unusually lateralized brains. In the first of two studies, 12 psychopathic and 12 nonpsychopathic incarcerated men completed three verbal tasks chosen to capitalize on lateralized cognition. Event-related potentials (ERPs) were measured during the tasks to approximate magnitude, location, and timing of cortical activation. In Study 2, participants completed four nonverbal tasks.

Overall patterns of lateralized performance and electrocortical activity suggest that psychopaths use unusual strategies and/or brain areas to process information with no apparent decrements in performance. It appears that psychopaths have diffusely organized brains for a wide variety of cognitions, rendering them incapable of integrating emotional and verbal information. As a result, they may be unable to follow social norms or develop meaningful relationships with others, while appearing intellectually normal.

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Introduction and Overview

> "... I think you would find, Copperfield, if you had an opportunity of observing his course, that money would never keep that man out of mischief. He is such an incarnate hypocrite, that whatever object he pursues, he must pursue crookedly. It's his only compensation for the outward restraints he puts upon himself. Always creeping along the ground to some small end or other, he will always magnify every object in the way; and consequently will hate and suspect everybody that comes, in the most innocent manner, between him and it. So, the crooked courses will become crookeder, at any moment, for the least reason, or for none." (from "David Copperfield" by C. Dickens, 1850, p. 636)

Well over 100 years after Charles Dickens described the cruel and conniving character Uriah Heap in his novel, David Copperfield, we continue to be plagued and yet intrigued by those we could label "psychopaths". Psychopathy continues to be a fascinating but socially costly disorder. Most clinicians and researchers agree that psychopathy is a serious personality disorder that disrupts or diminishes the individual's ability to control his or her behaviour, develop meaningful and stable relationships, and to experience the depth and quality of emotions that nonpsychopaths do (Cleckley, 1976; Hare, 1970). However, there is still little consensus on what actually causes or what is at the core of psychopathy.

Among the clearest evidence that psychopaths differ psychologically from nonpsychopaths is their apparent inability to integrate language and emotion. This has been noted in both clinical descriptions and research investigations. Cleckley (1976) believed that the psychopath "can learn to use ordinary words... [and] will also learn to reproduce appropriately all pantomime of feeling... but the feeling itself does not come to pass" (p. 230). Similarly, Grant (1977) commented that "... the ideas of mutuality of sharing and of identification are beyond his understanding in an emotional sense; he knows only the book meaning of words" (p. 50). Perhaps it is psychopaths' inability to process the affective aspects of language that impairs their ability to experience emotions important for morality and self-control, such as guilt, remorse, and empathy. What might be behind their inability to use connotative or emotional aspects of language? There is reason to suspect that an unusual organization of aspects of the cerebral hemispheres may interfere with optimal use of language functions of the right hemisphere. Also, functions usually housed in the left hemisphere in healthy right-handed individuals may be organized more diffusely across both sides of the cerebral cortex in psychopaths.

That psychopaths have a language disorder has been the focus of recent research (e.g., Gillstrom & Hare, 1988; Williamson, 1991; Williamson, Harpur, & Hare, 1991). These empirical studies were conducted after Flor-Henry (1973, 1976) had proposed that a dysfunction of the left fronto-temporal cortex and limbic system resulted in psychopathic behaviour. In particular, he argued that a deficient behavioural inhibition system due to a dysfunctional "dominant" or left hemisphere resulted in psychopathic disorders. His group conducted several studies with clinical populations (e.g., Flor-Henry, 1976,1985; Yeudall, 1977; Yeudall et al., 1981; 1982) to support these ideas. Although this hypothesis appears compelling, closer inspection of these studies suggests that left hemisphere dysfunction may be more related to criminality than to psychopathy. For example, Fedora and Fedora (1983) administered a large battery of neuropsychological tests to noncriminals and criminals divided into psychopathic and nonpsychopathic groups based on Hare's 22-item Psychopathy Checklist (PCL; Hare, 1980). It was clearly evident that the two criminal groups did *not* differ from each other on the bases of these tests. However, both criminal groups demonstrated deficits on tests that tap left frontal and temporal skills (such as verbal fluency). Deficits on these tasks may also be related to impulsivity, poor education, low socioeconomic status, drug and alcohol abuse, dyslexia, lack of motivation, and so on, all of which have been found to contribute to criminal behaviours.

In an early study, Hare (1979) had psychopaths and nonpsychopaths complete a divided visual field word identification task. Both groups showed a normal right-visual field (left hemisphere) advantage on this task, results inconsistent with Flor-Henry's hypothesis. A second study showed that psychopaths were less lateralized than nonpsychopaths but not dysfunctional in a verbal dichotic listening task (Hare & McPherson, 1984). Also, in some complex language tasks, it appeared that psychopaths relied more on right than left hemisphere resources (e.g., Jutai & Hare, 1983). Psychopaths tend to differ also in the way that they attend to stimuli (see Harpur & Hare, 1990), analyze nonverbal emotional information (Christianson, Forth, & Lidberg, 1995), and perhaps in the way which they process non-language tasks (Nachshon, 1988). We might speculate that many cognitive abilities of psychopaths are not as neurologically "organized" as they are in nonpsychopaths, and that a "dysfunctional dominant hemisphere" is not likely the "core" deficit in psychopaths.

Regardless of the inconclusive findings by Flor-Henry and Yeudall's group, an examination of left- and right-sided cortical functions led to some interesting findings, particularly that psychopathic criminals demonstrated measurable differences in the use of language and in the cortical organization of linguistic functions. This dissertation examined the lateralized cognitive abilities of psychopaths in order to obtain a clearer understanding of how psychopathic and nonpsychopathic criminals differ in brain organization, perhaps leading us closer to understanding the etiology of psychopathy.

Most researchers in the field of neuropsychology assume that lateralization of cortical function is adaptive, resulting in efficient information processing and compaction of large amounts of neural tissue into a cranium limited in size (Hellige, 1993). It could be argued that psychopathic traits are adaptive and highly evolved: Psychopaths feel little anxiety and depression, may succeed in various careers, and may generate many offspring because of their promiscuity. An alternate argument is that they are far from successful, in that they may spend a large portion of their lives incarcerated, live unstable and dangerous lives, feel chronically bored and dissatisfied, and never experience the joy and contentment of positive and loving relationships. From a larger, societal perspective, their behaviours are extremely maladapted, considering the amount of damage they do. Could a maladaptive organization of brain structures cause or at least contribute to the development of this personality disorder?

Left and right hemisphere activity can be examined in several ways. In this study I included both behavioural performance measures and electrocortical signals (event-related potentials or ERPs) to assess how psychopaths differ from nonpsychopaths in their lateralized brain activity during both language and non-language tasks. I also examined whether or not psychopaths are relatively dysfunctional on tasks that tap primarily left hemisphere resources, and whether they are more dysfunctional than nonpsychopaths on tasks that include an emotional component.

Review of the Literature

Assessment of Psychopathy

Until recently, psychopathy has been conceptualized and assessed in varying ways, making it difficult to compare results from different studies. The most easily measured aspects of psychopathy are its overt behavioural characteristics (e.g., antisocial activity, poor employment record, sexual promiscuity). Several assessment methods have focused on these characteristics; the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; American Psychiatric

Association, 1994) and its category of antisocial personality disorder (APD) provides the best example. Such procedures are often reliable, but they lack demonstrated validity. Other procedures incorporate a detailed assessment of personality and interpersonal characteristics, as well as an assessment of behaviour. The Psychopathy Checklist (PCL; Hare, 1980) and its revision (PCL-R; Hare, 1991, Hart, Hare, & Harpur, 1992) is an example of this method. Because of the extensive literature on its reliability and validity with forensic populations (e.g., Hare, 1985; Harpur, Hakstian, & Hare, 1989; Kosson, Smith, & Newman, 1990; Wong, 1984), the PCL-R was used in the present study.

The PCL-R consists of two stable correlated factors (Hare et al., 1990; Harpur, Hakstian, & Hare, 1988). Both are considered essential in the diagnosis of psychopathy. Factor 1 reflects affective and interpersonal characteristics such as glibness, arrogance, callousness, and manipulativeness, characteristics that are considered fundamental to the traditional clinical conception of psychopathy. This factor is correlated with self-report measures of empathy, narcissism, machiavellianism, and anxiety (Hare, 1991). Factor 2 reflects the behavioural characteristics of psychopathy. This factor is related to the DSM-III-R (APA, 1987) diagnosis of APD, criminal behaviours, and self-report measures of sensation-seeking and substance abuse (Hemphill, Hart, & Hare, 1990; Harpur et al., 1989). See Table 1 for a summary of the PCL-R items.

Table 1:

Items Comprising the Psychopathy Checklist-Revised (Hare, 1991)

1. Glibness/Superficial Charm
2. Grandiose Sense of Self-Worth
3. Need for Stimulation/Proneness to Boredom
4. Pathological Lying
5. Conning/Manipulative
6. Lack of Remorse or Guilt
7. Shallow Affect
8. Callous/Lack of Empathy
9. Parasitic Lifestyle
10. Poor Behavioural Controls
11. Promiscuous Sexual Behaviour
12. Early Behavioural Problems
13. Lack of Realistic Long-Term Goals
14. Impulsivity
15. Irresponsibility
16. Failure to Accept Responsibility for Own Actions
17. Many Short-Term Marital Relationships
18. Juvenile Delinquency
19. Revocation of Conditional Release
20. Criminal Versatility

The Discovery and Assessment of Cerebral Asymmetry

In the early and mid 1800s, European medical scientists and physicians such as Bouillaud, Dax, Auburtin, Broca, and Wernicke, observed that left hemisphere injuries often resulted in aphasia (loss of speech functions). Although there was some reluctance to accept that cognitive skills were localized, it was soon clear that the left cortical hemisphere was essential for most aspects of verbal functioning. However, the importance, function, and purpose of the right or "non-dominant" hemisphere remained unknown for several decades (Gibson, 1962; Kolb & Whishaw, 1990; Springer & Deutch, 1993).

By the late 1800s, John Hughlings Jackson promoted the importance of the "non-dominant" or right hemisphere. He noted that the brain is physically doubled, and that the two halves are both alike and different. Hughlings Jackson stated that it was obvious that the left hemisphere is almost always necessary for speech (by observing aphasic patients), but that the right hemisphere processes the automatic and emotional use of words. For example, an aphasic person with an injury to the left hemisphere may occasionally swear when vexed. Hughlings Jackson also suggested that we are not conscious of the most automatic functions of our nervous system, including the more automatic aspects of language use (conjuring up or reviving images of the symbolic meanings of words, attaching emotionality to language, etc.). He credited the right hemisphere, particularly the posterior portions, for awareness of one's surroundings, and for voluntary or conscious recognition of images (objects, places, persons, etc.). He also credited the right hemisphere for being the more "receptive" portion of the brain, and the left for being more "expressive" (Hughlings Jackson, 1915). Hughlings Jackson's speculations over 100 years ago were quite accurate, although much has been learned since about the specifics of what each portion of the brain is responsible for.

We now know much more about hemispheric specialization through clinical observation and research on abnormal populations, such as those with localized brain trauma, neurosurgery patients, and split-brain patients. For example, in 1935, Weisenberg and McBride assessed over 200 brain injured individuals, performing many hours of testing on each of them. They concluded that while those with left hemisphere damage tended to do poorly on verbal tests, those with right hemisphere damage tended to do more poorly on tests that emphasized geometry, puzzle assembly, and other tasks involving visual patterns, form, distance, and space relationships. However, a verbal-spatial dichotomy cannot account for all findings. For example, Brownell, Simpson, Bihrle, Potter, & Gardner (1990) found that stroke patients with left hemisphere damage had less difficulty interpreting metaphoric aspects of language than those with right hemisphere damage, suggesting that an intact right hemisphere is essential for the comprehension of metaphors. Results from direct stimulation of the brain (Penfield & Roberts, 1959), the Wada technique (where one cerebral hemisphere is anesthetized; Wada & Rasmussen, 1960), and split-brain patients (those epileptic patients who have had the corpus callosum surgically cut to prevent the spreading of seizures to both hemispheres; e.g., Sperry, 1968), support these general findings. That is, several sources of information from neurological patients illustrate that the cerebral hemispheres tend to be specialized for different types of cognitive skills. However, it could be argued that these results would be more tenable if there were similar findings in normal, healthy individuals. Fortunately, it has been found that it is possible to detect asymmetric cerebral specialization in normal individuals.

Several methods have been devised for conducting such research. For example, dichotic listening tasks provide a simple method for assessing which hemisphere is better equipped to analyze certain sounds. In these tasks, individuals hear different sounds in each ear simultaneously, and the ear contralateral to each sound should receive the information most quickly and completely. This is because the contralateral projections from each ear are stronger than the ipsilateral pathways. In fact, there is evidence that information traveling the ipsilateral route from ear to brain is suppressed or inhibited (Kimura, 1961; Rosenzweig, 1951). Among the earliest and most robust findings were that the left hemisphere is more accurate at detecting speech sounds (Kimura, 1961), while the right hemisphere is more accurate at identifying melodies (Kimura, 1964). In the visual mode, divided visual field (DVF) experiments provide a comparable paradigm. The visual system is organized such that information presented in the left visual field (LVF) is projected to the right cerebral cortex, and vice versa. Subjects focus their eyes on the centre of the visual field, and stimuli are flashed (too quickly to allow visual exploration by moving the eyes) to either the left or the right side of the fixation point. Again we find that the left hemisphere (information in the right visual field or RVF) is efficient at analyzing most verbal material, and the right hemisphere (stimuli in the LVF) is efficient at analyzing nonverbal material such as faces and dot localizations (Geffen, Bradshaw, & Wallace, 1971; Rizzolati, Umilta, & Berlucchi, 1971).

In a third method for measuring cerebral asymmetry, subjects perform two tasks at once. Kinsbourne (Kinsbourne & Cook, 1971; Kinsbourne & Hicks, 1978) found that right-handed finger-tapping (or balancing a dowel on the right index finger) is disrupted more by speaking than by reading silently. Left-handed performance tended to be the same, regardless of whether the subject was speaking or reading silently. These intriguing findings suggest that adjacent areas of the brain (i.e., the areas controlling speech and hand movements) may compete or interfere with each other. This principle is also applied in another paradigm termed the "probe evoked potential", which will be described below. The current investigation employed a dichotic listening task, several divided visual field tasks, and two probe evoked potential tasks.

We see that there are many ways to examine lateralized cognition, and that each hemisphere tends to be specialized. The emotional aspects of cognition have been found to be lateralized as well, although a clear left-right dichotomy is not evident. As Davidson (1993) points out, it is important to distinguish cerebral organization of emotional expression and experience from emotional perception and comprehension. It is believed that an intact left hemisphere is essential for experiencing and expressing positive emotions, while an intact right hemisphere is essential for negative emotions (for reviews, see Borod, 1992; Sackeim, 1991). An examination of the findings with patients undergoing the Wada technique (Branch, Milner, & Rasmussen, 1964; Wada, 1949), and those who have had focal lesions or lobectomies strongly suggests that destruction or suppression of left hemisphere activity (particularly frontal) leads to dysphoria (e.g., Gainotti, 1972; Robinson et al., 1984), pathological crying (e.g., Cantu & Drew; 1966; Sackeim et al., 1982) or a catastrophic reaction unrelated to the degree of deficit (Gainotti, 1972). Destruction or suppression of the right hemisphere usually leads to indifference, euphoria, or mania (e.g., Starkstein, Boston, & Robinson, 1988) or pathological laughing (Sackeim et al., 1982). Sackeim et al. (1982) also reviewed 103 reports of epileptic patients with uncontrollable laughing or crying, the latter being far more rare. Uncontrollable laughter was more typically associated with left-sided foci, and uncontrollable crying with right-sided foci. Upon reviewing this literature, Sackeim (1991) proposed that there is a contralaterally mediated, reciprocal inhibitory control over mood and emotional expression. Considering affective states as “preprogrammed release phenomena”, he says, "states of depression and euphoria, whether or not pathological, reflect alterations in the balance of inhibitory and excitatory control in the lateralized affective systems" (p. 220). Psychopaths' indifference in the face of difficulties such as imprisonment would suggest they have dysfunctional right frontal structures.

Asymmetry of emotional experience has been studied in neurologically intact individuals as well, and the principles outlined above are supported. McFarland and Kennison (1989) found that right-handed individuals rated music as more positive when it was presented to the right ear (the left hemisphere receiving the information more completely than the right) and more negative when presented to the left ear (the right hemisphere receiving the information more completely than the left), whereas they found the opposite pattern with left-handed individuals. Drake (1984, 1985) found that when normal subjects had (inferred) greater left- than right-sided cortical activation (rightward orientation of attention, right-ear input, and right-sided visual stimuli), they were more optimistic and recommended greater risk-taking than those with (inferred) greater right-sided cortical activation. Drake proposed that left-sided stimulation increases positive affect. Davidson and his colleagues (e.g., Davidson, 1993; Henriques, & Davidson, 1991; Wheeler, Davidson, & Tomarken, 1993) proposed that these patterns of frontal activation may predispose an individual to respond to environmental triggers in a particular way: for example, right frontal hyperarousal may be associated with proneness to depression. Using EEG measures of arousal, they demonstrated that increased left-sided frontal activity is related to the experience of positive affect, whereas increased right-sided activation is related to the experience of negative affect. Normal individuals with extreme and stable left frontal activation tend to experience more positive dispositional mood, while those with extreme and stable right frontal activation tend to experience more negative dispositional mood. In sum, most research supports the contention that right-sided and left-sided frontal electrocortical activity is associated with the experience of negative and positive affect, respectively.

Comprehension and perception of emotion appear to rely on an intact right hemisphere. Right-sided cerebral injuries result in difficulties understanding emotional tone in faces and speech, regardless of valence or type of emotion (e.g., Borod, 1992; Heilman, Scholes, & Watson, 1975; Tucker, Watson, & Heilman, 1977). Perception of emotion in faces is mediated by the right hemisphere, independent of right hemisphere superiority for spatial analysis (e.g., Etcoff, 1984; Strauss & Moskovich, 1981). Ladavas, Cimatti, Pesce, and Tuozzi (1993) presented a split-brain patient with emotionally-laden (sexual, disgusting) and neutral slides. They found that the two hemispheres were equally competent for recognition and categorization of the emotion and the content of the slides, even without conscious awareness of their content. In contrast, only emotional slides presented in the left visual field (LVF) elicited heart-rate changes. A recent dichotic listening study by Bulman-Fleming and Bryden (1994) demonstrated that in normal individuals accuracy for word identification was greater for the right ear than for the left ear, but accuracy in identifying emotional tone was greater for the left ear than for the right ear. This suggests that the two hemispheres integrate content and emotional tone to fully comprehend speech.

The right hemisphere's role in the perception of the emotional content of visually presented words is less clear. Divided visual field (DVF) tasks show that the left hemisphere is more accurate and faster at identifying words than is the right hemisphere, regardless of emotionality (Eviator & Zaidel, 1991; Graves, Landis, & Goodglass, 1981; Strauss, 1983). However, the right hemisphere does seem to have some skill at identifying the emotionality of visually presented words. Graves et al. (1983) found that normal males identified twice as many emotional words than nonemotional words presented in the LVF. In sum, the right hemisphere is more involved in the processing of emotional information than is the left hemisphere.

Psychopathologies such as depression, mania, anxiety disorders, alcoholism, and schizophrenia have been studied from the perspective of cerebral asymmetries. Research with those suffering from mood disorders suggests that depression disrupts normal lateralized neurocognitive function, especially functioning of the right hemisphere. These patients exhibit greater difficulties with tasks tapping visuospatial skills than with those measuring verbal skills (e.g., Flor-Henry, Koles, Howarth, & Burton, 1979; Gruzelier, Seymour, Wilson, Jolley, & Hirsch, 1988). Attention and concentration, both clearly disrupted in depressed individuals, may account for these performance deficits. Wale and Carr (1990) administered two verbal dichotic listening tasks to depressed patients and matched controls. One task drew on attentional resources, the other on perceptual skills. The two groups were differentiated on the former, but not the latter. Also, anxious depressed individuals showed a normal ear asymmetry, while those with symptoms of withdrawal and psychomotor retardation demonstrated an abnormal reduced asymmetry for the task. The authors proposed that depression initially involves a right hemisphere-centered dysfunction associated with negative mood and a decline in overall attentional capacity. Then, those who develop the withdrawal-retardation symptoms have a failure of the left frontal modulatory mechanisms, resulting in a reduction of left hemisphere attentional functioning. However, some researchers have found reversed asymmetries in depressed patients. Johnson and Crockett (1982) found that dichotic listening task performance for both words and musical chords was abnormally lateralized in depressed patients, but reverted to normal asymmetry upon remission of symptoms. Davidson, Schaffer, and Saron (1985) had depressed and normal-mood subjects rate emotion on bilaterally presented happy, sad, and neutral faces. Depressed subjects rated faces presented in the LVF as more happy than those presented in the RVF, a pattern opposite to that of the non-depressed controls. It is difficult to compare the results from these different studies, especially because of differing stimuli and modes of presentation (verbal versus nonverbal and visual versus auditory). A study combining verbal and nonverbal tasks presented in both visual and auditory modes may help sort out the mixed results.

Those suffering from mania show performance deficits that also suggest right hemisphere dysfunction. For example, Bruder et al. (1994) found that manic patients failed to show the normal left ear (right hemisphere) advantage in a dichotic complex tone task (and displayed a slight right ear advantage instead), but that their performance returned to normal with remission of symptoms. However, the manic patients also showed slight verbal (left hemisphere) dichotic listening task decrements for both ears relative to normal controls. Flor-Henry et al. (1979) suggested that mania involves a loss of contralateral inhibition, leading to left hemisphere hyperactivity. This may account for the racing thoughts, excessive speech, and thought disorder present in mania. It may also account for the unusual results found by Bruder and colleagues.

Otto, McNally, Pollack, Chen, & Rosenbaum (1994) examined perceptual asymmetries and memory biases for threatening material in those suffering from panic and generalized anxiety disorders. In healthy controls, memory for threatening words was unrelated to perceptual asymmetries in a dichotic listening task. In contrast, a greater right-ear (left hemisphere) advantage was associated with a tendency to recall threatening words in a subsequent memory task in the patient groups. They concluded that a tendency toward cognitive avoidance (due to fear) is associated with a greater right-ear (left hemisphere) advantage for verbal tasks in anxiety-disordered individuals. Thus, it appears that anxious individuals may be more lateralized for verbal skills than are non-anxious people. This may be related to the increased left hemisphere activation found in anxious individuals (Tucker, Antes, Stenslie, & Barnhardt, 1978). The results found by Otto and associates also support much of the research on mood disorders and asymmetries: Those suffering from affective disturbances exhibit right hemisphere deficits or left hemisphere hyperactivity.

Cerebral asymmetries have been studied in alcoholics and those at risk for alcoholism; typically there is some evidence of right hemisphere deficits (Drake, Hannay & Gam, 1990; Errico, Parsons, & King, 1991; Mills, 1989; Schandler, Brannock, Cohen, Antik, & Caine, 1988; Schandler, Cohen, McArthur, Naliboff, & Hassal, 1988). What is confusing about this literature, however, is that alcoholic people may exhibit a variety of psychiatric and neurologic disorders. In particular, most researchers do not differentiate between alcoholics who have concurrent mood disorders and those who have psychopathic traits. What is clear is that antisocial tendencies are an important consideration in understanding neuropsychological deficits in alcoholics (Bauer, Hesselbrock, O'Connor, & Roberts, 1994; Malloy, Noel, Rogers, Longabaugh, & Beattie, 1989). For example, Mills (1989) found that those at risk for alcoholism due either to genetic-familial patterns or antisocial personality style exhibited right cortical hyperarousal during visuospatial tasks.

Finally, there is a large body of research examining psychosis and cerebral asymmetries, and most investigators have argued for a left hemisphere disorder associated with psychosis (e.g., Flor-Henry, 1976; Gruzelier & Venables, 1974; Gruzelier et al., 1988; Johnson & Crockett, 1982). However, the abnormalities in lateralized cognition associated with psychosis appear to be more complicated than simply left hemisphere dysfunction. In a recent study by Richardson and

Gruzelier (1994), subjects displaying positive symptoms of schizotypy ("active" and "unreality" syndromes) made more left-sided errors on a dot localization task than those displaying negative symptoms ("withdrawn" syndrome). Those with negative symptoms tended to make more right- than left-sided errors instead. In their second study (Gruzelier & Richardson, 1994), the "active" psychotically-prone subjects exhibited better memory for words than faces, while the "withdrawn" psychotically-prone subjects exhibited a bias in favour of memory for faces. This would suggest that subjects showing subclinical positive symptoms of psychosis have right hemisphere dysfunction, while those with subclinical negative symptoms have left hemisphere dysfunction. Some researchers have argued that faulty interhemispheric transfer of information by the corpus callosum produces schizophrenic symptoms (for a review, see Coger & Serefetinides, 1990).

One could speculate that disorders resulting in high arousal or emotional reactivity (mania, anxious depression, generalized anxiety disorder, and the positive symptom profile of psychosis) are related to right hemisphere dysfunction and left hemisphere activation, while disorders that result in low arousal or emotional reactivity (withdrawn forms of depression and negative symptoms of psychosis) are related to left hemisphere dysfunction. As Springer and Deutsch (1993) point out, in most psychopathology there may be both (subtle) lateralized cortical and subcortical dysfunction as well as unusual or defective interhemispheric communication and balance of arousal that can account for or contribute to the affective and cognitive symptoms. It is difficult to disentangle these processes.

Models of Cerebral Asymmetry and Their Relevance for Psychopathy

Many theories have been proposed in order to understand what evolution has designed each hemisphere to do. Most have attempted to specify a fundamental processing dichotomy that distinguishes the two hemispheres, such as verbal-nonverbal (e.g., Curry, 1967) and serial-parallel (Cohen, 1973). Although there is support for the idea that the left hemisphere is more equipped for well-learned, verbal, and sequential information, and the right hemisphere is better equipped to process non-verbal, spatial, and novel information (see Benton, 1985; Boles, 1991; Davidson, Chapman, Chapman, & Henriques, 1990; Kimura, 1961, for some examples and overviews of the literature), Boles (1991) has pointed out that most of these dichotomous approaches have been empirically contradicted to some extent (e.g., Boles, 1984; White & White, 1975). Other theories attempt to tie the activities of the two hemispheres together in a more interactive and comprehensive manner. Hellige (1993) has proposed that a model of lateralized cerebral organization should take into account five principles. These are (1) that many cognitive and behavioural asymmetries can be accounted for by asymmetries in the brain; (2) the two cortical hemispheres are parts of a much larger, anatomically extensive information-processing system; (3) some asymmetries in humans have behavioural and biological parallels in other species; (4) there are individual differences in patterns of hemispheric asymmetries and in the ways that the two hemispheres interact; and (5) the development of hemispheric asymmetries, both over the lifespan and the course of evolution, is important for understanding the nature and creation of these asymmetries. Hellige also pointed out that there is both subtlety and breadth to the various observed behavioural and cognitive asymmetries. That is, psychological and anatomical studies show us that, despite many measured differences, the two hemispheres are more alike than different, and that both sides of the brain can perform most tasks at some level. However, it has also been shown that asymmetric skills are very broad in nature, making it unlikely that any one neurological substrate or psychological dimension can account for all asymmetries. Hellige suggests that it is more sensible to search for how the two hemispheres *complement* each other. That is, both hemispheres are likely involved in most cognition, working in concert (with the help of other brain structures such as the corpus callosum and the limbic system) to carry out thought and behaviour in an efficient manner.

An example of a fairly comprehensive model of cerebral asymmetry is provided by Tucker and Williamson (1984). They propose that the two hemispheres work in concert to self-regulate attentional processes. The left hemisphere, dependent particularly on dopaminergic innervation, is important for focusing attention on specific, motivated, and complex motor tasks and for conscious control of behaviour. Well-learned and sequential cognitive skills (such as verbal and arithmetic skills) are best handled in this mode. Tucker and Williamson term this mode "activation". The right hemisphere, dependent primarily on noradrenergic innervation, works in an "arousal" mode, and when primed allows one to focus more broadly on a wide variety of novel information. This hemisphere is better suited than the left for spatial orientation and global perception, and for integration of emotional cues from visceral and sensory channels. Depending on the individual's environmental needs, one or the other hemisphere becomes particularly active. Jutai's (1984) review of the cerebral asymmetry of attention supports this theory. Tucker and Williamson tie their model to psychopathology and personality style. For example, they suggest that an extrovert has a bias toward right-sided arousal, as he or she seeks out new and interesting information. Similarly, an hysteric person may have unmodulated right hemisphere arousal, and deficient incorporation of left hemisphere involvement in cognition. In contrast, those who are introverted, anxious, or obsessive may have a bias toward high left hemisphere activation and suppressed right hemispheres. From Tucker and Williamson's postulations we could predict that, cognitively, psychopaths may show an imbalance in favour of more left- than right hemisphere activity, in that they show few deficits in well-learned and motivated tasks, tend to "over-focus" their attention, and do not integrate or interpret emotional (visceral, sensory) experiences and cues with verbal labels.

However, psychopaths' personality style favours a prediction of more right-sided activation, in that they are sensation-seeking, deficient in analytic reasoning skills, low in anxiety, and have exaggerated (but superficial) emotional responsiveness.

Another broad and relevant theory of cerebral organization is Geschwind and Galaburda's (1987) "neurodevelopmental model". This theory, although compelling, has been criticized on the basis that it is essentially impossible to test in its full form (Boles, 1991; McManus & Bryden, 1991). In this model, it is postulated that hormonal and genetic factors combine to organize the developing brain. Geschwind and Galaburda speculate that during development retarded development of one area causes increased development of adjacent (beside the area within the same hemisphere) and homologous portions (the same area in the opposite hemisphere). Nonadjacent, nonhomologous areas that show strong neural connections (connectedness) to an area of increased development will also show increased development. In particular, fetal testosterone affects the rate of neural growth, and predicts the development of handedness, developmental disorders, degree of "normal" lateralization, and functioning of the immune system. Although their theory does not cover cognitive styles or psychopathology, it does make predictions about anomalous asymmetry and the lateralization of cognitive skills. That is, those who are exposed to excessive testosterone during fetal development are likely to have delayed growth of the posterior left hemisphere and anterior right hemisphere, and a compensatory increased growth of the posterior right hemisphere. Therefore, these individuals may be more likely to display functionally reversed or decreased lateralization of cognitive skills. This theory, however, makes predictions that are likely irrelevant to psychopathy. For example, the same neurodevelopmental defects are supposedly related to an increase in autoimmune disorders, left handedness, cancer, facial deformities, and low IQ. Regardless, perhaps the manner in which the brains of psychopaths develop results in diffuse organization or limited interconnections among brain areas, limiting their ability to incorporate emotional information into other cognitive processes.

In summary, there are several aspects of these models of cerebral organization that are relevant to cerebral asymmetries in psychopathy. It is now widely accepted that we are congenitally prone to develop lateralized brains, both in terms of neuroanatomy and cognitive and behavioural processes. A wide variety of biological and environmental processes (e.g., genetics, birth trauma, pre- and post-natal hormones, early experiences such as education, nutrition, head injuries) may account both for the tendency to develop lateralized brains and for a wide array of individual differences in neural organization. For most of us, the left hemisphere tends to be better equipped to process sequential, focused, detailed, and well-learned cognition, information that is of high spatial frequency. It conducts most aspects of verbal processing. The left hemisphere may also be responsible for logic and self-control. The right hemisphere is better suited for low-spatial frequency information (broad attention to the environment, spatial skills) and for incorporating input important for emotion from sensory and visceral cues. The two hemispheres work together to perceive, process, and act. The corpus callosum may act as a gate, filtering, enhancing and directing the interhemispheric transfer of information. Finally, each hemisphere may have the capacity to inhibit the other when appropriate (i.e., to enhance the attentional resources of one brain area by reducing competing information processing in another area). This cooperative "division of labour" enables us to experience a wide range of thoughts and emotions most efficiently. Finally, aberrant lateralization has been proposed to account for many psychopathologies and extreme personality styles, and I propose that it may account for psychopathy.

We might argue that psychopaths lack the highly developed network of cells that allows most of us to feel and incorporate a wide variety of emotional information. This network of cells, believed to be housed in the right hemisphere, may be replaced by other connections that process non-emotional information (such as much of language), resulting in the psychopath being less lateralized than others for typically left hemisphere skills. Can it simply be that the psychopath is deficient in one aspect of cognition (i.e., the analysis of emotional information) or in one particular area or structure of the brain? What other cognitive skills have been "rearranged" during development in the psychopath? Can abnormal lateralization of the brain account for the many symptoms of this severe personality disorder?

Cerebral Asymmetry and Psychopathy

Affective Processing

Some of the cardinal features of psychopathy are shallow and volatile emotions, an apparent lack fear, a lack of attachment to, or love for, others, and an inability to learn from punishment. Apart from these clinical observations that psychopaths seem to have difficulty with experiencing and expressing genuine emotion, there is some empirical evidence as well. Most research that has been conducted on affective processing of emotion in psychopaths has involved perception or analysis of emotional stimuli, and their autonomic responses to these stimuli, measures of more right-sided than left-sided cortical involvement. Processing of the emotional aspects of language, as well as non-verbal, affective DVF tasks will be described in following sections.

Hare, Frazelle, and Cox (1978) found that psychopaths showed unusual physiological responses in anticipation of aversive blasts of noise. The psychopaths demonstrated larger increases in heart rate (likely related to a decrease in cortical arousal and an increase in "sensory-rejection") but smaller skin conductance responses (indicating less anticipatory fear) than did nonpsychopaths, suggesting that the former "tuned out" threatening stimuli. Similarly, Patrick (1994) found impaired startle potentiation in psychopaths, as well as in those criminals high only on Factor 1 (the interpersonal and affective aspects of psychopathy) and not Factor 2 (the socially deviant aspects of the disorder). He argued that the psychopathic subjects were deficient in the ability to utilize aversive cues to prime normal defensive reactions. In a very different paradigm, Christianson et al. (1995) presented several slides to psychopaths and nonpsychopaths, and asked them to report peripheral and central details (e.g., colour of a car in the background or the person's coat in the foreground). Nonpsychopaths recalled as many central as peripheral details in nonemotional slides, but more central details in emotional slides. Psychopaths, however, recalled as many peripheral and central details on the emotional slides, suggesting they did not appropriately focus their attention on emotional detail.

Unusual processing of emotion in psychopaths is not a consistent finding. For example, Forth (1992) recorded central (EEG activity from frontal and parietal sites) and peripheral (skin conductance and heart rate) physiological activity, subjective ratings, and facial expression during emotional slides and film clips. There were few positive findings: the psychopaths and nonpsychopaths differed very little from each other, other than in abnormally low right frontal activation in psychopaths during the "disgusting" film.

Language Tasks

Most research involving cerebral asymmetry in psychopaths has examined the processing and organization of verbal abilities, and there have been several findings of abnormality. The findings cannot be accounted for by a greater incidence in psychopaths of left handedness or right hemisphere dominance for motor skills (Hare & Forth, 1985; Nachshon, 1988). Also, there is no evidence that psychopaths have an unusually high or low IQ (Harpur et al., 1989), nor do they differ from nonpsychopaths in most measures of neuropsychological performance (Hare, Frazelle, Bus, & Jutai, 1980; Hart, Forth, & Hare, 1990; Smith, Arnett, & Newman, 1992).

Examining how psychopaths analyze emotional verbal information serves two purposes. The first is to aid in understanding their apparent increased "use" of the right hemisphere (or reduced use of the left) in nonemotional language tasks. Therefore, an examination of how psychopaths analyze the emotional components of language should tell us whether it is a more left- or right-sided task for them. If psychopaths are unable to process or utilize the affective components of language, then this may imply that their right cortical hemispheres are "missing" this function, or that their language functions are so organized that they are not able to connect meaning and emotion. Also, evidence that they have difficulty with the emotional aspects of language may shed light on the observation that psychopaths have more shallow emotions, or are less controlled by their emotions, than is the case with nonpsychopaths.

In 1979, Hare reported the findings of a simple visual word recognition task. Both psychopaths and nonpsychopaths performed similarly, and both showed a strong right visual field (RVF) or left hemisphere advantage on this task. Hare (1979) speculated that if there is indeed a difference in cerebral asymmetry between psychopaths and nonpsychopaths, then it may only be apparent with a more difficult task. He did conclude, however, that the hypothesis that psychopathy was related to a dysfunctional dominant hemisphere was not supported. Hare's early speculations appear to have been borne out. Hare and McPherson (1984) examined cerebral asymmetry in another manner. Psychopaths and nonpsychopaths performed a verbal dichotic listening task in which they heard sets of one-syllable words delivered through earphones. Each set was made up of three pairs of words (one member of each pair presented in each ear), and subjects were instructed to recall as many words as possible. They found that psychopaths showed a smaller right-ear advantage than did nonpsychopaths, but did not recall significantly more or fewer words. This led Hare and McPherson to speculate that language processes (for word detection) are not as lateralized in psychopaths and/or that they have lower left hemisphere arousal than is the case with nonpsychopaths. More recently, Raine, O'Brien, Smiley, Scerbo, and Chan (1990) replicated Hare and McPherson's (1984) findings. Psychopathic and nonpsychopathic adolescents performed a dichotic listening task; they were instructed to recall as many dichotically presented syllables as possible. Again, psychopathic and nonpsychopathic subjects did not differ in overall performance, but the right-ear (left hemisphere) advantage found in the nonpsychopathic group was not found in the psychopathic group. The psychopathic adolescents appeared to be less lateralized for the identification of syllables than were the nonpsychopathic subjects. However, psychopathy was diagnosed by cluster-analyzing self-reports of antisocial behaviour and impulsivity, and staff and experimenter ratings of antisocial behaviour (and conduct disorder). That is, diagnoses were not made with the PCL-R, and so comparisons with the findings from Hare's laboratory must be made with caution.

Nachshon (1988) presented three groups of incarcerated men with three dichotic listening tasks, two of them verbal. In the first, they heard three pairs of digits, and in the second, they heard four pairs of digits, presented bilaterally through headphones. Subjects reported as many of the digits as they could. Although no significant group differences were found on these two tasks, there was a trend for the violent offenders to show a smaller right ear advantage than the nonviolent offenders (i.e., the violent offenders were less lateralized than the nonviolent offenders). Nachshon speculated that the group of violent offenders likely contained psychopathic offenders, as they were more likely than the nonviolent offenders to have committed a series of crimes, often involving property damage or personal injury. Again, it is difficult to compare this study with others in which psychopathy was carefully assessed, but the results are suggestive.

Other studies support the contention that psychopaths' brains are lateralized in an unusual way, particularly for linguistic processing. Jutai and Hare (1983) found that nonpsychopathic criminals exhibited a consistent left hemisphere superiority on verbal tasks involving either simple recognition or semantic categorization of words presented visually. Psychopathic criminals also showed left hemisphere superiority when the task involved simple recognition of the verbal stimuli, but an unexpected right hemisphere superiority when the task involved categorization to a particular semantic class. It appeared that categorizing words is most efficiently conducted by the left hemisphere in nonpsychopaths, but in psychopaths the task is performed better in the right hemisphere. A similar study was published by Hare and Jutai in 1988. They found that as language tasks increased in complexity, nonpsychopaths relied more on the left hemisphere to process the information, while psychopaths relied more on the right hemisphere. On simple recognition and categorization tasks, performance for left and right visual fields was no different for the groups, but for the abstract categorization task (the most complex of the three tasks), those who had low scores on the PCL (and noncriminals) made more left- than right-sided errors, and those who scored medium and high on the PCL made more right- than left-sided errors. Thus, the implications of these two studies differ slightly from those mentioned above. While Hare and McPherson (1984) and Raine et al. (1990) found psychopathic males less lateralized than nonpsychopaths for linguistic processing in relatively simple dichotic listening tasks, Hare and

Jutai (1988; Jutai & Hare, 1983) found that psychopaths tended to rely more on right hemisphere resources than did nonpsychopaths for more complex language tasks. It appears that psychopaths, whether performing a simple dichotic listening task or a more complex abstract categorization task, rely less on left hemisphere resources and more on the right hemisphere than do nonpsychopaths.

A few recent studies have examined how psychopaths and nonpsychopaths process the affective component of language. Williamson et al. (1991) presented psychopaths and nonpsychopaths with a lexical decision task in which they were to indicate whether a string of letters shown on a computer screen was a word or not. Decision time and electrocortical activity associated with the processing of the stimuli were recorded. As expected, the nonpsychopathic subjects responded more quickly when the word had an affective component than when the word was emotionally neutral (e.g., "cancer" versus "river"). Also, their electrocortical signals (or event-related potentials [ERPs]) were larger and more prolonged when they were presented with the emotional words than when they processed the neutral words. In sharp contrast, psychopaths did not respond more quickly to emotional words than to the neutral words, and their ERPs did not differ for the two types of words. In fact, psychopaths tended to respond more slowly to the emotional words, rather than more quickly, suggesting that they found emotional words more difficult to identify or process than the neutral words. No significant visual field effects were found in this study. In a related study, Day and Wong (1995) examined psychopaths' and nonpsychopaths' ability to discriminate between negative emotional and nonemotional words. They presented bilateral pairs of words in a tachistoscope; one word of each pair was considered to be negative in connotation. Half of the time the negative word was in the LVF and half of the time it was presented in the RVF. Nonpsychopaths were more accurate and faster when the emotional word was presented in the left than in the right visual field. The opposite was true for psychopaths: they were faster and more accurate when the emotional word was presented in the RVF (left hemisphere). Also, PCL-R Factor 1 scores were strongly and positively correlated with the RVF advantage. Note that psychopaths and nonpsychopaths were equally accurate in detecting the more emotional words, but the psychopaths tended to be slower, again suggesting that they are unable to benefit from the right hemisphere resources for detecting emotionality of information. Day and Wong's results must be interpreted with caution, however, considering that others have found that normal right-handed males tend to process words presented in the RVF more quickly and accurately than when they are presented in the LVF, regardless of emotional valence of the stimuli (Eviator & Zaidel, 1991; Graves et al., 1981; Strauss, 1983). Finally, Hayes (1995) recently reported that psychopaths were significantly less able than nonpsychopaths to accurately label emotional valence of metaphors, despite being able to interpret their meanings. Some researchers have reported that an intact right hemisphere is necessary for processing metaphoric aspects of language. For example, Brownell et al. (1990) reported that those with right-sided cerebral vascular accidents (strokes) had more difficulty choosing metaphoric word alternatives than those with left-sided or no damage.

Nonaffective measures of language use in psychopaths have yielded unusual findings. For example, Gillstrom and Hare (1988) found that psychopaths used significantly more "beats" (unintentional hand gestures unrelated to semantic content that may help to divide the discourse into discrete functional units) during speech than did nonpsychopaths. The authors proposed that the psychopath's language is organized into relatively small conceptual units and that they use the extra hand gestures to help compensate for their difficulties in encoding verbal material. Other researchers have found that normal right-handed individuals favour right-handed gestures during speech (Dalby, Gibson, Grossi, & Schneider, 1980; Lavergne & Kimura, 1987). While

Gillstrom and Hare found that the subjects in their study also generated more right- than left-handed gestures, there was a trend for psychopaths to gesture with their left hand more than would be expected. Lavergne and Kimura (1987) theorized that right-sided hand gestures indicate stimulation or increased arousal of the left hemisphere during speech, and credit the left hemisphere for their production. If psychopaths tend to use more of these gestures than nonpsychopaths, with a trend toward more "beats" for both hands, one could speculate that they possess a diffuse organization of verbal skills, or arousal of both hemispheres during speech. Finally, Gillstrom (1995) administered several measures of abstraction to psychopathic and nonpsychopathic inmates and found that psychopaths were significantly deficient in their ability to comprehend proverbs.

In summary, the results of these language studies imply three things: 1) For simple verbal dichotic listening tasks, psychopaths are less lateralized than nonpsychopaths. Their left and right hemispheres seem to be equally involved in the task, while nonpsychopaths rely more on left hemisphere resources; 2) For more complex non-emotional language tasks, normal individuals rely more on left hemisphere resources, while psychopaths draw more on right hemisphere resources. These skills may more diffusely organized in the cortices of psychopaths; 3) Linguistic emotional tasks involve right hemisphere resources more than do nonemotional tasks, and nonpsychopaths utilize the emotional information to increase speed and accuracy in language processing. In contrast, psychopaths may not use specialized right hemisphere resources to analyze emotional information, and do not seem to distinguish between emotional and nonemotional words without increased cognitive effort (perhaps relying on the left hemisphere lexicon). In fact, they seem to be relatively slow at deciding if a word is emotional, and use the left hemisphere to do so.

Non-language Tasks

Very few studies have examined lateralized non-language tasks in psychopaths, and so little is known about how they organize or process non-verbal material. Nachshon (1988) presented pairs of tones dichotically to violent and nonviolent offenders, and then asked them to identify from memory (by multiple choice) one of the tones in a predetermined ear. This task generally shows a right ear (left hemisphere) advantage, and the nonviolent offenders in this study were able to identify more of the tones when they were presented to the right ear than to the left ear. However, the violent offenders showed a left-ear (right hemisphere) advantage, despite the fact that their overall performance equaled that of the nonviolent offenders. Nachshon interpreted the results as evidence that "psychopaths" (the violent offenders) have left hemisphere dysfunction (rather than reversed asymmetry.)

Day and Wong (1995) had psychopaths and nonpsychopaths indicate which of two bilaterally presented faces was more emotional. They predicted that psychopaths would be slower and less accurate at this task, and would show a smaller LVF advantage than would the nonpsychopaths. Day and Wong's hypotheses were not supported. Although there was a slight trend for psychopaths to be slower at the task, they were not less accurate than the nonpsychopaths. Also, they showed the same LVF advantage the nonpsychopaths did. It is difficult to reconcile this finding in light of the other studies that have shown abnormal cerebral asymmetry to both emotional and nonemotional, and to verbal and nonverbal processing. The present study will attempt to examine in more depth these inconsistent findings.

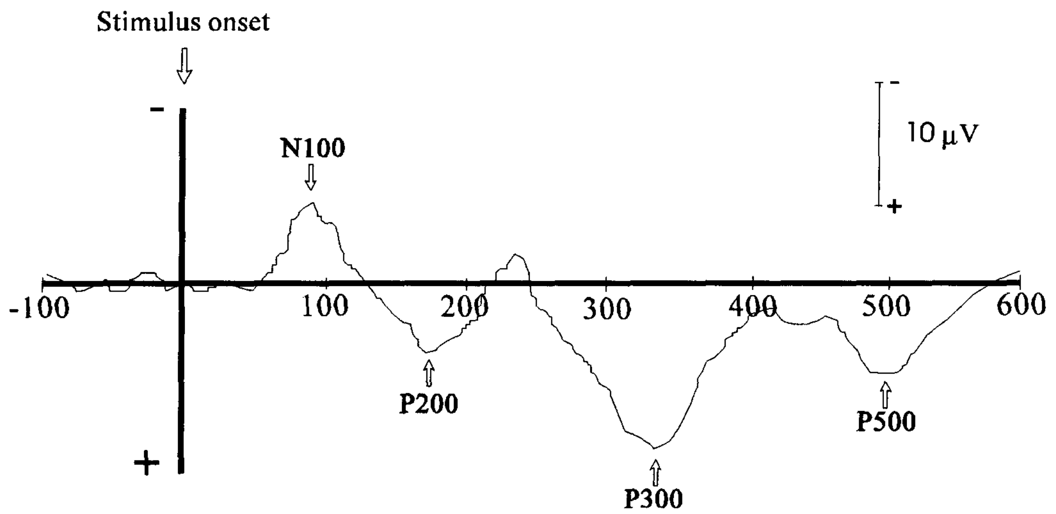
Event-Related Potentials (ERPs) in Psychopaths

Most neuropsychological and other behavioural or performance-based laboratory tasks tell us little about what parts of the brain are most active. We are left to conclude what parts of the brain are most involved or most dysfunctional by comparing performance in normal individuals with those with known brain lesions. However, technological advances have allowed us to gain insight into these processes by measuring brain activity during various tasks. One of the most "portable" and least intrusive measures is the electroencephalogram (EEG).

EEG recording of an alert individual looks merely like "noise", and it is very difficult to glean from it meaningful information (such as discrete changes in brain activity or differences in brain activity from distinct cortical areas) without using more sophisticated, computerized techniques. ERPs can be measured by using these techniques. A stimulus encountered in any modality will elicit a sudden change in electrical brain activity, and if one measures several of these responses and averages the concomitant brain activity, a series of waves or peaks emerges from the background EEG "noise". The morphology of these peaks (the ERPs) varies at different latencies post-stimulus, or due to the nature of the stimulus, or because of the nature of the task itself. Their shape and amplitude also depend on the area of the brain from which they are measured. Thus, the ERP can be used as a tool to understand cortical responses that occur within a brief period (about one second) after stimulus presentation. See Figure 1 for a depiction of a set of "idealized" ERPs.

Figure 1: Averaged EEG Showing Significant ERPs Occurring

Approximately 100, 200, 300 and 500 msec Post-Stimulus



Typically, the first significant peak post-stimulus is the N1 (a negative wave that occurs approximately 100 msec post stimulus). This is followed by a large positive wave approximately 200 msec post-stimulus (P2). This N1-P2 complex has generally been attributed to activity in the primary sensory pathways, but can be modified by attention. When a subject attends to the stimulus a negative electrical shift occurs beginning about 60 msec post-stimulus, and lasts for up to 500 msec. This negative shift (which alters the N1-P2 wave) is referred to as the Nd (Hillyard, Hink, Schwent, & Picton, 1973; Naatanen, 1982). A useful paradigm which applies the Nd is called "probe evoked potentials". While a subject is engaged in a cognitive activity, he or she is exposed to irrelevant and repetitive light flashes or tones (the "probes"). N1-P2 ERPs are elicited to the probes, but are overlapped by the Nd in the area of the brain that is least engaged in the task and more responsive to the tones (Papanicolaou & Johnstone, 1984). For example, if a subject is engaged in a geometric puzzle (which draws on right parietal brain areas) while hearing repetitive tone pips, there will be a smaller negative shift of the N1-P2 complex over the right parietal lobe than in other cortical areas, suggesting that some of the cognitive resources are pulled away from processing the tones to complete the task. This paradigm is followed for two tasks in the present investigation.

The next significant wave is termed the P300, a positive-going wave that occurs approximately 300 msec post-stimulus. The P300 wave has been widely studied as an index of mental "effort" during performance of a task. This wave is generated whenever the subject evaluates or categorizes a stimulus, or experiences an unusual or unexpected stimulus. It is maximal over parietal brain areas. Also, the more elaborate the evaluation of the stimulus or difficulty in detecting it, the greater will be the P300 amplitude (e.g., Callaway, Tueting, & Koslow, 1978). Latency of the P300 peak has been shown to reflect the time required for stimulus evaluation and categorization (McCarthy & Donchin, 1981; Magliero, Bashore, Coles, & Donchin, 1984). Another relevant ERP is the late positive component (LPC), sometimes referred to as the "positive slow wave" (PSW) or P500. It peaks between 400 and 800 msec post stimulus, and appears to be correlated with extended analysis or elaboration of the stimulus (Polich & Donchin, 1988; Ruchkin, Johnson, Mahaffey, & Sutton, 1988).

The N1-P2 complex, P300, and P500 were used as indices of cortical activation in this dissertation. The present study was not designed to determine whether or not psychopaths have abnormal ERPs, but instead used ERPs as tools to understand and clarify how much cognitive activity occurred in response to stimuli or during cognitive tasks. It was hoped that ERP differences would illuminate unusual activity under specific circumstances. That is, if psychopaths' brains are lateralized in an unusual manner, both ERP and performance data should help clarify their pattern of brain organization.

In order to make predictions in the present study, it is important to understand what unusual cortical activation patterns have been found thus far in psychopaths. Unfortunately, the ERP studies of psychopaths are extremely diverse and many suffer from methodological flaws, so it is difficult to draw conclusions. A few studies will be described as illustrative examples, and I will attempt to summarize the more reliable findings.

In order to investigate cortical activation during linguistic tasks, Jutai, Hare, and Connolly (1987) assessed whether or not psychopathy was associated with low left hemisphere arousal during speech processing, during a perceptual-motor task, and during a dual task (both tasks simultaneously). In the speech processing task subjects were instructed to press a microswitch when they heard the less frequent "oddball" phoneme. In the perceptual-motor task subjects played a video game (involving flying a "jet" and shooting at other planes). No abnormalities of the N100 wave were observed for either group during either single task, suggesting that central arousal was similar for both psychopaths and nonpsychopaths. However, an unusually large late positive slow wave was recorded over central midline and left temporal lobe sites in the psychopathic group during the dual task. The authors interpreted the results as indicating that the psychopaths had more difficulty performing the dual task than did the nonpsychopaths, perhaps due to limited left hemisphere resources for processing linguistic stimuli. Note that for the single tasks no ERP abnormalities were found in the psychopathic group, suggesting that, at least on simple tasks, their electrocortical responses are not abnormal.

Forth and Hare (1989) examined cortical responses of psychopaths and nonpsychopaths during anticipation of stimuli in an interesting and motivating task. They were interested in the contingent negative variation (CNV). The CNV is a slow negative potential shift that occurs in the interval between a warning stimulus and a signal to which the subject must make a response (Walter, 1964). The CNV was of interest because other research findings showed that psychopaths and nonpsychopaths differed in their electrodermal and cardiac responses while anticipating aversive events (e.g., Hare et al., 1989). Forth and Hare (1989) found that psychopaths and nonpsychopaths were similar in their task performance, and in their N100 and P300 responses to the task stimuli. Psychopaths produced larger early CNVs (a reflection of orienting) in response to the warning tones than did nonpsychopaths, suggesting that they were able to allocate their attention to interesting information.

As mentioned above, Williamson et al. (1991) examined performance and electrocortical activity while psychopaths and nonpsychopaths performed a lexical decision task, a fairly complex verbal exercise. ERP responses suggested that affective and neutral words were processed differently by the nonpsychopaths (the affective words may have contained more information and may have generated more mental elaboration than the neutral words), while psychopaths appeared to process the two types of words similarly. Many ERP differences were found between the two groups. For instance, psychopaths produced an unusually large late negative wave (N500) over fronto-central sites, which may have been related to their reduced ability to integrate word meanings, or to regulate their behavioural responses. Second, the late positive component (LPC) was smaller in psychopaths than in nonpsychopaths. Perhaps psychopaths did not extract as much information from the stimuli, or did not mentally elaborate the words as much as the nonpsychopaths did. Finally, psychopaths showed a nonsignificant trend toward greater negativity over the right than left hemisphere at the P150-N180 latency (while nonpsychopaths showed greater left than right hemisphere negativity). Group differences were significant over the right temporo-parietal sites. Williamson et al. (1991) pointed out that greater right-sided negativity at this latency indicates reduced or unusual lateralization of language processing. This was the only lateralized abnormality found, but they only measured lateralized electrocortical activity over temporo-parietal areas.

Raine and his colleagues (e.g., Raine & Venables, 1988; Raine, Venables, & Williams, 1990) have conducted several studies of ERPs in psychopathic populations. Raine and Venables (1988) instructed psychopaths and nonpsychopaths to press a button as soon as they saw the digit "5" flash in the centre of a computer screen (and to ignore the other digits between 1 and 9, appearing in a random order). Psychopaths showed larger P300 ERPs to target stimuli (but not to nontargets), and slower P300 recovery (the enhanced positivity took longer to return to baseline, indicating enhanced additional processing) than did nonpsychopaths. Note that they found these differences at parietal and not temporal sites, and there were no unusual left- or right-sided differences. It is also noteworthy that psychopaths' and nonpsychopaths' ERPs to non-targets were not different from each other. Raine et al. (1990) measured ERPs in school children to a reaction time test. Subjects heard a warning tone, and then had the opportunity to press a button to turn off an unpleasant tone. N100, P300, and CNV ERPs were analyzed. Subjects were followed into adulthood, and "psychopathic" (as determined by a combination of self-report and teacher ratings of antisocial behaviours and attitudes) criminals were found to have larger N100 and CNV responses to the warning stimulus relative to nonpsychopaths. The authors interpreted the results as evidence for the notion that psychopaths have an enhanced ability to focus their attention when highly motivated. A recent review by Harpur and Hare (1990) has emphasized that psychopaths may indeed over-focus their attentional resources, but it is not yet known why or how this is done.

Raine (1989) reviewed the ERP/psychopathy literature, and was able to draw a few (weak) conclusions. He pointed out that it is difficult to draw conclusions when studies are extremely disparate in terms of assessment of psychopathy, soundness of methodology, and the procedures used to assess electrocortical activity. However, he described three "emerging themes". Based on an examination of early evoked potentials (latency 1 - 50 msec poststimulus) he suggested that psychopaths may be under-aroused relative to nonpsychopaths. For the middle components (50 - 250 msec poststimulus), there is no distinct pattern overall, and for the late evoked potentials (250 msec + poststimulus), it appears that psychopaths, compared to nonpsychopaths, more often show an enhanced positivity, particularly during tasks that are intrinsically interesting and motivating. Jutai (1989) suggested that the observed enhancement of the positive slow wave in psychopaths may be due to increased mental effort and limited processing capacity. However, it is noteworthy that the enhanced positive slow wave is not a consistent finding (Forth & Hare, 1989; Williamson et al., 1991).

In conclusion, it is very difficult to state in what ways the electrocortical activity of psychopaths differs from nonpsychopaths. Early CNVs tend to be larger in psychopaths than in nonpsychopaths when anticipating an event, and their P300s tend to be larger during interesting perceptual motor tasks (and smaller in linguistic tasks). The few studies that have examined lateralized ERP differences provide mixed results (Raine & Venables, 1988; Williamson et al., 1991). A few other generalizations may be cautiously offered. It appears that for simple tasks, psychopaths and nonpsychopaths have similar ERP responses, but ERP differences are drawn out on tasks that are highly interesting and motivating, and on tasks that have an emotional or highly complex aspect to them. This underscores the utility of combining electrocortical and behavioural data for understanding the cognitive differences between psychopaths and nonpsychopaths. Although few lateralized ERP abnormalities have been found in psychopaths, the present study was the first to combine several tasks designed to draw out cerebral asymmetries in electrocortical activity in this population.

Rationale for The Present Investigation

To date, no one has attempted to examine simultaneously the three dimensions relevant to the left-right cerebral organization in psychopaths, namely the verbal/non-verbal, emotional/neutral and left hemisphere/right hemisphere dimensions. Likewise, cortical activation at multiple brain sites in response to these stimuli has not been recorded in psychopaths. This study is likely the first to investigate if the abnormalities in psychopaths lie along one of these dimensions.

The seven tasks used in this investigation were chosen carefully to allow an examination of the three dimensions. In the first study, subjects completed three verbal tasks. The first task replicated and extended the methodology of Day and Wong's (1995) emotional words task. As described above, Day and Wong interpreted the group by visual field interaction to mean that psychopaths did not use the emotional information incorporated in the words to complete the task, and "used" left hemisphere resources only. In order to contrast this task with one in which emotionality was not involved, a DVF task of subthreshold word identification was chosen. Boles (1991) found this task to be the strongest measure among many of left hemisphere skill. The third task, verbal visual search (Mills, 1989), which is both verbal and nonemotional, was chosen to tap right hemisphere skills.

In the second study, four tasks were chosen. The first was an attempt to replicate and extend the methodology of Day and Wong's (1995) DVF emotional face task. As mentioned above, they did not find group effects. The second task was a mental rotation task (Begleiter et al., 1984) which typically taps right hemisphere resources. This task is perceptual, with no emotional component. The third task, nonverbal visual search, is also a nonemotional and nonverbal right hemisphere task (Mills, 1989). Two nonverbal, nonemotional tasks tapping right hemisphere resources were chosen because little is known about the psychopaths' manner of processing this sort of information. The fourth task was a replication and extension of Nachshon's (1988) task. This dichotic listening task taps left hemisphere resources and is nonverbal and nonemotional.

During all tasks, electrocortical activity was measured. This enabled me to draw inferences about where and how quickly the brain analyzes the information. The overall patterns of results may allow us to speculate on the underlying neuroanatomical and neurocognitive differences between psychopaths and nonpsychopaths.

Experiment 1 (Verbal Tasks)

Method

Subjects

Subjects were 27 male volunteer prison inmates incarcerated in a medium security federal institution. A research assistant with extensive training and experience used interview and file information to complete the PCL-R for each inmate involved in this research. Potential participants were also administered several questionnaires related to this study: the Lateral

Preferences Inventory (Coren, 1992; 1993a; 1993b), the Drug Abuse Screening Test (DAST; Skinner, 1982), the Michigan Alcoholism Screening Test (MAST; Selzer, 1971), and a health survey to assess for epilepsy, psychosis, head injuries, visual and auditory impairments, and medication use. Finally, participants were administered the Block Design and Vocabulary subtests of the Wechsler Adult Intelligence Scale - Revised (WAIS-R; Wechler, 1981), as well as the Reading subtest of the Wide Range Achievement Test (WRAT; Jastak & Wilkinson, 1984).

The PCL-R consists of 20 items that measure the behavioural and personality characteristics of psychopaths. Each item is scored on a three point scale (0, 1, or 2) according to the extent to which it applies to the offender. The resulting total score can range from 0 to 40; the higher the score, the more prototypically psychopathic is the individual. There is extensive support for the PCL-R as a valid and reliable measure of psychopathy. The interrater reliability and alpha coefficients for the total scores are usually above .80. Previous studies with incarcerated males have shown that the mean PCL-R score is typically approximately 24 with a standard deviation of 8 (Hart et al., 1992). An examination of the most recent 100 psychopathy scores at Matsqui Institution (the medium security prison for men near Vancouver, British Columbia in which this research was conducted), yielded a mean of 24.6 (SD = 7.1). In accordance with a considerable amount of previous research (see a review by Hare, 1991), subjects with a PCL-R total score of 30 or above were defined as psychopaths, and those with a total score of 24 or less (i.e., below the mean) were classed as Nonpsychopaths. There is evidence that groups selected in this manner do not differ significantly in IQ, education, parents' social class, or neuropsychological function (Harpur et al., 1989; Hart et al., 1990). Factor scores on the PCL-R were calculated using items described by Hare et al. (1990).

Only those subjects who were strongly right-handed and for whom English was their first language were included in the study. It is well documented that the cortical organization of cognitive skills in left-handed individuals is often different than in right-handed individuals (e.g., Loring et al., 1990). Inmates who suffered from seizures, hallucinations, or those who had experienced a serious head injury were excluded from the study. "Serious" was defined as anyone who reported having experienced a coma or period of unconsciousness longer than a few hours, a skull fracture, or brain surgery. No attempt was made to exclude subjects on the basis of prescription or illicit drug use because of their widespread use and the difficulty in obtaining accurate self-reports. Because there was essentially no medical information in institutional files, self-report was used to make the decisions as to who could or could not be included as a research participant. After being screened for these exclusion criteria, subjects were placed into either the Psychopathic (n=12) or Nonpsychopathic (n=12) group. Three subjects with scores between 25 and 29 on the PCL-R participated, but their results were included in the correlational analyses only.

Procedure

The research was conducted in a small room in the institution. Each inmate was seen individually, and participated in two sessions, each 1 to 2 hours long. Following an explanation of the research, he was asked to sign the following consent forms: consent for the researcher to have access to his institutional files; consent to do the interview; consent for the interview to be videotaped (in order to enable a second rater to provide an independent psychopathy assessment, the interview must be videotaped and a synopsis of the file information made). In the first session, the inmate participated in a semi-structured interview designed for use with the PCL-R, and completed the questionnaires and tests described above.

When the subject arrived for the second session, he was told that his brain activity during three tasks would be recorded and studied. He was then asked to read and sign a consent form describing this research. In order to encourage optimum performance and concentration on the tasks, inmates were offered a monetary reward for the best and second-best performance on the tasks overall, ten and five dollars respectively. The Electro-cap was placed on the subject's head and 13 electrode sites under the cap were lightly abraded with a blunt sterilized needle and syringe. Electrode gel was inserted into the electrode cups embedded in the cap at the 13 brain sites (see Appendix A). The three tasks were administered, with a two minute break between each. When the tasks were completed, the Electro-cap was removed, and the subject completed the Beck Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) and the State form of the State-Trait Anxiety Inventory (Speilberger, Gorsuch, & Lushene, 1970) in order to get an estimate of his current mood. The subject was free to ask questions and was debriefed accordingly.

Apparatus

The presentation of the stimuli and collection of the data were controlled by two 486-DX2 66 MHz personal computers. A 16-channel Biomedical Monitoring System and the Electro-cap were used to record EEG. All physiological signals were sampled and digitized on-line at a rate of 128 times per second, and analyzed off-line. All visual stimuli were presented on a PC monitor using an interactive, Windows-style software package called "Showtime Stimuli Presentation System, v. 1.10" (Pacific Research Systems). This package also allowed the recording of errors and reaction times for the tasks involving visual displays. For the tasks involving sound, stimuli were presented on a stereo cassette deck through earphones, and performance was recorded on paper score sheets.

ERPs were measured at left and right frontal, temporal, central and parietal sites (Fp1, Fp2, F3, F4, T3, T4, C3, C4, P3, P4) and two vertex sites (Fz and Pz), all referred to the central vertex (Cz). Note that "Fp" means prefrontal, F frontal, T temporal, C central, and P parietal. Odd numbers are left-sided sites, and even numbers are right-sided sites. Fz, Cz and Pz are situated over the midline frontal, central and parietal areas respectively, where "z" means zero or zenith. See Appendix A for a schematic diagram of electrode sites. The Electro-cap contains electrodes embedded at these and other sites in accordance with the International 10-20 System (Jasper, 1958). The ERPs were recorded with a low pass filter set at 35 Hz. Electrical impedances were kept below 5000 ohms. Eye blinks were recorded from forehead electrodes in the cap (Fp1, Fp2). ERPs were calibrated by inputting a 100 μV signal on each channel prior to recording. Upon visual inspection of all raw data, all trials that contained large eye movements (in particular, blinks) between 200 msec prestimulus and 800 msec post-stimulus were removed from the analyses. The raw ERP data were averaged to reliably draw out significant peaks. The amplitude and latency of peaks of interest for each subject at each brain site were recorded manually.

The subject sat approximately 1 metre from a computer screen. He was instructed to place his chin in a head rest and to sit as still and relaxed as possible while performing the three tasks (in order to prevent electromyographic activity from interfering with the ERP recordings). The order of the three tasks was randomized for each subject, and counterbalanced across groups. Set-up and completion of the three tasks took approximately one hour, and each subject was paid five dollars.

Statistical Methods

SPSS for Windows Advanced Statistics (Release 6.0, SPSS, Inc.) was the commercial package used for all analyses. Repeated measures analyses of variance (ANOVAs) were used to assess most statistical differences among variables. In all cases, ANOVAs were assessed for violations of the assumption of homogeneity of variance and covariance using Cochran's C tests, and Box's M tests, respectively. When violations of sphericity of the pooled variance-covariance matrix occur, Hays (1988) recommends a three-step procedure. If the F value is non-significant, one should do no further analyses. If the F is significant, he recommends the easily calculated but conservative Geisser-Greenhouse procedure to adjust the degrees of freedom. If the F remains significant, then no further adjustment to the degrees of freedom is needed. If the value of F is no longer significant, the less conservative (but tediously calculated) Box's adjustment can be implemented, and used as the definitive F to assess statistical significance. Howell (1987) recommends Huynh and Feldt's development of Box's adjustment for calculating the value of ε (by which to multiply the degrees of freedom). For all ANOVAs, I followed these three steps, and all significant F values remained significant despite violations of the sphericity assumption in several cases. Hence, only the original F values and associated probability levels are reported.

Several analyses of variance were computed, and in order to reduce the chances of making Type 1 errors, significance level was set at $p < .01$. However, all analyses significant up to a probability level of .1 were examined and interpreted for two reasons. First, I have low statistical power. Second, this is likely the first study to combine such a wide variety of measurements, and the risks involved in making Type 2 errors may be as serious as makingType 1 errors. Examining the trends and the overall pattern of results should provide us with useful information that will aid in directing future research.

Post-hoc pairwise comparisons for significant differences among means were conducted using Tukey's Honestly Significant Difference (TSD) tests according to the recommendations in Hays (1988). Finally, varying degrees of freedom reflect differing numbers of subjects for certain analyses. It is common to exclude data from electrophysiological studies (e.g., for a particular subject who blinked too often during a task to make his data reliable).

Description of Language Tasks

Task 1: Emotional Word Discrimination.

This task has an emotional component and tends to draw on right hemisphere resources. It is a replication and extension of a portion of a study by Day and Wong (1995). Negative emotional words and neutral words were presented bilaterally in pairs. A bilateral display was chosen because asymmetry effects have been found to be stronger than in unilateral displays (e.g., Boles, 1990). Each word was four or five letters in length. The emotional and neutral word lists were equated as closely as possible for imageability and word frequency. I used the same words as Day and Wong did in their study (see Appendix B).

The subject was instructed to focus his eyes on a '+' in the centre of the screen. After 1.5 to 2.5 seconds (varied randomly to avoid predictability), the focal point was replaced with a bilateral pair of words and a central fixation digit (a number from 1 to 4) for 197 msec. A longer exposure time would allow for unwanted saccadic eye movements prior to the offset of the stimuli (Sergent, 1983). Words were presented horizontally. The RVF word was placed such that its first letter was 2 cm from the centre of the screen, and the LVF word had its last letter 2 cm from the centre of the screen. The subject was asked to decide as quickly and accurately as possible which side displayed the more emotional word, and he indicated his choice by pressing a left- or right-sided key on the PC keyboard. Once he made his response, he verbally reported the fixation digit he saw to ensure that he had focused on the centre of the screen. If the digit was not accurately reported, the trial was excluded from the analyses. There was a 2-second delay before the next trial began. There were 30 practice trials and two blocks of 40 trials each, with a two minute break between blocks.

EEG data were collected continuously while the subject performed the task. Accuracy and reaction time data were collected for each subject and were recorded on the computer hard drive. A 2 (Group) X 2 (Visual Field) ANOVA was performed on each of the two dependent variables, percent accuracy and reaction time. In order to compare left- and right-sided brain activity, three 2 (Group) X 2 (Visual Field) X 2 (Hemisphere) ANOVAs were conducted on the P300 peak at frontal, temporal, and parietal sites.

Finally, "laterality coefficients" were calculated in order to allow for comparison of relative accuracy of discrimination in the left and right visual fields. The laterality coefficient was derived by subtracting the percent accurate in the LVF from the percent accurate in the RVF, divided by the total correct in both fields. The formula is: (R-L)/(R+L) (where R and L represent percent accurate emotional word detection in the right and left visual fields respectively). Day and Wong (1995) found that right visual field advantage (RVFA, a larger positive value of the laterality coefficient) correlated strongly and positively with PCL-R Factor 1 scores, and a similar but weaker correlation was found with Factor 2 scores.

Based on Day and Wong's findings, I expected that nonpsychopathic criminals would be more accurate and faster when emotional words were presented to the LVF (right hemisphere or RH) than when they appeared in the RVF (left hemisphere or LH), while the psychopaths would show the reversed pattern of performance asymmetry. Note, however, that this expectation was inconsistent with findings in at least three other studies. These three investigations found superior RVF performance, regardless of emotional valence, in a normal population. With respect to ERPs, I expected that nonpsychopaths would show larger P300s over the right hemisphere than over the left, corresponding to greater cortical involvement on this side of the brain while evaluating negative information (e.g., Papanicolaou, Levin, Eisenberg, & Moore, 1983). It was difficult to predict the pattern of cortical arousal for the psychopaths, but it seemed likely that P300s would be greater in the left than the right hemisphere (reflecting greater left hemisphere involvement in the task).

Task 2: Non-Emotional Word Discrimination.

This task does not have an emotional component, and tends to draw on left hemisphere resources. Boles (1991) reported that this task resulted in a strong and reliable RVF (left hemisphere) advantage. As practice and to ensure proper pronunciation, each subject read the list out loud before beginning the task. Words were three letters long and were presented vertically in capital letters (see Appendix C for the word list). The subject was then presented with pairs of words flashed on the computer screen, one in each visual field, and a simultaneous central fixation arrow. He then verbally identified the word in the LVF or RVF, depending on the direction of the central arrow, and responses were recorded on cassette tape. For instance, if the arrow at the centre of the screen was a ">" the participant reported the word he saw in the RVF. Each trial consisted of a 750 msec fixation '+', a 100 msec blank, a stimulus display for 150 msec, another 100 msec blank, and then a masking display of Xs for 150 msec. The mask of Xs reduces further perceptual evaluation of the stimuli by providing new input to short-term visual store. The next trial began after a delay of approximately three seconds. There were two blocks of 36 trials. EEG data were collected continuously while the subject performed the task. A 2 (Group) X 2 (Visual Field) ANOVA was conducted for the dependent variable, percent accuracy. P300 amplitude at frontal, temporal, and parietal sites was compared in 2 (Group) X 2 (Visual Field) X 2 (Hemisphere) ANOVAs.

Based on Hare's (1979) study, I predicted that both groups would be more accurate when they were to identify the words presented in the RVF (LH) than in the LVF (RH). Subjects were expected to show greater left-sided than right-sided P300s in response to these verbal stimuli. Again, laterality coefficients were calculated on the LVF and RVF percent correct scores, and then correlated with Factor 1 and Factor 2 scores from the PCL-R.

Task 3: Verbal Visual Search.

This task does not have an emotional component, and although it involves verbal material it appears to draw more on more right than left hemisphere resources (Jutai, Chwyl, & Chou, 1988; Mills, 1989). The subject was presented with a sheet of paper on which was displayed a random array of different letters of the alphabet (Weintraub & Mesulam, 1985; see Appendix D). He was instructed to search for and cancel (with a marker) all instances of one letter, selected in advance by the experimenter. Each array had 48 of each target letter dispersed among 256 non-target letters. The subject was encouraged to be as accurate as possible, but to work quickly as well. While engaged in this task he heard repetitive tones (approximately 70 dB, 1000 Hz) in both ears through earphones, at the rate of 1.3 per second. He was instructed to ignore the tones. Auditory ERPs were collected to 76 tone pips.

Errors of omission were recorded manually, and analyzed for group differences. A 2 (Group) X 2 (Side (left, right)) ANOVA was conducted on errors of omission (missed targets). Comparisons of N1 and P2 amplitudes were conducted by performing 2 (Group) X 2 (Hemispheres) ANOVAs at the three brain sites.

I expected that psychopaths and nonpsychopaths would perform equally well. I also expected that nonpsychopathic subjects would show a smaller Nd (thus, larger P2 amplitude) in the less taxed (left) than in the more taxed (right) hemisphere. Mills (1989) found that men at risk for alcoholism demonstrated a smaller-than-expected RH Nd (which resulted in larger amplitude P2 peaks) to tone probes, suggesting that they were unable to efficiently allocate resources away from the irrelevant probes to the primary task, or that their right hemispheres were less involved in visual search than would be expected. Because there is a correlation between risk for alcoholism and antisocial personality style, we might expect that psychopaths in the present study would also show smaller-than-expected RH Nds in response to the tone probes. That is, the psychopaths should show a smaller negative shift of the N1-P2 component in response to the tones over the right hemisphere sites, than would the nonpsychopaths.

Results

Demographic and Background Data

Table 2 summarizes the means and standard deviations of Factor 1, Factor 2 and total PCL-R ratings for the two groups. Interrater reliabilty, using double ratings on approximately 30 percent of the entire group of participants was 0.95.

Table 2:

Study 1 PCL-R Scores

Group	Factor 1	Factor 2	PCL-R
Psychopaths	13.2 (1.8)	13.9 (1.8)	32.5 (2.3)
Nonpsychopaths	6.6 (3.3)	10.1 (1.8)	19.8 (4.2)

As can be seen in Table 3, there were no statistically significant differences between psychopaths and nonpsychopaths on any of the measured demographic and background variables. All differences were measured by univariate t-tests, uncorrected for Type 1 error rate. Thus, the failure to find group differences with this liberal approach makes it unlikely that any group differences on performance or electrophysiological measures are due to these background and demographic variables.

It is clear that this population as a whole has had experiences that could contribute to cognitive and neuropsychological dysfunction. Scores on the MAST and DAST all suggest serious substance abuse. Note that one-third of each group reported experiencing a mild head injury, but no head injuries were documented in inmate files. Self-reports of head injury are not surprising for a forensic population. However, the mean IQ (in the average range for both groups), education, and reading levels (where WRAT scores over 60 means reading level at or above Grade 10) suggest that these individuals were functioning adequately. IQ estimates were calculated in the manner suggested by Silverstein (1982). He has presented data showing that two subtests (Block Design and Vocabulary) provide a statistically reliable and valid estimate of IQ, appropriate for research purposes. The two measures of mood suggested that psychopaths and nonpsychopaths were similar to each other, and scored in nonpathological ranges. That is, anxiety levels of each group fell in the 50th percentile range of a normative sample, and levels of depression were low.

Table 3:

Study 1 Background Variables

	Group				
	Psychopaths (n=12)		Nonpsychopaths (n=12)		
Variable	M	(SD)	M	(SD)	t
Age	33.67	(10.27)	28.75	(3.84)	1.55
Education	10.58	(1.97)	10.58	(1.78)	0.00
IQ Estimate	101.75	(11.97)	98.83	(9.14)	0.67
Reading (WRAT)	65.75	(12.74)	59.17	(10.37)	1.39
Years in Prison	8.12	(6.15)	6.79	(3.51)	0.65
Drugs (DAST)	13.17	(6.53)	15.25	(6.18)	-0.88
Alcohol (MAST)	14.92	(15.32)	21.58	(14.56)	-1.09
Anxiety (STAI-S)	32.17	(7.11)	34.91	(7.26)	-0.92
Depression (BDI)	5.67	(4.72)	6.42	(4.10)	-0.42
Reported Head Injury	33.3 %		33.3 %		

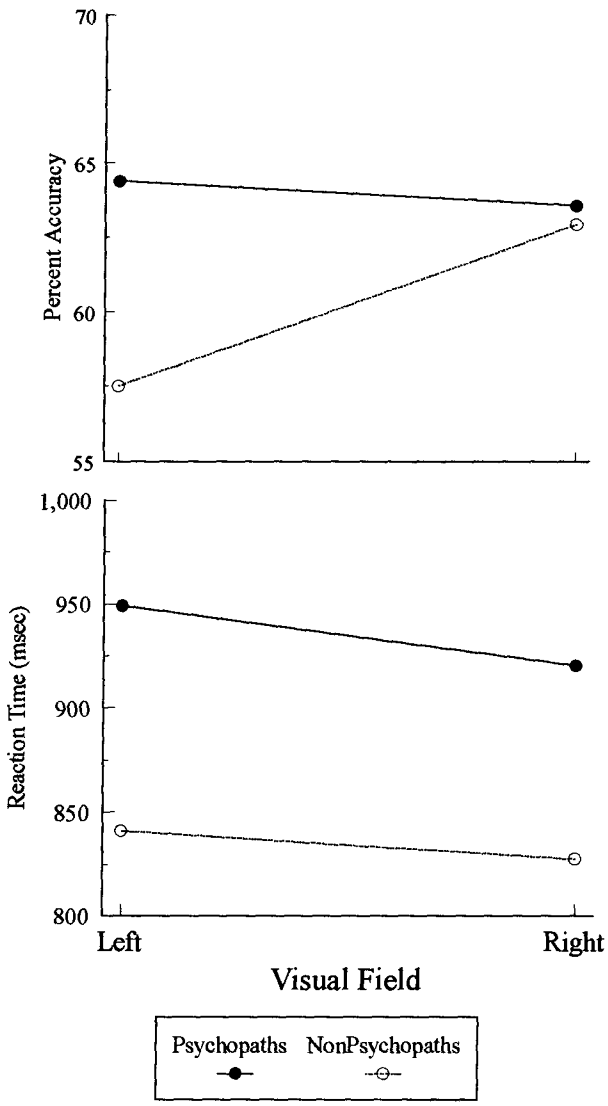
Emotional Word Discrimination

Performance.

As mentioned earlier, Day and Wong (1995) found that nonpsychopaths were more accurate and faster at identifying emotional words in the LVF than in the RVF, while psychopaths showed a RVF advantage. However, several other researchers have found that similar verbal DVF tasks elicit a RVF advantage in normal populations, regardless of emotionality of the stimuli. Thus, a replication of Day and Wong's results was not expected, and it was difficult to predict group differences.

A 2 (Group) X 2 (Visual Field) ANOVA was performed on each of the two dependent variables, percent accuracy and reaction time. There were no significant main effects or interactions. As can be seen in Figure 2, it appears that psychopaths were slightly (but nonsignificantly) slower and more accurate in performing this task, indicating they were as capable as nonpsychopaths in discerning which of two words has a more emotional meaning.

Figure 2: Emotional Word Task Performance



Laterality coefficients [(R-L)/(R+L)] were correlated with Factor 1, Factor 2, and total PCL-R scores. Although, the correlations between RVF advantage and Factor 1, and RVF advantage and full scale PCL scores were negative (suggesting that as one exhibits more psychopathic characteristics, one is likely to have an (abnormal) LVF advantage for identifying the more emotional words), these correlations were not significantly different from zero (see Table 4). Thus, Day and Wong's (1995) pattern of results was not replicated.

Table 4:

Correlations Between Emotional Word RVFA*

and PCL-R Ratings

	Factor 1	Factor 2	PCL - R
RVFA	-0.23 $p < 0.26$	0.02 $p < .94$	-0.12 $p < .54$

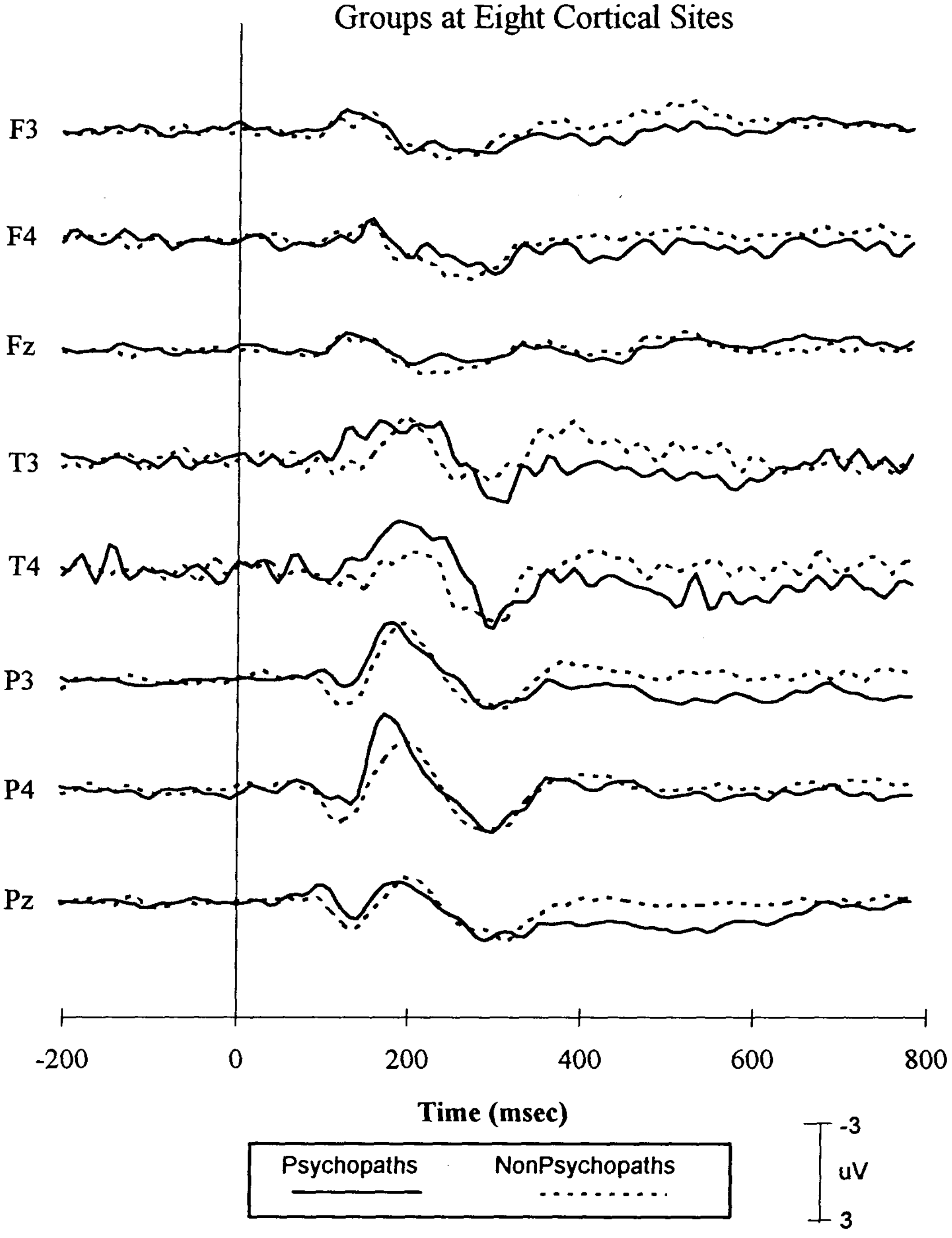
*right visual field advantage
N=27

Electrocortical Measures.

After trials contaminated by eyeblinks and other artifacts were removed from the data, one-second epochs (200 msec prestimulus and 800 msec poststimulus) of data were averaged for each trial, separating left-sided emotional word trials from right-sided emotional word trials. The P300 peak, the most positive going waveform between 250 and 450 msec post-stimulus, was chosen by manually moving a cursor to the point of highest voltage in each trace (i.e., for each channel or brain sight: F3, F4, Fz, T3, T4, P3, P4, Pz). Amplitude values are relative to a 100 msec prestimulus baseline. Figure 3 illustrates the electrocortical waveforms over the eight sites of interest.

It was expected that nonpsychopaths would emit larger P300 peaks over right anterior sites than over other cortical areas in response to emotional words. Although there were overall trends to show that nonpsychopaths utilized right anterior resources, while psychopaths showed relatively less right frontal activity and more right parietal activity than nonpsychopaths during the emotional word task, group by hemisphere interactions were not significant.

Figure 3: Emotional Word Task ERPs for Both Groups at Eight Cortical Sites



Three 2 (Group) X 2 (VF) X 2 (Hemisphere) repeated-measures ANOVAs were performed for P300 amplitude and latency at frontal, temporal, and parietal sites. Two 2 (Group) X 2 (VF) ANOVAs were performed for P300 amplitude and latency at Fz and Pz sites as well.

At frontal (F3, F4) sites, P300s tended to be larger in response to emotional words in the RVF than to emotional words in the LVF ($F(1, 21) = 4.68$, $p < .05$; see Figure 4). Neither the Group main effect nor the Group X VF interaction was significant. P300 latency was also submitted to the same analyses. At frontal sites (F3 and F4), only the Group X VF X Hemisphere interaction approached significance ($F(1, 21) = 5.92$, $p < .03$). As can be seen in Figure 5, nonpsychopaths tended to have later P300 peaks over the right frontal area when the emotional word was on the left, and earlier P300 peaks over the right frontal area when the emotional word was presented on the right, whereas the psychopaths' P300 latencies displayed the opposite pattern. Regardless of the condition, the P300 peak over F3 occurred at approximately the same time for both groups. However, a Tukey test[1] showed that there were no group differences in latencies for any of the four comparisons, and so this must be interpreted with caution. All other analyses with latency effects were not significant.

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[1] Because I have chosen a conservative significance level, all F test results significant up to a level of .05 were examined by Tukey tests to explore where differences may lie. While some researchers (e.g., Hays, 1988) insist that it is necessaary for the overall F to be significant, others (e.g., Howell) suggest that a more liberal approach is warranted.

Figure 4: Frontal P300 Amplitude for Emotional Words

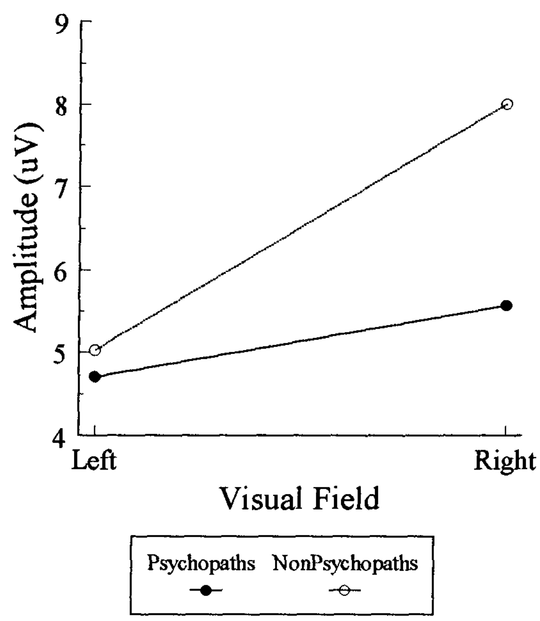
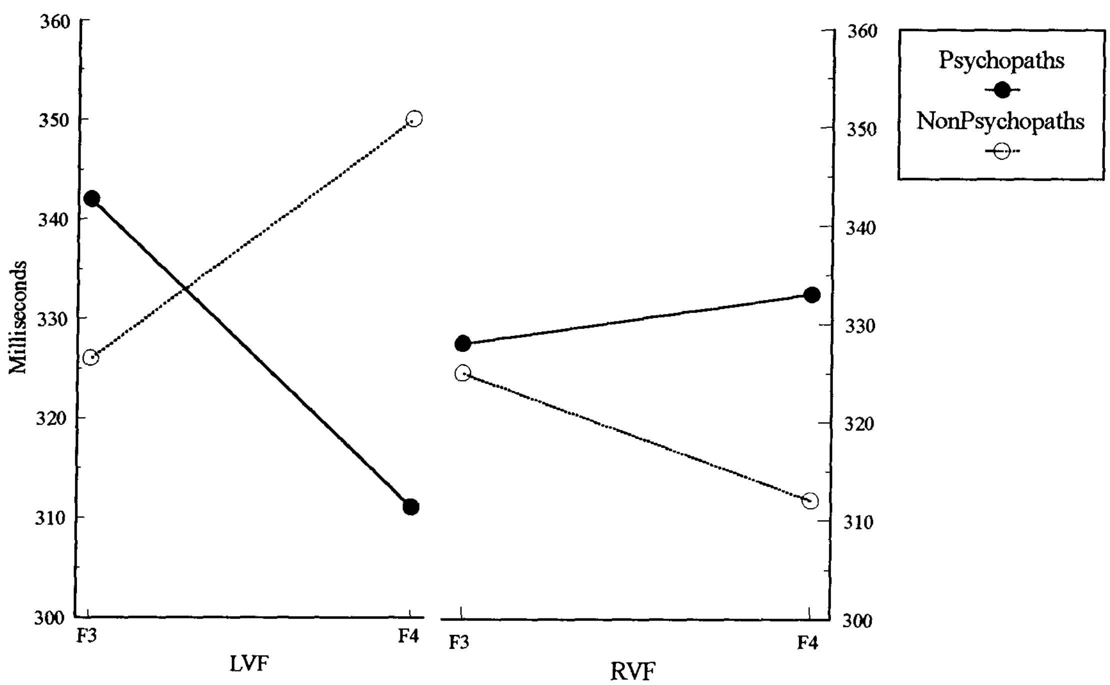
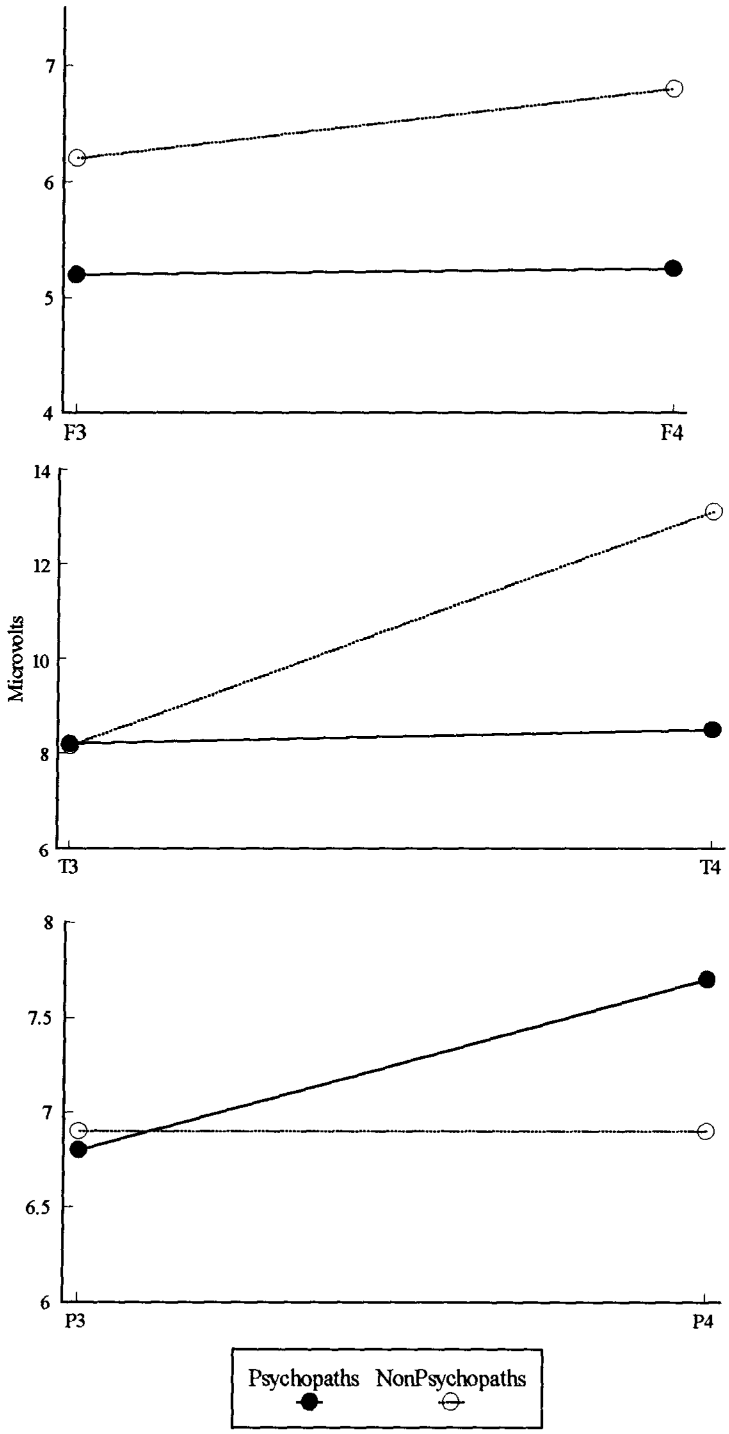


Figure 5: Left and Right Frontal P300 Latency for Left and Right Visual Field Emotional Words



As can be seen in Figure 6, P300 amplitude at temporal sites tended to be greater in the right hemisphere than in the left hemisphere ($F_{(1, 22)} = 5.53$, $p < .03$). This pattern also tends to be stronger for the nonpsychopathic inmates, but the interaction only approached statistical significance (Group X Hemisphere, $F_{(1, 22)} = 3.52$, $p < .08$). There were no significant main or interaction effects of P300 latency, other than a trend for the P300 to occur later over the right hemisphere relative to the left ($F_{(1, 22)} = 4.09$, $p < .06$). At parietal sites there were no significant effects.

Figure 6: P300 Amplitude for Emotional Words at Left and Right Frontal, Temporal, and Parietal Sites

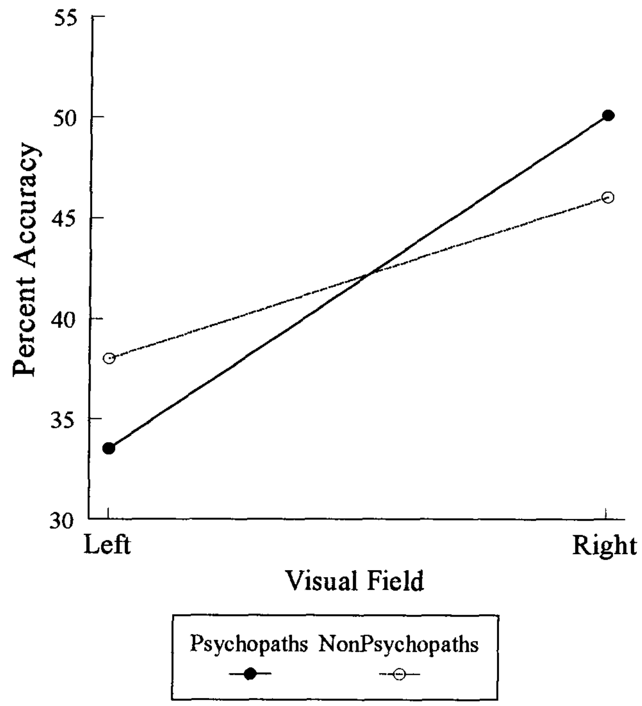


Non-Emotional Word Discrimination

Performance.

As this was not a timed task, only percent accuracy was submitted to a 2 (Group) x 2 (Visual Field) ANOVA. It was predicted that both groups would perform more accurately when they were required to identify RVF words than LVF words. As can be seen in Figure 7, both groups displayed the expected RVF advantage for word recognition ($F(1, 22) = 14.25$, $p < .01$). There was also a tendency for the psychopaths to be *more* lateralized, but the Group X VF interaction was not significant.

Figure 7: Nonemotional Word Task Performance



To explore the Group X VF interaction further, laterality coefficients were computed as for the previous task, and right-visual field advantage (RVFA) was correlated with Factor 1 and Factor 2 (of the PCL-R) and total PCL-R scores. RVFA was positively correlated with all three psychopathy measures (see Table 5), and significantly with Factor 1.

Table 5:

Correlations Between Nonemotional Word

RVFA and PCL-R Ratings

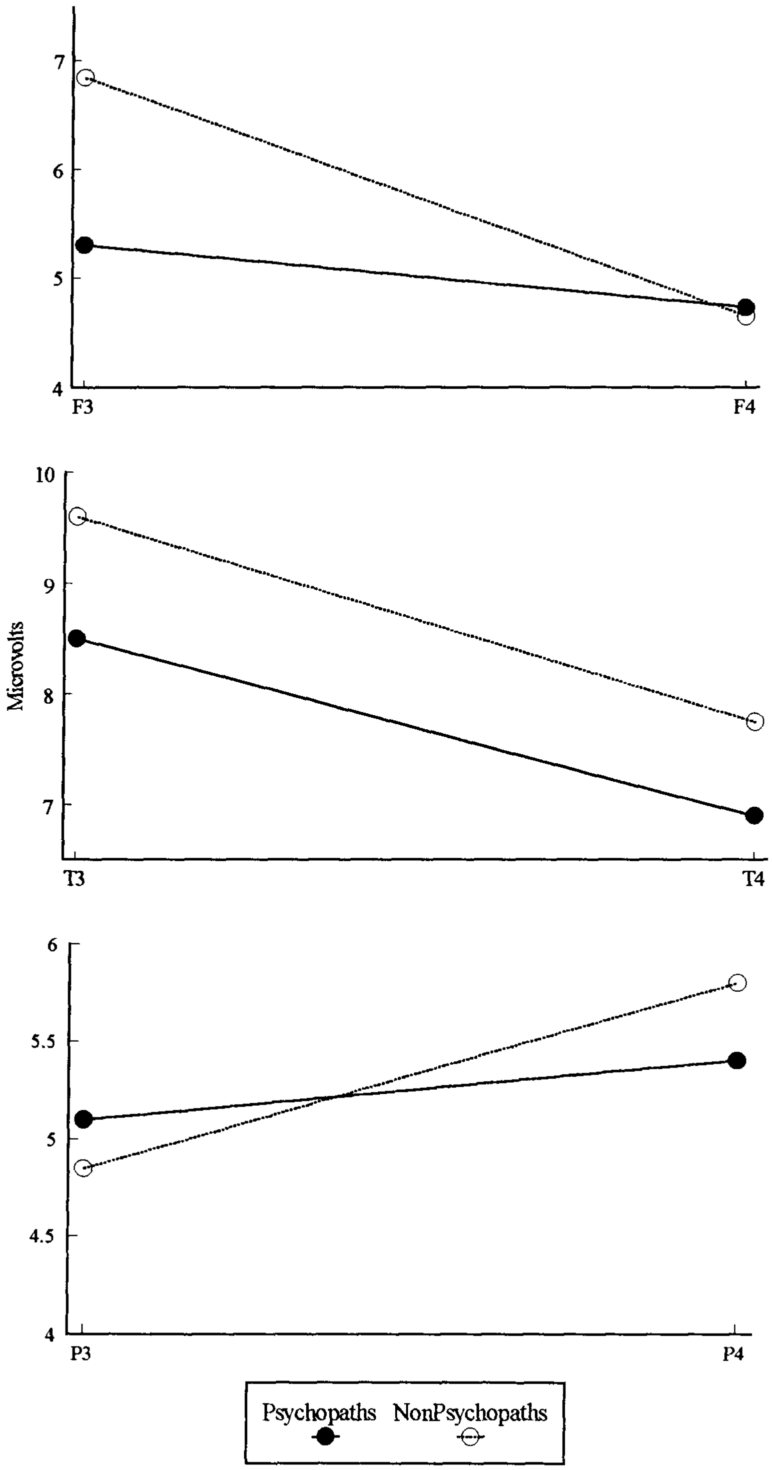
	Factor 1	Factor 2	PCL - R
RVFA	0.49 $p < .01$	0.45 $p < .03$	0.46 $p < .02$

*right visual field advantage
N=27

Electrocortical Measures.

P300 amplitudes and latencies were processed and analyzed in the same manner as for the emotional word task. Figure 8 shows the mean P300 amplitudes at each lateralized site, while a diagram of the ERP waveforms is presented in Appendix E. There was an expected trend for nonpsychopaths to give greater left than right hemisphere responses to nonemotional words at frontal and temporal sites. This pattern is very different from that found in the emotional word task, which showed an opposite hemispheric activation pattern at these more rostral sites. However, most patterns are weak, and statistical tests confirm that these patterns are nonsignificant and must be interpreted cautiously.

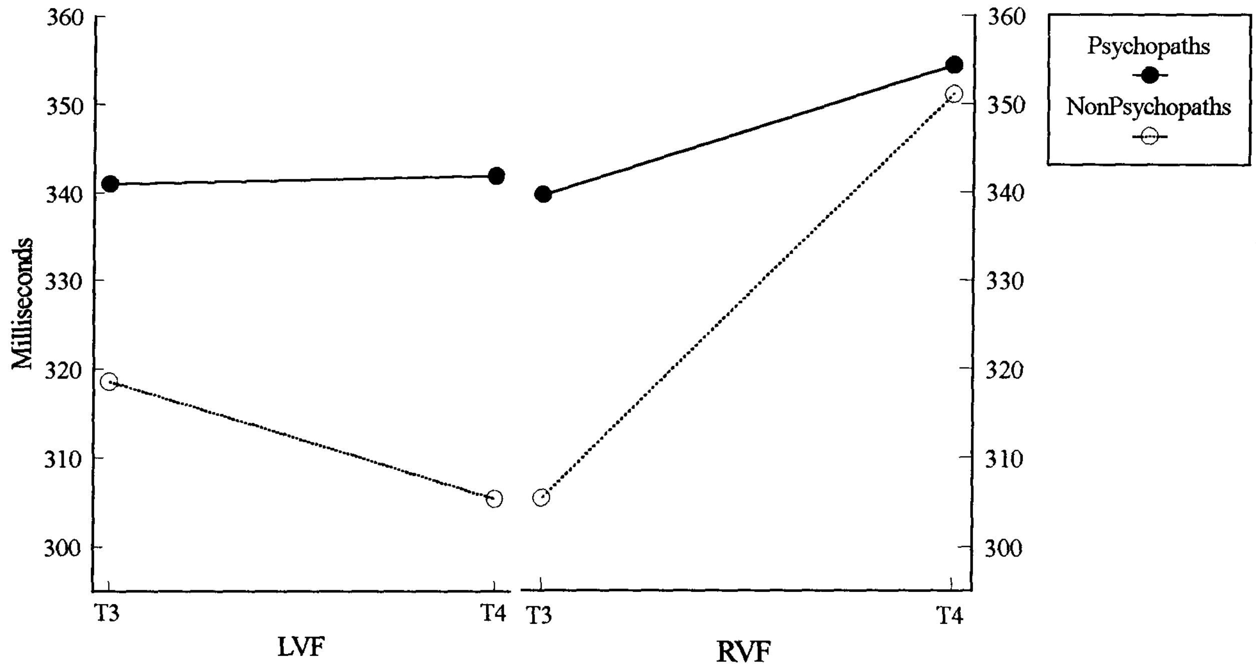
Figure 8: P300 Amplitude for Nonemotional Words at Left and Right Frontal, Temporal, and Parietal Sites



At frontal sites, the Group main effects and interactions were not significant. There was a trend for a VF effect over Fz ($F_{(1, 22)} = 4.46$, $p < .05$). That is, P300s tended to be larger in response to words presented in the RVF than to words presented in the LVF. No VF effects were obtained at the other frontal sites. ANOVAs of P300 latency yielded no significant main effects or interactions.

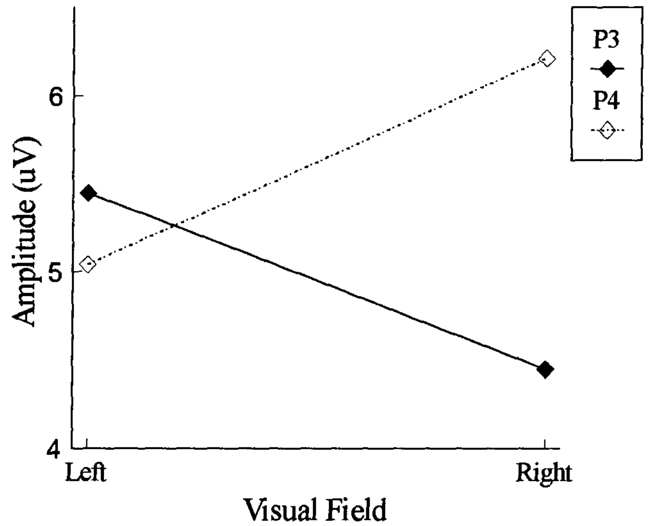
At temporal brain sites, there were no significant main effects or interactions for P300 amplitude. The P300 peaks over temporal sites tended to occur later in psychopaths than in nonpsychopaths (see Figure 9), but the difference was not significant ($F_{(1, 20)} = 3.00$, $p < .10$). The Group X VF X Hemisphere interaction approached significance ($F_{(1, 20)} = 4.67$, $p < .05$). As can be seen in Figure 9, for nonpsychopaths, P300s to RVF words occurred later over T4 than T3. P300s for LVF words elicited the opposite pattern. In contrast, lateralized latency effects appeared almost nonexistent for the psychopaths. However, Tukey Significant Difference tests illustrated that there were no group differences (TSD (20) = 41.33, $p < .05$) for any of the four comparisons.

Figure 9: Left and Right Temporal P300 Latency for Left and Right Visual Field Nonemotional Words



At parietal sites, there was a significant VF X Hemisphere interaction for amplitude of the P300 ($F_{(1, 22)} = 8.30$, $p < .005$; see Figure 10). That is, when words were presented in the RVF the P300s were larger in the right hemisphere than in the left hemisphere (TSD (22) = 1.56, $p < .05$). No other parietal comparisons of P300 amplitude were statistically significant.

Figure 10: Parietal P300 Amplitude Visual Field by Hemisphere Interaction for Nonemotional Words



Lateralized Word Identification - Two Tasks Combined

As described above in the two "performance measures" sections, it appears that psychopaths were somewhat *less* lateralized for emotional word processing, and *more* lateralized for non-emotional word processing than were nonpsychopaths. To explore this further, percent accuracy was subjected to a 2 (Group) X 2 (VF) X 2 (Task; emotional versus nonemotional) ANOVA. Not surprisingly, there was a strong VF effect ($F(1, 22) = 10.82$, $p < .01$) and task effect ($F(1,22) = 19.36$, $p < .001$), indicating that accuracy was greater for RVF words than for LVF words overall, and for the emotional word task than for the nonemotional word task. There was also a trend toward a VF X Task interaction ($F(1, 22) = 3.35$, $p < .09$), suggesting that visual field advantage was stronger or more pronounced for the non-emotional word task than for the emotional word task. The Group X VF X Task interaction was not significant ($F(1, 22) = 1.92$, $p < 0.19$).

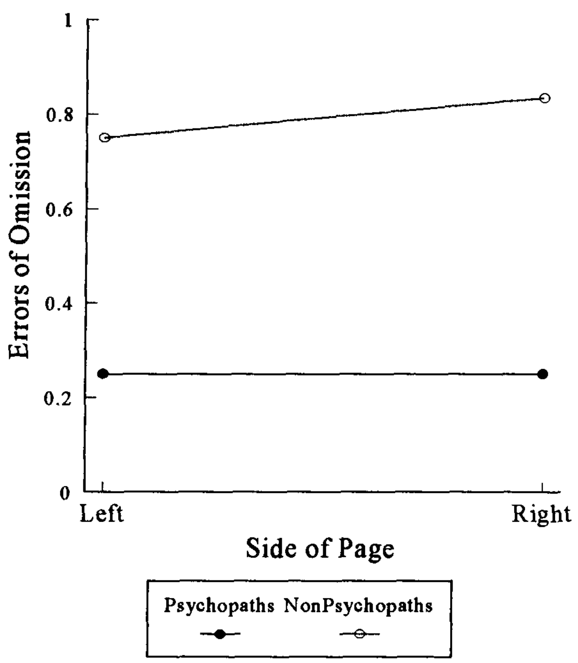
Another way in which to explore the different pattern of lateralization for the two groups across the two verbal tasks was to compute a 2 (Group) X 2 (laterality coefficient for each task) ANOVA. However, the Group X Laterality Coefficient interaction was not significant.

Verbal Visual Search

Performance.

Number of errors was submitted to a 2 (Group) X 2 (Side) ANOVA. Group differences were not expected. Although psychopaths made fewer errors than did nonpsychopaths, the difference was not statistically significant ($F(1, 22) = 3.10$, $p < .10$). Overall, very few targets were missed (see Figure 11).

Figure 11: Verbal Visual Search Performance



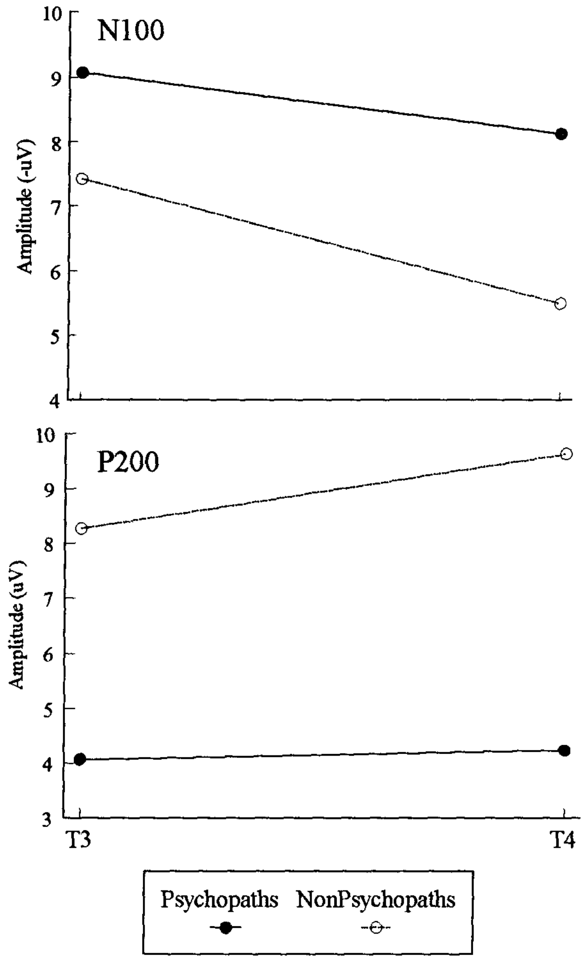
Electrocortical Measures.

EEG data were digitally filtered and then examined visually, and all trials contaminated by eyeblinks or other artifacts were deleted from the analyses. The remaining EEG data were averaged in blocks 600 msec in length (100 msec pre-stimulus). The amplitude of the N100 (the most negative-going wave 60-150 msec post-stimulus) and P200, the most positive-going wave between 100 and 250 msec post-stimulus, following the N100) were selected for all subjects at each brain site (see Appendix E for an example of the waveforms). The amplitudes of these waves were subjected to separate 2 (Group) X 2 (Hemisphere) ANOVAs. It was expected that these electrocortical indices of attention would verify that nonpsychopaths utilize right hemisphere resources to conduct visual search.

There were no group differences in N100 amplitude at frontal, temporal or parietal sites. However, there was a trend for the N100 to be larger in amplitude (more negative) in the left temporal lobe than in the right temporal lobe ($F_{(1, 18)} = 4.09$, $p < .06$). A similar (but nonsignificant) pattern was observed at frontal and parietal sites.

At temporal lobe sites the nonpsychopaths tended to have larger P200 responses than did the psychopaths ($F_{(1, 18)} = 5.42$, $p < .04$). The Group X Hemisphere interaction was not significant. See Figure 12.

Figure 12: Temporal Lobe N100 and P200 Amplitude for Verbal Visual Search



Discussion

Psychopaths and nonpsychopaths did not differ in their performance on the three verbal tasks. However, the patterns of group differences suggest that the two groups used different strategies or that their brains analyzed the information in different ways. This is especially instructive, considering that they were no different on the many background variables that could influence cognitive performance or neurological functioning. See Table 6.

Table 6:

Summary of Study 1 Statistically Significant Results and Trends

Task	Significant Results or Trends	Description and Interpretation
Emotional Word Task	Performance:	
	Nothing significant	Nonpsychopaths displayed the RVF advantage expected from the literature for percent accuracy and reaction time. Psychopaths appear less lateralized than nonpsychopaths, especially for percent accuracy
	ERPs (P300 amplitude):	
	F3, F4: VF*................ p < .05	RVF words elicited larger P300s than LVF words
	T3, T4: $H^{■}$.....................p < .03	Larger P300s over T4
	G^{Ψ} X H.............p < .08	The involvement of more right hemisphere resources than left is more evident for the nonpsychopaths than the psychopaths
	ERPs (P300 latency):	
	F3, F4: G X H X VF..... p < .03	Nonpsychopaths' left frontal area processed LVF words faster than the right frontal area. The opposite is true for RVF words. The psychopaths show the opposite pattern overall. This is difficult to interpret.
	T3, T4: H.......................p < .06	P300s occurred later over the right hemisphere, suggesting this brain area took longer to process the information

Table 6 continued:

Task	Significant Results or Trends	Description and Interpretation
Nonemotional Word Task	Performance (percent accuracy):	
	VF: .... $p < .002$	Accuracy is greater for RVF words than LVF words
	Positive correlation between: RVFA and Fact. 1 .... $p < .008$ RVFA and Fact. 2 .... $p < .03$ RVFA and PCL-R .... $p < .02$	Psychopathic traits are correlated with a more pronounced RVFA for identifying nonemotional words. Nonpsychopaths' rates of LVF and RVF accuracy match those of noncriminal populations, while psychopaths are more strongly lateralized
	ERPs (P300 amplitude):	
	Fz; VF .... $p < .05$	RVF words elicited larger P300 responses than LVF words, but no similar effect found at F3 and F4
	P3, P4; VF X H.......... $p < .008$	RVF words elicited larger right hemisphere responses than left hemisphere responses. The right hemisphere may have fewer resources for verbal tasks and is thus more taxed
	ERPs (P300 latency):	
	T3, T4; G..................... $p < .10$	Psychopaths had later-occurring P300s
	VF X H ....$p < .09$	Weak interaction, better explained by G X VF X H interaction
	G X VF X H.... $p < .05$	For nonpsychopaths, LVF words elicit later left than right hemisphere P300s, and RVF words elicit later right than left hemisphere P300s. Considering that information is projected contralaterally in the cortex, this is the expected pattern. In psychopaths, the P300s appear to occur at the same time, regardless of VF or H.

Table 6 Continued:

Task	Significant Results or Trends	Description and Interpretation
Verbal Visual Search	Performance (errors):	
	G .... $p < .10$	Nonpsychopaths tended to miss more target letters
	ERPs (N100 amplitude)	
	T3, T4; H.................... $p < .06$	Larger amplitude in the left temporal lobe than the right. This brain area is responding more to the tones, as the right is presumably more involved in the task than is the left side.
	ERPs (P200 amplitude)	
	T3, T4; G .... $p < .04$	Nonpsychopaths tended to have larger P200 peaks, suggesting they were more involved in the task and less responsive to the tones than the psychopaths

Ψ G = group
■ H = hemisphere
* VF = visual field

Nonpsychopaths showed a nonsignificant RVF advantage for identifying the more emotional words in word pairs. These findings are quite different from those of Day and Wong (1995), despite my attempts to replicate their paradigm precisely (with the addition of EEG recording). I used computerized tasks rather than a tachistoscope (as they did), which allowed greater control over the timing of stimuli presentation. This may explain the different outcome. Recall that the psychopaths in Day and Wong's study showed a RVF advantage while the nonpsychopaths showed a LVF advantage. In contrast, the nonpsychopaths in the current study had lateralized percent accuracy scores very similar to those in comparable studies using normal populations (Eviator & Zaidel, 1991; Graves et al., 1981; Strauss, 1983). Psychopaths, in contrast, were less lateralized than nonpsychopaths for percent accuracy. Their right and left hemispheres seemed equally capable of identifying which word was more emotional. Considering that they were over ten percent slower than nonpsychopaths at this task, we could speculate that their ability to "use" both hemispheres does not improve their performance. These patterns in group differences were not statistically significant, however, and requires further exploration.

The patterns of electrocortical activation in response to the emotional words also allow us to speculate how psychopaths and nonpsychopaths are similar and different. Nonpsychopaths had somewhat greater right frontal and right temporal activity than psychopaths, suggesting that in nonpsychopaths these brain areas were more involved in processing or analyzing the emotionality of word meaning than was the case with psychopaths. Right visual field words, the words yielding greater recognition for nonpsychopaths, resulted in greater frontal activity and shorter P300 latencies, especially over right frontal areas than did left visual field words. These results make intuitive sense. While the left hemisphere remains superior for identification of lateralized verbal material, it appears to draw on the right anterior brain areas to process emotional meaning. Considering that similar emotional word tasks have shown that we process these words more quickly than neutral words (e.g., Williamson et al., 1991), and that they involve more right hemisphere resources than do nonemotional words (e.g., Graves et al., 1981), we could speculate that the two hemispheres work together efficiently and quickly to process information of relevance and interest. This may be due to greater inter- and intra-hemispheric transfer of interesting or important information. Psychopaths, although their performance was not significantly poorer, did not seem to use right anterior brain areas to the same extent as did nonpsychopaths. In contrast, although not statistically significant, there was a tendency for psychopaths to utilize right parietal resources. We could speculate that psychopaths use right parietal areas to complete this task, are just as accurate at identification of word meaning, but are not able to utilize the more sophisticated and interconnected rostral brain areas to quickly elaborate upon the emotionality of the information. Their performance patterns suggest that, as in Jutai and Hare's (1983) study, the psychopaths semantically categorized the words, using right parietal resources to do so.

The non-emotional word identification task produced quite different results. Both groups displayed the expected left hemisphere advantage, but the RVF advantage was more pronounced in the psychopaths than in the nonpsychopaths. The performance of the latter group was similar to that of Boles's (1991) three normal samples. He found an overall 8.4 percent performance advantage for the RVF for three normal samples, whereas the nonpsychopaths in the present study showed a 7.9 percent RVF advantage. The psychopaths, however, showed a 16.9 percent performance advantage for identifying words in the RVF. Thus, simple words presented in the LVF were more rarely identified by psychopaths than nonpsychopaths. Perhaps the psychopaths' right hemispheres are not equipped with a lexicon, or there is poorer communication between the two hemispheres than in nonpsychopaths. However, considering the psychopaths tended to be *less* lateralized for the more complex emotional word task, the results are quite difficult to interpret.

The patterns of electrocortical results allow further speculation. Nonpsychopaths showed the expected greater left than right hemisphere activity over frontal and temporal areas, suggesting greater involvement of the left rostral cortex than of right rostral cortex. Psychopaths, in contrast, were less lateralized in terms of electrocortical activity, and showed less involvement of frontal and temporal brain areas than did nonpsychopaths. In temporal areas in particular, nonpsychopaths showed slightly more cortical activity for RVF words than for LVF words. Latency patterns over temporal areas suggest that nonpsychopaths also processed the information more quickly than did psychopaths. The exception to this was P300 latency for RVF words over T4. Stimuli in the RVF are projected contralaterally to the left temporal area, and the right temporal area (an area normally less involved in word recognition) processes the words later, whether because this area receives the information later (due to fewer inter-hemispheric connections), or simply takes longer to respond (due to fewer intra-hemispheric connections or cells devoted to this type of cognitive activity). For psychopaths, RVF words elicited less temporal activity than they did in nonpsychopaths, and temporal P300s occurred later for words presented in both visual fields. The RVF stimuli were more easily identified by the psychopaths than by the nonpsychopaths, but perhaps the temporal lobes of psychopaths were less involved in the analysis than they were in nonpsychopaths. The information appears to be processed more slowly at rostral sites for the psychopaths than for the nonpsychopaths, particularly over right areas. It is unfortunate that the design of this task did not allow an examination of reaction time, because we could speculate that despite equal performance overall, psychopaths may have been slower than the nonpsychopaths.

In sum, for nonpsychopaths, the less pronounced asymmetry in performance and greater left fronto-temporal hemisphere activity, relative to the psychopaths, suggests that they more adequately or efficiently transferred information between the hemispheres. Words were sometimes identified in the LVF, but perhaps the left hemisphere did most of the "work". In contrast, the relatively smaller and slower P300 peaks over fronto-temporal areas in psychopaths, coupled with the tendency for greater asymmetry of performance than in the nonpsychopaths, may indicate that this task was very simple and motivating for psychopaths, as long as the words were presented in the RVF. Thus, while the left hemisphere did most of the "work" in both groups, more difficult or inaccessible LVF words simply were not processed by the psychopaths.

For verbal visual search, psychopaths had slightly better performance than nonpsychopaths, suggesting that they may have been better able to focus their attention and detect more targets. However, the larger P200 peaks (due to a smaller negative shift) in response to the tone probes on the part of the nonpsychopaths (relative to psychopaths) over temporal areas (especially over the right hemisphere) suggests that the nonpsychopaths utilized these brain areas to complete the task. This may indicate that the nonpsychopaths focused their attentional resources more efficiently on the task than did the psychopaths. This is difficult to interpret, because it appears that the psychopaths, who were more responsive to the tones than the nonpsychopaths (and supposedly more distracted by them) had better search performance. In a review, Harpur and Hare (1990) concluded that psychopaths do not typically show attentional deficits, but have an unusual ability to mobilize their attentional resources. They are more likely than nonpsychopaths to overfocus on a motivating task. Is it possible that the brain structures in psychopaths that respond to the tones are divorced from those involved in the search task? That would mean they are better able than nonpsychopaths to divide their attention between these two sets of stimuli.

It appears that administration of three verbal tasks (one emotional, one nonemotional, and one visuospatial) was fruitful in drawing out some group differences in processing strategies. Psychopaths utilized brain areas in an unusual way, suggesting that there may be odd communication among their brain areas, both between and within hemispheres. They did not incorporate as many right frontal resources in analyzing verbal emotional information as did nonpsychopaths, and yet were less lateralized in performance. The psychopaths tended to draw on the resources of both hemispheres to identify nonemotional words, and yet were more lateralized in performance than nonpsychopaths. For verbal visual search, psychopaths were able to respond to irrelevant tones, appearing inappropriately focused on them, and yet performed as if they were better able to focus than the nonpsychopaths. All interpretations must be undertaken with caution, as most group differences were nonsignificant trends. However, verbal skills (emotional, nonemotional, and visuospatial) appear to be organized in an unusual manner in psychopaths. An examination of nonverbal skills may shed light on where the abnormalities lie, and how psychopaths compensate intellectually for their deficits.

Experiment 2 (Nonverbal Tasks)

Method

This experiment involved measuring accuracy, reaction time, and electrocortical activity during four non-verbal tasks. Although Experiment 1 included only three tasks, we have far less information on lateralized non-verbal performance in psychopaths, so a fourth task was included here.

Subjects

Twenty-six male inmates were assessed for psychopathy. As in Experiment 1, they were placed into Psychopathic (n=12) and Nonpsychopathic (n=12) groups. Two middle-range scorers were included for correlational analyses. Two differences in inclusion and exclusion criteria must be noted, however. First, three subjects spoke English as a second language, but they had lived in Canada for many years, and were fluent in English. Second, subjects had their hearing tested before being included as subjects, and if they had significant differences in left and right acuity they were excluded from the study.

Procedure and Apparatus

The general procedure, apparatus and statistical methods used in Experiment 1 were followed for Experiment 2.

Description of Non-Language Tasks

Task 1: Emotional Faces Discrimination.

This task is modeled after Day and Wong's (1995) facial emotion discrimination task. This task incorporates emotional processing and is expected to draw more on right than left hemisphere resources. Subjects were presented with bilateral pairs of faces, chosen from Ekman and Friesen's (1975) photographs of facial affect. The faces were of male posers with sad, angry, fearful, disgusted and neutral expressions. The stimulus set included 40 pairs of faces; an emotional face was always paired with a neutral face of the same poser. In 20 of the pairs, the emotional face was on the left, and in 20, on the right. The photographs were computerized, so that the stimulus onset and offset times were carefully controlled. The subject pressed a designated left- or right-sided computer keyboard key, the side corresponding to the side of the computer screen that displayed the more emotional face. A digit between 1 and 5 appeared at the centre of the screen simultaneously with the onset of the faces, and after the subject chose which face he thought was more emotional, he verbally reported the digit (trials in which the digit reported was incorrect were deleted from the analyses). Each trial consisted of a central '+' for 1.5 to 2.5 seconds, and then the stimuli for 197 msec. There were 2 seconds between each trial. EEG data were collected continuously while the subject completed the task. Reaction time and accuracy data were collected and stored on the computer hard drive.

Two 2 (Group) X 2 (Visual Field) ANOVAs were performed on the dependent variables, percent accuracy and reaction time. As in Experiment 1, laterality coefficients were calculated, and correlated with PCL-R Factor 1 and 2 scores. Three 2 (Group) X 2 (Visual Field) X 2 (Hemisphere) ANOVAs were conducted on the P300 ERP component at frontal, temporal, and parietal sites. It was expected, based on Day and Wong's findings, that there would be no significant differences between groups on either performance measure on this task. Both groups were expected to show a LVF advantage for reaction time and accuracy, and greater right hemisphere activity in response to the faces.

Task 2: Mental Rotation Task.

This is a nonemotional right hemisphere task involving mental rotation of visually presented material. It was modeled after a study by Begleiter, Porjesz, Bihari, and Kissen (1984). Subjects were instructed to focus on a '+' in the middle of the computer screen. They then saw one of five possible stimuli at a time. The stimuli were presented in a random order for 29 msec in the centre of the screen. There were 160 presentations of the non-targets (large plain circles), and 20 of each of four possible target stimuli (240 trials in total). The target stimuli were created to represent an aerial view of the head, with a nose and one ear showing (see Appendix F). On 20 of the stimuli, the nose was pointing toward the top of the screen, and the left ear was visible. On 20 of the stimuli, the nose pointed upward, and the right ear was visible. Similarly, 20 displayed the nose pointing toward the bottom of the screen with the left ear visible, and 20 with the right ear visible. Subjects were instructed to decide quickly whether they saw a right ear or a left ear, and press a left- or right-sided key on the computer keyboard with their index finger on the corresponding side. When the nose is pointing upward the task is relatively easy, but when the nose is pointing downward, it is much more difficult. Begleiter et al. (1984) found that the more difficult version elicited the largest amplitude P300 waves, the easier version smaller P300 waves, and the non-targets very small P300 waves. Unfortunately, they only recorded brain activity from mid-line sites, making predictions about the morphology of lateralized ERPs difficult here.

Stimuli were presented for 29 msec each, and the central '+' was present at all times the stimuli were not. The interstimulus interval varied from 2 to 4 seconds. If the subject failed to respond before 1500 msec post-stimulus, the next trial was initiated. Subjects got a two minute break half-way through the task (i.e., after 120 trials).

ERPs were collected while subjects completed this task. Accuracy and reaction time data were collected and stored on the computer hard drive. 2 (Group) X 2 (easy versus difficult Condition) ANOVAs were conducted for the percent accurate data and for reaction time. P300 amplitude and latency were analyzed in 2 (Group) X 2 (Condition) X 2 (Hemisphere) ANOVAs, at frontal and parietal sites only, as P300 peaks were not reliably produced at temporal sites. PSW (P500) amplitude and latency were analyzed in a similar manner at all three brain areas. It was expected that psychopaths and nonpsychopaths would perform similarly on this task, but no predictions could be made regarding ERP data. However, one would expect generally more right than left parietal involvement in this type of task.

Task 3: Nonverbal Visual Search.

This task is very similar to Task 3 in Experiment 1. Thus, it is an unemotional task, and draws on right hemisphere skills. Each subject was presented with a piece of paper and a pen. On the paper was a random array of non-verbal symbols (Weintraub & Mesulam, 1985; see Appendix G). The participant was asked to search for and cross-out all instances of a pre-determined target symbol. As above, there were 48 instances of the target dispersed among 256 non-target symbols. While he was completing this task, he heard 76 tone pips delivered through bilateral earphones, which he was to ignore. Subjects were encouraged to be as accurate as possible, but to work quickly as well. Number of errors (missed targets) were recorded manually and analyzed by a 2 (Group) X 2 (Side) ANOVA. EEG data were recorded as described above. Comparisons of N1 and P2 amplitudes were conducted by performing 2 (Group) X 2 (Hemispheres) ANOVAs at the three brain sites. It has been found that this nonverbal visual search task involves more right than left hemisphere resources (Jutai et al., 1988; Mills, 1989). It was predicted that the psychopaths and nonpsychopaths would perform equally well, but that the psychopaths might show less right hemisphere involvement in the task than the nonpsychopaths (Mills, 1989).

Task 4: Four Tone Test.

This task is taken from Nachshon (1988), and can be considered a left hemisphere non-emotional task. Each subject heard four different tones (400, 700, 1100, and 1500 Hz), presented in pairs (one of each of the 12 possible combinations, presented dichotically through earphones). Tone duration was 500 msec. The subject was instructed to attend to either the left or the right ear for the first 12 trials, and the other ear for the second 12 trials. After each pair of tones, there was a 12.5 second interval. Then he heard all four tones (in both ears simultaneously) presented sequentially, each separated by two seconds. The participant was instructed to listen to the four choices, choose the tone he heard in the designated ear, and mark his answer on a score sheet. EEG data were collected during the 24 trials of this task. Ear order was randomized and counterbalanced across groups.

Percent correct responses were submitted to a 2 (Group) X 2 (Ear) ANOVA. It was expected that nonpsychopaths would show a stronger right ear advantage than would psychopaths, but that overall performance of the groups would not differ. Laterality coefficients were calculated by the following equation: (R-L)/(R+L), where R represents right ear percent correct responses, and L represents left ear percent correct responses. Laterality coefficients were correlated with PCL-R scores, and negative correlations were expected, suggesting that the more psychopathic one is, the more of a left ear advantage he has. P300 amplitude and latency were each analyzed in a 2 (Group) X 2 (Hemisphere) ANOVA. Although it was difficult to predict, ERP activity should indicate more left hemisphere involvement in this task for the nonpsychopaths, and perhaps greater right hemisphere activity in the psychopathic subjects.

Results

Demographic and Background Data

See Table 7 for means and standard deviations of Factor 1, Factor 2 and total PCL-R ratings for the two groups.

Table 7:

Study 2 PCL-R Scores

Group	Factor 1	Factor 2	PCL-R
Psychopaths	13.1 (1.8)	14.1 (1.6)	31.9 (1.9)
Nonpsychopaths	5.0 (3.5)	9.7 (2.1)	17.8 (5.1)

As summarized in Table 8, there were no group differences on any of the measured variables. The background characteristics of the two groups were also quite similar to the subjects in Study 1. Thus, any group differences on the performance and electrocortical measures were likely due to psychopathic personality differences.

Table 8:

Study 2 Background Variables

	Group				
	Psychopaths (n=12)		Nonpsychopaths (n=12)		
Variable	M	(SD)	M	(SD)	t (22)
Age	32.33	(9.69)	30.75	(6.37)	0.47
Education	10.50	(1.93)	9.83	(1.75)	0.89
IQ Estimate	101.42	(11.49)	99.91	(8.34)	0.36
Reading (WRAT)	63.83	(12.93)	60.64	(9.27)	0.68
Years in Prison	7.5	(5.78)	4.79	(2.94)	1.45
Drugs (DAST)	13.67	(5.78)	9.82	(7.76)	1.36
Alcohol (MAST)	16.64	(14.66)	22.83	(16.64)	-0.94
Anxiety (STAI-S)	31.75	(7.83)	33.67	(12.81)	-0.44
Depression (BDI)	4.33	(3.60)	5.75	(5.61)	-0.74
E.S.L. *	1	(8.3%)	2	(16.7%)	
Reported Head Injury	4	(33%)	5	(42%)	

* English as a second language

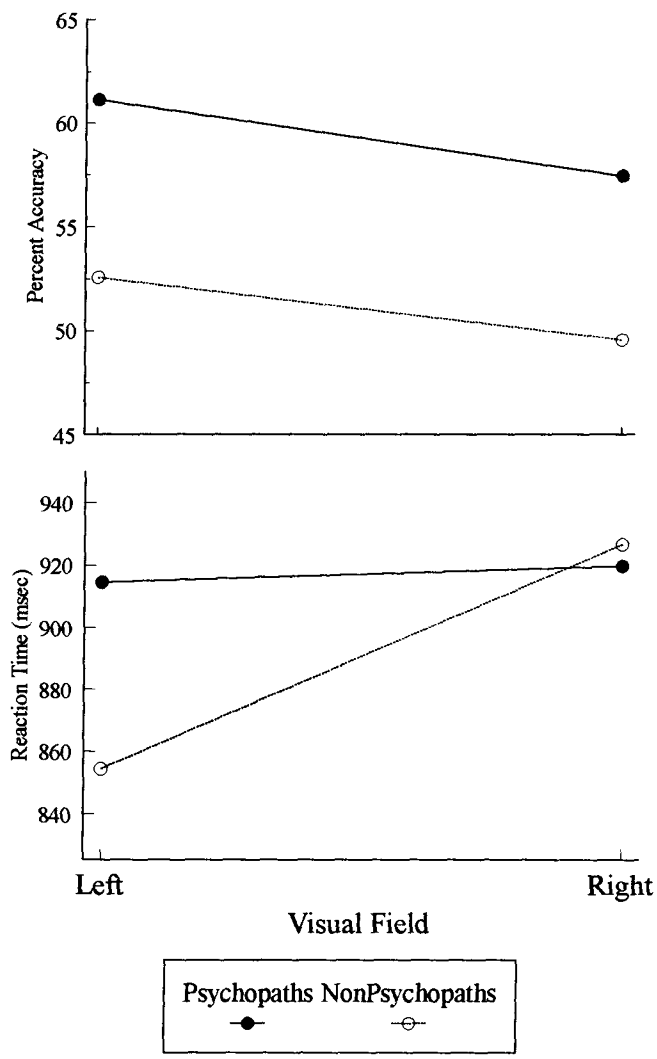
Emotional Face Discrimination

Performance.

A 2 (Group) X 2 (Visual Field) ANOVA was computed for each of the two dependent variables, percent accuracy and reaction time. It was expected that both groups would be more accurate and faster at identifying LVF than RVF emotional faces.

The ANOVAs for percent accuracy and reaction time did not yield a significant Group main effect. Subjects were marginally faster at identifying the more emotional face when it was displayed in the LVF than in the RVF ($F_{(1, 22)} = 5.11$, $p < .04$). Thus, while accuracy was not dependent on visual field, subjects showed the expected LVF advantage in speed of response. Also of interest, there was a trend for the LVF advantage to be stronger in nonpsychopaths than for psychopaths (Group X VF ANOVA: $F_{(1, 22)} = 3.86$, $p < .07$; see Figure 13).

Figure 13: Emotional Face Task Performance



To explore these Group X VF relationships further, laterality coefficients were computed for accuracy and reaction time, and each was correlated with Factor 1, Factor 2, and full scale PCL-R scores. Considering the ANOVA results, it was not surprising that RVF advantage in accuracy did not correlate significantly with psychopathy characteristics. However, as can be seen in Table 9, reaction time advantage for the RVF faces (i.e., faster at identifying emotional faces in the right side of the computer screen) tended to correlate positively but nonsignificantly with psychopathy (especially full scale scores).

Table 9:

Correlations Between RVFA* of Emotional Face Identification Reaction Time and PCL-R Ratings

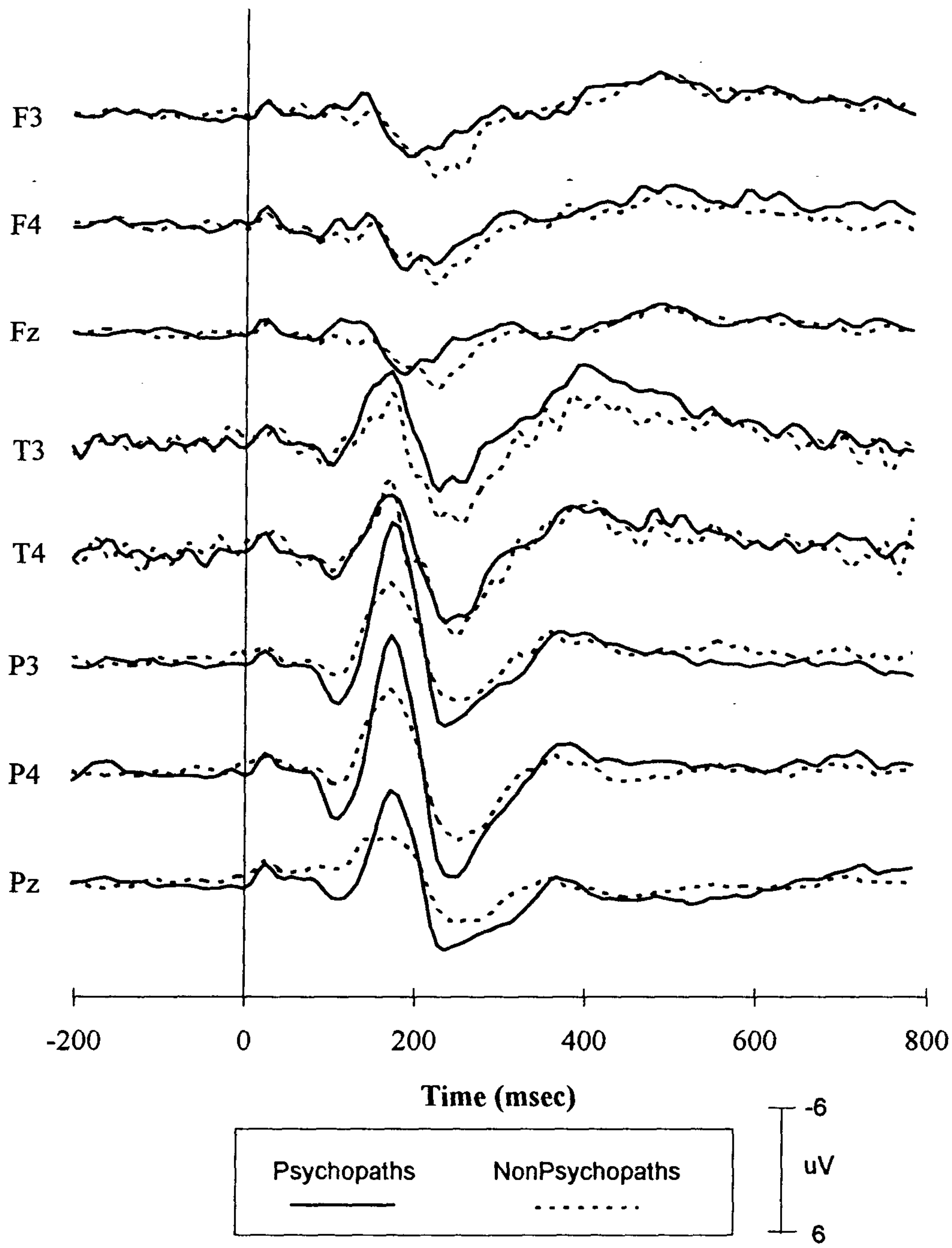
	Factor 1	Factor 2	PCL - R
RVFA	.24 p < .24	.25 p < .23	.34 p < .10

*right visual field advantage
N=26

Electrocortical Measures.

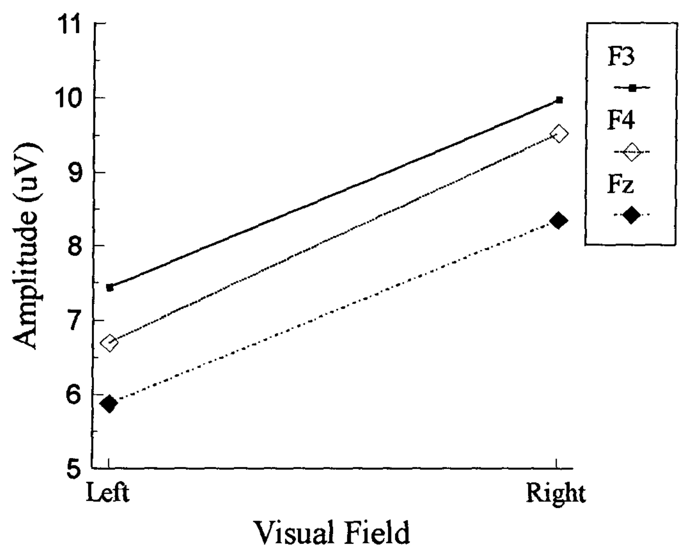
As in Study 1, P300 peaks were selected for each channel at each brain site of interest, and P300 amplitude and latency were subjected to a 2 (Group) X 2 (Hemisphere) X 2 (VF) repeated measures ANOVA at frontal, temporal, and parietal sites. Fz and Pz P300 amplitude and latency were each analyzed with a 2 (Group) X 2 (VF) ANOVA. It was expected that nonpsychopaths would emit larger right- than left-sided P300s in response to emotional faces. See Figure 14 for an illustration of ERP waveforms for this task.

Figure 14: Emotional Face Task ERPs for Both Groups at Eight Cortical Sites



At frontal brain areas, there was a trend for a main effect of VF, both at lateralized ($F(1, 21) = 5.15$, $p < .04$) and midline sites ($F(1, 21) = 7.30$, $p < .02$). Thus, it appears that subjects' P300 peaks tended to be greater in response to RVF faces than to LVF faces (see Figure 15). The visual field effect for P300 latency was not significant at F3 and F4 ($F(1, 21) = 2.77$, $p < .12$), but marginally significant at Fz ($F(1, 21) = 6.03$, $p < .03$). Thus, when the emotional faces were presented in the LVF, the subjects tended to emit later P300 peaks than when the faces were presented in the RVF.

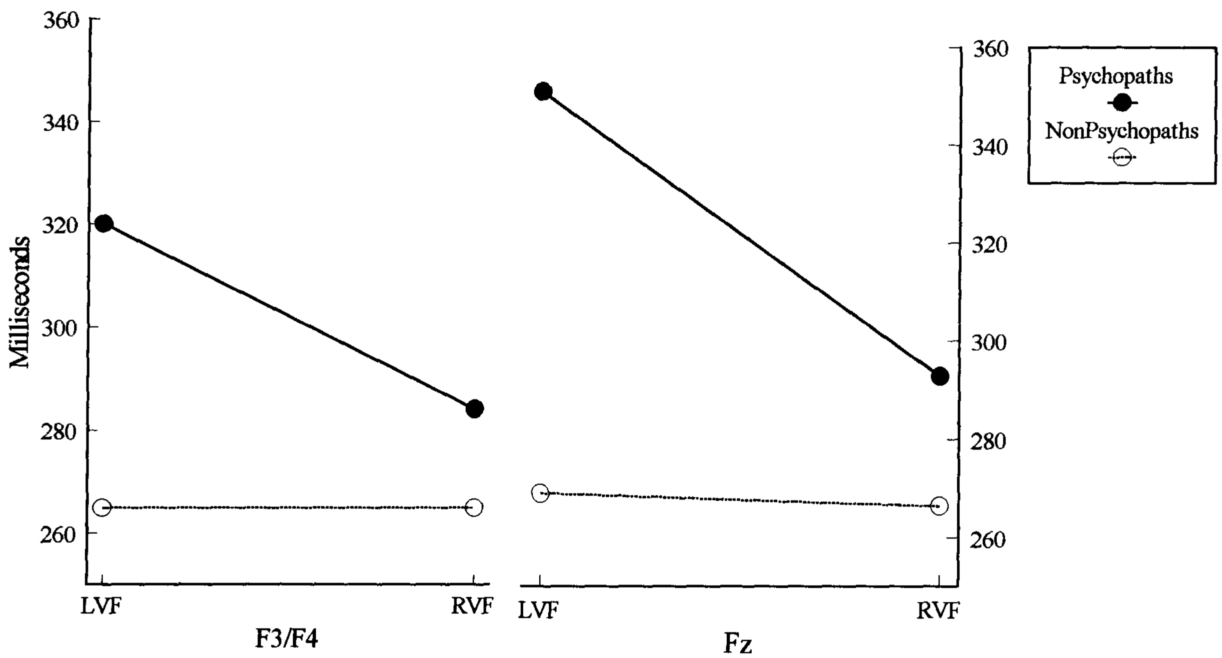
Figure 15: Frontal P300 Amplitude for Emotional Faces, All Subjects Combined



There were some group trends for P300 latency at frontal sites. There was a marginally significant effect of Group at lateralized frontal sites ($F(1, 21) = 6.02$, $p < .03$) and at Fz ($F(1, 21) = 7.95$, $p < .02$). The psychopaths tended to produce later-occurring P300 waves than did the nonpsychopaths. Finally, the Group X VF interaction was almost significant at Fz ($F(1, 21) = 5.05$,

$p < .04$), but not significant at the other frontal sites ($F(1, 21) = 2.00$, $p < .12$). Tukey tests confirmed that psychopaths tend to have later-occurring P300 peaks when the emotional faces were presented on the left side of the computer screen relative to the nonpsychopaths at Fz (TSD (21) = 50.64, $p < .01$; see Figure 16).

Figure 16: P300 Latency for Left and Right Visual Field Faces at Lateralized and Midline Frontal Areas



At temporal brain sites, the same types of ANOVAs were computed. There were no significant main or interaction effects for P300 amplitude. However, the VF X Hemisphere interaction approached significance ($F(1, 21) = 3.37$, $p < .09$). As expected, when the emotional face was presented in the LVF, ERPs tended to be greater in the right hemisphere than in the left hemisphere. In contrast, when the emotional face was presented on the right, subjects emitted larger P300s over the left hemisphere than the right hemisphere.

For P300 latency, a 2 (Group) X 2 (VF) X 2 (Hemisphere) ANOVA did not produce statistically significant effects. However, there was a trend for a significant Hemisphere effect ($F_{(1, 21)} = 3.35$, $p < .09$), indicating that the P300 tended to occur later in the left hemisphere than in the right hemisphere.

At lateralized parietal brain sites, the ANOVA yielded a significant main effect of Hemisphere ($F_{(1, 21)} = 25.23$, $p < .001$). Thus, while subjects analyzed the emotionality of faces their P300 responses were larger in the right parietal lobe than in the left parietal lobe (see Figure 17). Similar ANOVAs were computed for P300 latency at P3, P4, and Pz. For the P3/P4 ANOVA, there was a marginal main effect of Group ($F_{(1, 21)} = 4.87$, $p < .04$). At Pz, the Group effect was not significant ($F_{(1, 21)} = 2.80$, $p < .11$). There were no other statistically reliable main or interaction effects. As can be seen in Figure 18, it appears that P300s occurred earlier in the psychopaths than in the nonpsychopaths at parietal sites. Figures 17 and 18 also illustrate the tendency for psychopaths to have larger and earlier P300 peaks at posterior than anterior sites, and for nonpsychopaths to have larger and earlier P300 peaks at anterior than posterior sites.

Figure 17: P300 Amplitude for Emotional Faces at Frontal, Temporal, and Parietal Sites

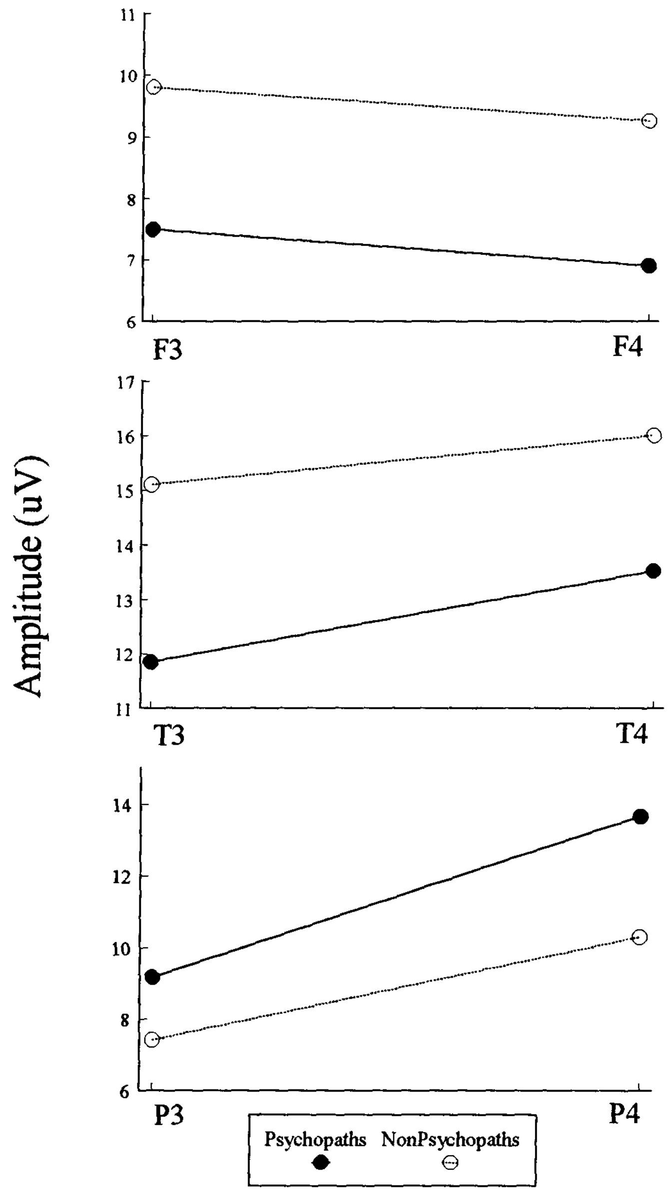
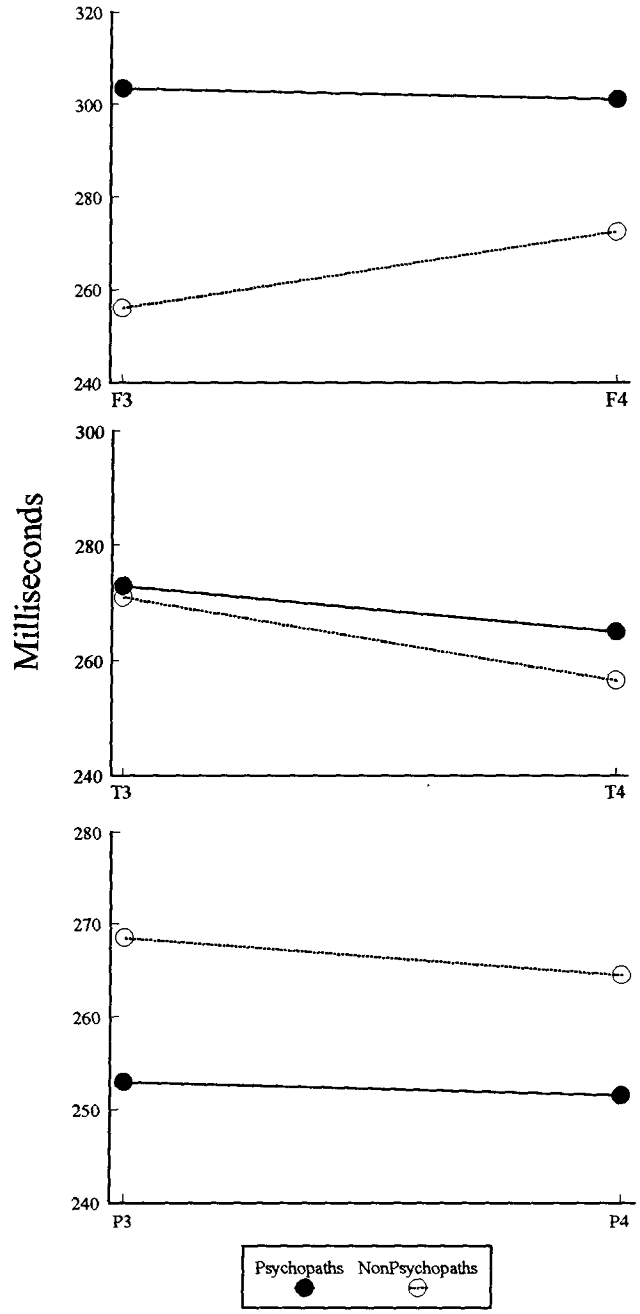


Figure 18: P300 Latency for Emotional Faces at Frontal, Temporal, and Parietal Sites



Mental Rotation Task

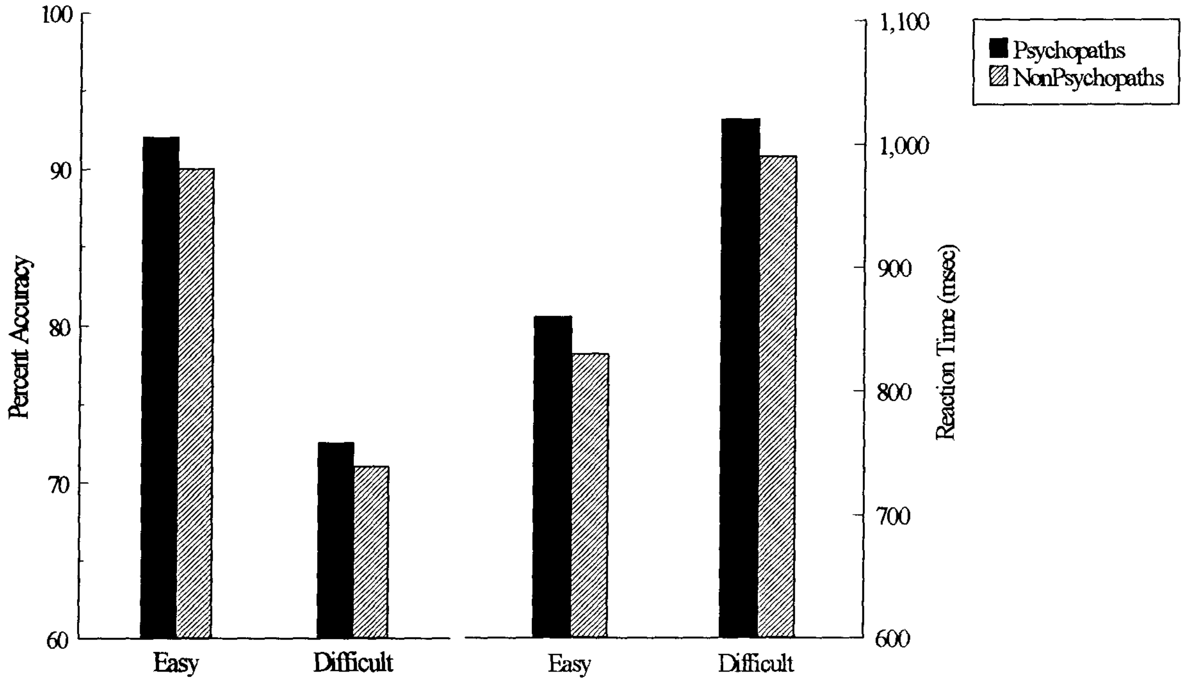
Performance.

This task taps right hemisphere resources, but does not involve an emotional component or lateralized presentation of stimuli. Percent accuracy was submitted to a 2 (Group) X 2 (Condition; easy and difficult) ANOVA.

As expected, there were no group differences in accuracy or reaction time. Both groups were much more accurate when choosing which ear they saw when the nose was pointing toward the top of the computer screen than when the nose was pointing downward (Condition for accuracy: $F_{(1,21)} = 35.29$, $p < .001$). The reaction time ANOVA yielded comparable results (Condition for reaction time: $F_{(1, 21)} = 41.29$, $p < .001$). See Figure 19 for an illustration of the percent accuracy and reaction time results.

Figure 19: Mental Rotation Task Accuracy and Reaction Time

for Easy and Difficult Conditions

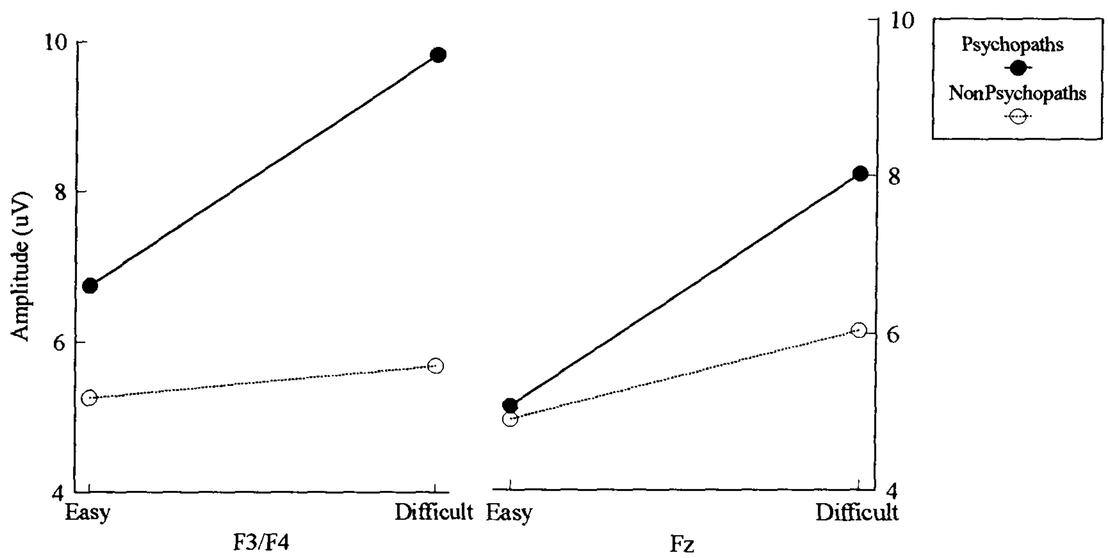


Electrocortical Measures.

To understand whether or not psychopaths differed from nonpsychopaths in the processing of these nonverbal, nonemotional stimuli, electrocortical indices were analyzed. It was expected that P300 and P500 peaks would be readily identified, but, surprisingly, many subjects produced negative-going waves, especially at temporal sites, in the 300-450 msec poststimulus time window ("N400"). Therefore, P300 amplitude and latency were analyzed at frontal and parietal areas only, and P500 at all three brain areas. It was expected that P300 and P500 amplitudes would indicate that both psychopaths and nonpsychopaths utilize right posterior resources more than they do other cortical areas for this task. It was also expected that the difficult version would elicit greater peaks than the easy version. (See Appendix H for an illustration of ERP waveforms. Electrical cross-talk from the stimulus input was removed from this diagram).

The P300: At frontal sites, a 2 (Group) X 2 (Hemisphere) X 2 (Condition) ANOVA yielded a marginal main effect of Condition ($F_{(1, 18)} = 6.57$, $p < .03$). It appears that, as expected, the more difficult condition (Nose Down) resulted in larger P300 amplitudes than did the easy condition (Nose Up). Similarly, at Fz, the Condition effect was marginally significant ($F_{(1, 19)} = 7.00$, $p < .02$). There was also a trend for a Group X Condition effect ($F_{(1, 18)} = 3.78$, $p < .07$) at the F3/F4 sites, but not at Fz. This pattern of results is illustrated in Figure 20, showing that this task, especially the difficult condition, resulted in greater frontal activity for the psychopaths than for the nonpsychopaths.

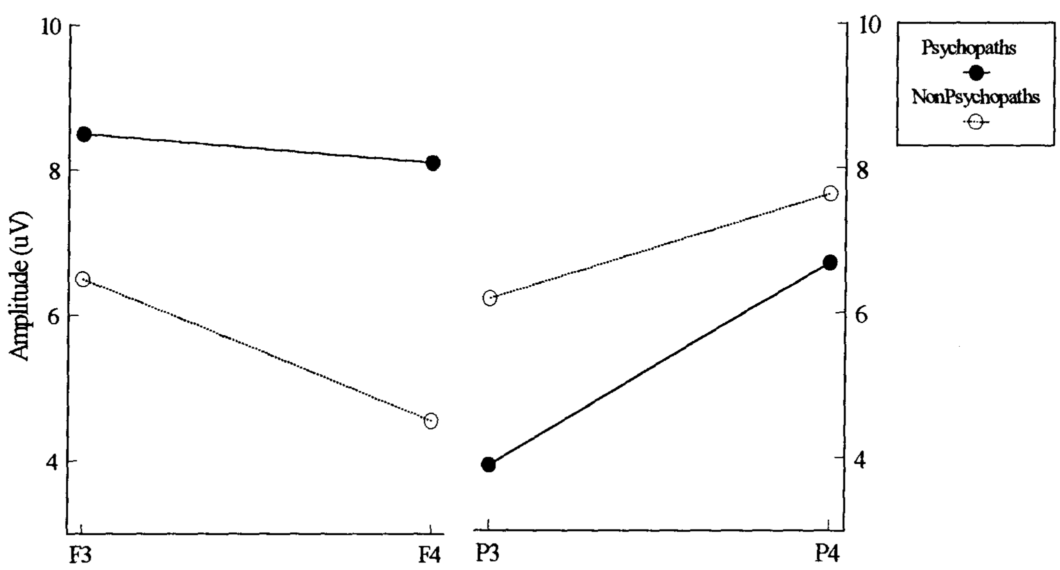
Figure 20: Lateralized and Midline Frontal P300 Amplitude for Easy and Difficult Mental Rotation Tasks



Latency of P300 peaks was also analyzed, and it was found that the P300 wave tended to occur later in the right hemisphere than in the left hemisphere ($F(1, 18) = 5.12$, $p < .04$). No other frontal effects of note were found.

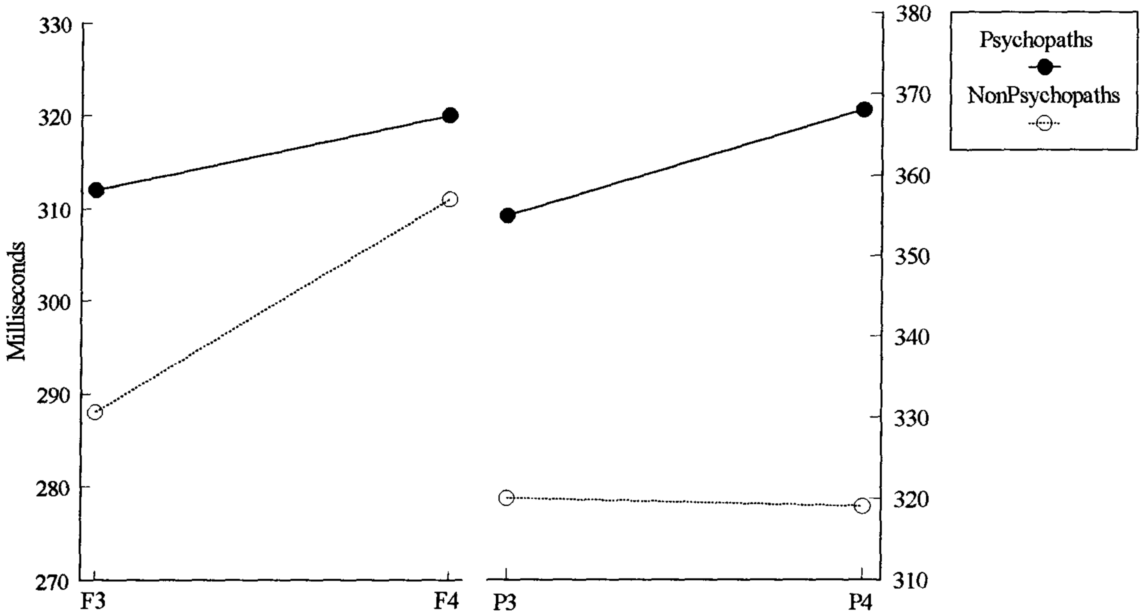
ANOVAs at parietal sites indicated a marginal main effect of Hemisphere ($F(1, 16) = 4.75$, $p < .05$). As can be seen in Figure 21, P300 peaks were somewhat higher in voltage over the right (P4) than the left (P3) hemisphere, as one would expect for a visuospatial task. There were no other notable effects (including at Pz), suggesting that the groups were quite similar in terms of P300 amplitude. Note also in Figure 21 the tendency for the nonpsychopaths to have greater parietal than frontal ERPs (while the psychopaths showed the opposite pattern).

<u>Figure 21</u>: Mental Rotation P300 Amplitude at Frontal and Parietal Sites, Both Conditions Combined



Latency analyses yielded a trend for a Group effect ($F_{(1, 17)} = 3.31$, $p < .09$). It appears that psychopaths had later-occurring P300 peaks than did the nonpsychopaths. This trend was not evident at Pz ($F_{(1, 18)} = 2.50$, $p < .14$; see Figure 22).

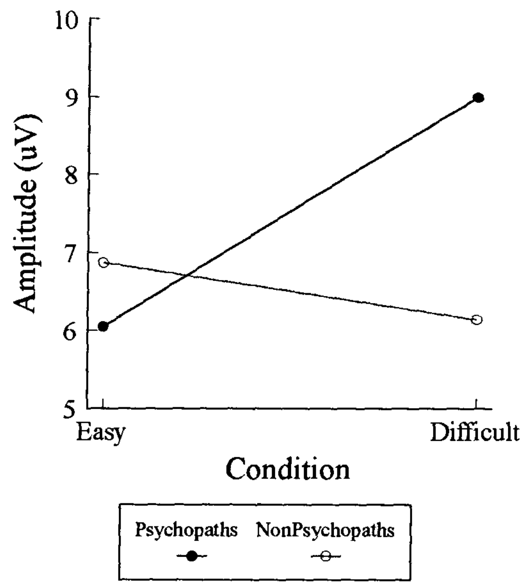
<u>Figure 22</u>: Mental Rotation P300 Latency at Frontal and Parietal Sites, Both Conditions Combined



The P500: Voltage of the P500 over frontal sites was analyzed, and the main effect Condition was found to be marginally significant at Fz only ($F_{(1, 17)} = 5.68$, $p < .03$). Thus, the difficult condition resulted in somewhat larger P500 waves over Fz than did the easy condition. This result must be viewed with caution, because the Condition effect was not significant at the two other frontal sites ($F_{(1, 16)} = 1.98$, $p < .18$). There were no notable main effects or interactions with respect to P500 latency at frontal brain areas. Similarly, at temporal sites, there were no significant main or interaction effects for amplitude or latency measures.

At parietal (P3/P4) sites, there was a trend for a Group X Condition interaction ($F_{(1,20)}$ = 3.22, $p < .09$), but this was not repeated at Pz ($F_{(1, 20)}$ = 2.13, $p < .17$). However, as can be seen in Figure 23, it appears that the groups were very similar in P500 amplitude for the easy condition, but that the psychopaths tend to have larger P500 peaks than the nonpsychopaths for the difficult task. Latency effects were not significant, indicating that the P500 waves occurred at about the same time, regardless of group, site, or condition.

Figure 23: Parietal (P3 & P4) P500 Amplitude for Mental Rotation Task

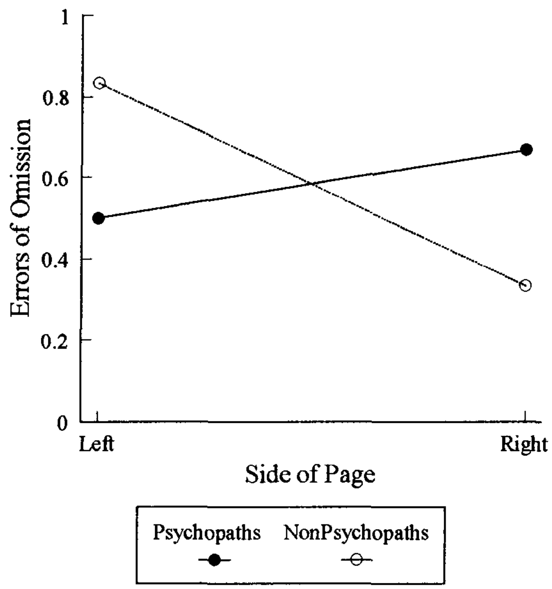


Nonverbal Visual Search

Performance.

Visual search errors were submitted to a 2 (Group) X 2 (Side) ANOVA. No group differences in performance were expected. Despite the appearance of a Group X Side interaction (see Figure 24), this expectation was supported. Laterality coefficients were calculated [(1 + left errors - right errors) / (1 + left errors + right errors)], and correlated with Factor 1, Factor 2, and total PCL-R scores. Psychopathy measures correlated positively with a tendency to make right-sided errors, but the correlation coefficients did not differ significantly from zero.

Figure 24: NonVerbal Visual Search Performance

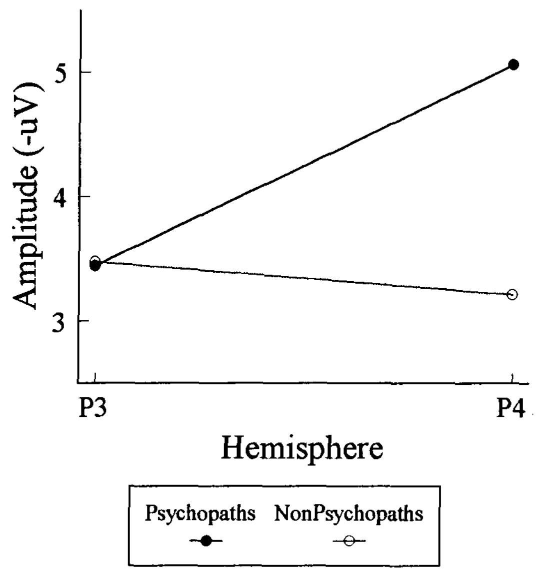


Electrocortical Measures.

Averaged N100 and P200 responses to the tone probes were measured for each subject for each brain site. A 2 (Group) X 2 (Hemisphere) ANOVA was conducted for each waveform for frontal, temporal, and parietal brain sites. It was expected that the electrocortical indices of attention would indicate that the nonpsychopaths utilized right hemisphere resources during nonverbal visual search, whereas the psychopaths did not. See Appendix G for a plot of ERP waveforms.

There were no main or interaction effects for the amplitude of N100 at frontal or temporal sites. However, at parietal sites, there was a trend for a significant Hemisphere effect ($F_{(1, 20)} = 3.55$, $p < .08$). There was also a marginally significant Group X Hemisphere interaction ($F_{(1, 20)} = 6.88$, $p < .02$), illustrating that the greater negativity in the right hemisphere relative to the left is evident only for the psychopathic subjects. This was confirmed by a Tukey test ($TSD_{(20)} = 1.44$, $p < .01$). Over P4, psychopaths had significantly larger N100 peaks than did the nonpsychopaths. Also, the psychopaths' N100 peaks were greater in the right than in the left hemisphere. (See Figure 25). One-way ANOVAs for N100 amplitude at Fz and Pz did not yield significant results. Similar analyses for the amplitude of the P200 waveform did not result in statistically significant main effects or interactions.

Figure 25: Parietal N100 Peaks to Tone Probes in NonVerbal Visual Search Task



Tone Identification Task

Performance.

A 2 (Group) X 2 (Ear) ANOVA was performed on the percent accuracy scores. I expected that nonpsychopaths would show a right ear advantage (REA) on this task, while psychopaths would show a LEA. Although in the expected direction, the apparent Group X Ear interaction was not significant ($F_{(1, 20)} = 2.47$, $p < .14$, see Figure 26). However, computation of laterality coefficients indicated that a right ear advantage for this task correlated negatively with psychopathy (see Table 10). The negative correlations between a right ear advantage and Factor 1 and full scale PCL-R scores approached statistical significance. Again, it is interesting to note that the strongest correlation was with Factor 1, the more affective/interpersonal aspect of psychopathy.

Figure 26: Memory for Tones Task Performance

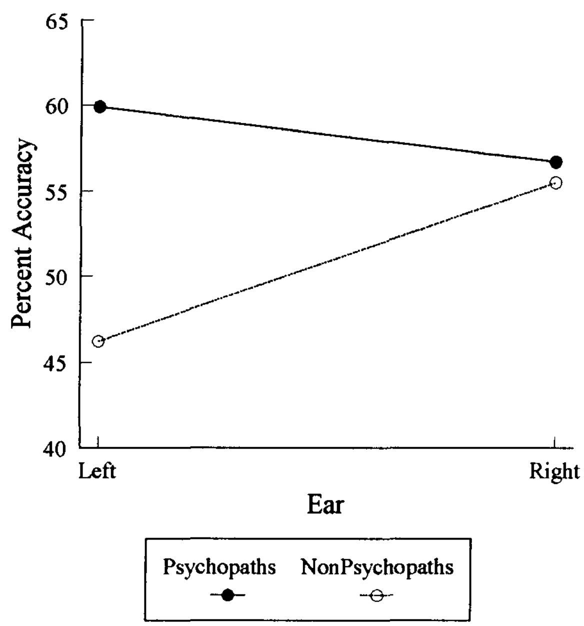


Table 10:

Correlations Between REA for Tone Identification

and PCL-R Ratings

	Factor 1	Factor 2	PCL-R
REA*	-.43 $p < .04$	-.28 $p < .18$	-.41 $p < .05$

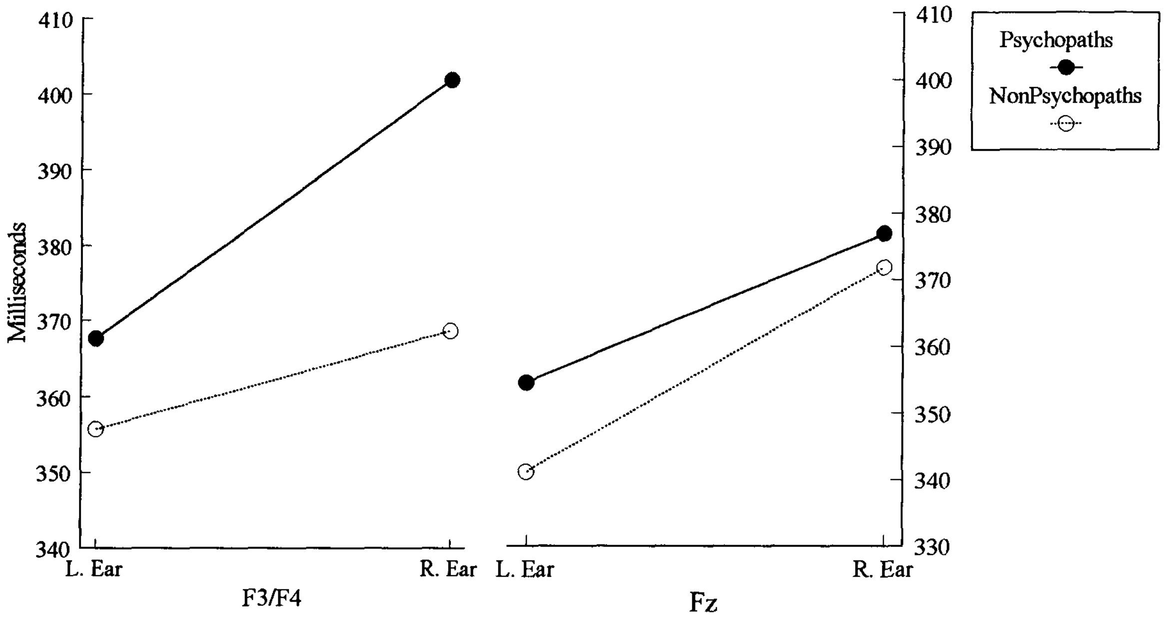
*Right Ear Advantage
N=24

Electrocortical Measures.

The ERP waveforms are presented in Appendix H. The amplitude and latency of P300 responses at each brain site were submitted to separate 2 (Group) X 2 (Hemisphere) X 2 (Ear) ANOVAs.

There were no significant effects for P300 amplitude at frontal sites. For latency analyses, there was a marginal Ear effect at lateralized sites. The latency of P300s to the right ear tones were longer than those to left ear tones ($F_{(1, 18)} = 4.46$, $p < .05$). At Fz, the tendency for right ear tones to elicit later peaks than did left ear tones was not significant ($F_{(1, 18)} = 2.58$, $p < .13$). See Figure 27 for an illustration of frontal latency effects The apparent trend for the psychopaths to have later frontal P300 peaks than the nonpsychopaths over lateralized frontal sites was not statistically significant (for F3/F4, $F_{(1, 18)} = 2.90$, $p < .11$). There were no other notable main or interaction effects.

Figure 27: Frontal P300 Latency for Memory For Tones Task

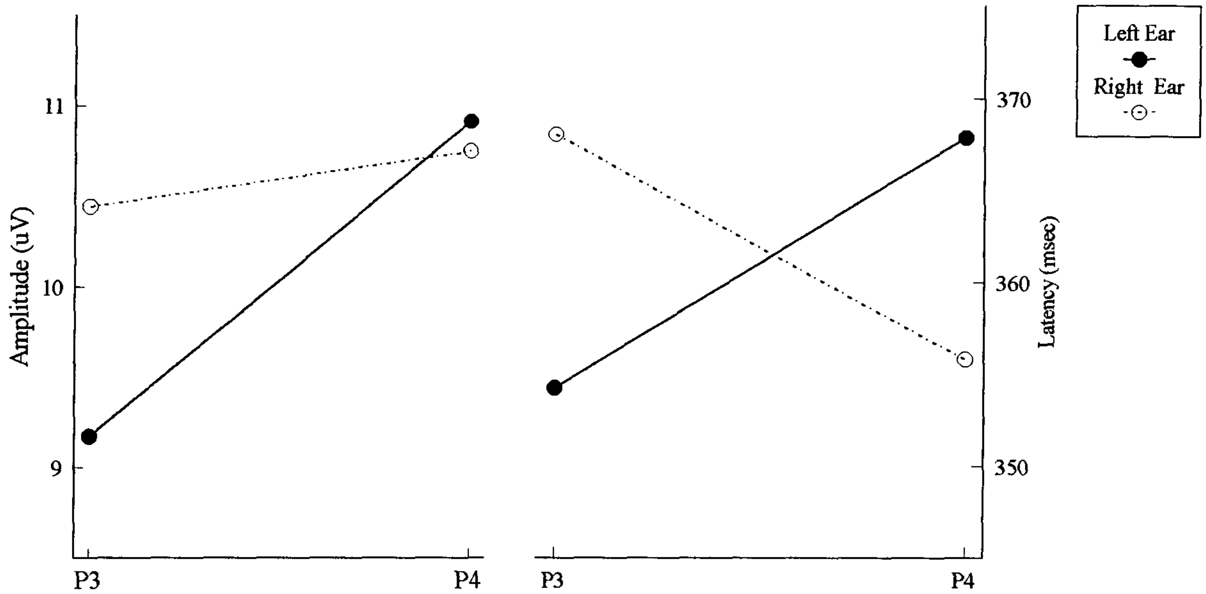


At temporal sites, there were no statistically significant results for amplitude or latency measures of the P300.

At parietal sites, P300s tended to be larger in the right hemisphere than in the left hemisphere ($F_{(1, 19)} = 3.55$, $p < .08$). A trend for an Ear X Hemisphere interaction ($F_{(1, 19)} = 3.47$, $p < .08$) was difficult to interpret (see Figure 28). It appears that right parietal activity was greater than left, but especially in response to left ear tones.

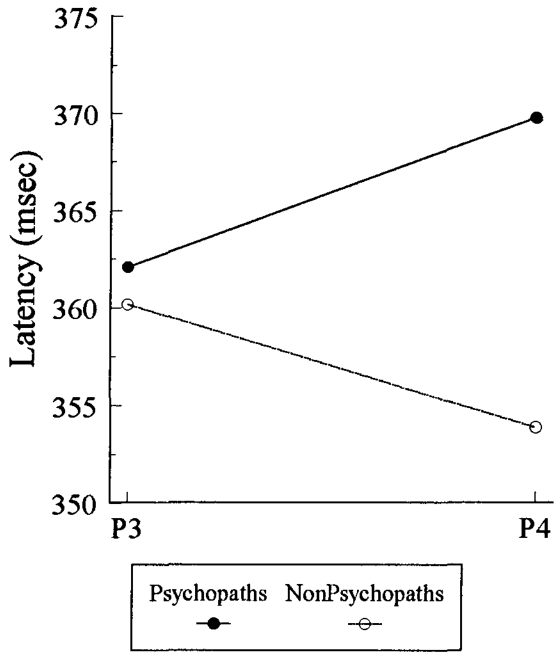
Figure 28: Parietal P300 Amplitude and Latency Ear by Hemisphere

Interactions for Memory for Tones Task



Latency analyses yielded some interesting results (see Figure 28). There was a reliable Ear X Hemisphere interaction ($F_{(1, 19)} = 9.78$, $p < .01$) at parietal sites. Thus, while identifying left ear tones, the latency of the P300 peaks was longer at P4 (right hemisphere) than at P3 (left hemisphere). While identifying right ear tones, P300 latency was longer at P3 than at P4. Although the Group X Hemisphere interaction was not significant ($F_{(1, 19)} = 3.27$, $p < .09$; see Figure 29) it appears that, for psychopaths, the P300 occurred later over P4 than over P3. For nonpsychopaths, P300s occurred earlier over the right parietal area than over the left. There were no notable effects at Pz.

Figure 29: Left and Right Parietal P300 Latency for Memory for Tones Task



Discussion

As in Study 1, there were no differences in the measured demographic variables, indicating that group differences in responses to lateralized nonverbal tasks were likely due to the presence or absence of psychopathic personality style. Four nonverbal tasks (one emotional, one auditory normally tapping left hemisphere resources, and two visuospatial) drew out some interesting group differences and trends, adding to the results of Study 1. See Table 11 for a summary of statistically significant results and trends.

Table 11:

Summary of Study 2 Statistically Significant Results and Trends

Task	Significant Results or Trends	Description and Interpretation
Emotional Face Task	Performance (reaction time):	
	VF .... $p < .04$	LVF emotional faces were identified more quickly than RVF faces
	G X VF .... $p < .07$	Psychopaths were less lateralized than nonpsychopaths
	Positive correlation between: RVFA and PCL-R........$p < .10$	Psychopathic characteristics tend to correlate with an unusual RVFA for identifying emotionality in faces.
	ERPs (P300 amplitude):	
	F3, F4; VF ....$p < .04$ Fz; VF .... $p < .02$	RVF faces elicited more frontal activity, likely because they are more difficult to process.
	T3, T4; VF X H .... $p < .09$	RVF faces elicited greater left than right P300s. LVF faces elicited greater right than left P300s. It is likely that the contralateral hemisphere is perceiving the stimuli.
	P3, P4; H .... $p < .001$	The right parietal lobe emitted greater P300 peaks in response to the faces, as expected
	ERPs (P300 latency):	
	F3, F4; G ....$p < .03$ Fz; G .... $p < .02$	Psychopaths emitted later P300 responses at frontal sites
	VF .... $p < .03$ G X VF .... $p < .04$	LVF faces elicited later P300 responses, but this is only evident for the psychopaths. Nonpsychopaths' P300s occurred at the same time for LVF and RVF faces
	T3, T4; H .... $p < .09$	P300 peaks tended to occur later in the left hemisphere than the right, perhaps because the left is less equipped to process this information
	P3, P4; G .... $p < .04$	Psychopaths tend to have earlier P300 peaks than nonpsychopaths

Table 11 continued:

Task	Significant Results or Trends	Description and Interpretation
Mental Rotation Task	Performance (percent accuracy and reaction time):	
	C*............................ p < .001	In both performance measures, the Easy condition resulted in more accurate and faster performance than the Difficult condition
	ERPs (P300 amplitude):	
	F3/ F4; C .... p < .03 Fz; C .... p < .02	The Difficult version resulted in larger frontal P300s at lateralized and midline sites than for the Easy version
	F3/F4; G X C .... p < .07	The Difficult version resulted in larger P300 peaks for the psychopaths relative to the nonpsychopaths, and relative to their own responses to the Easy version
	P3/ P4; H .... p < .05	P300 responses were larger over right than left parietal sites, as expected
	ERPs (P300 latency)	
	F3, F4; H .... p < .04	P300 peaks occurred later in the right hemisphere than in the left
	P3/P4; G .... p < .09	Psychopaths had later-occurring P300s than did the nonpsychopaths, suggesting that the psychopaths have difficulty utilizing the posterior cortex for this task.
	ERPs (P500 amplitude):	
	Fz; C .... p < . 03	The Difficult version resulted in larger P500s than did the Easy version
	P3/P4; G X C .... p < .09	The psychopaths tended to produce larger P500 peaks than did the nonpsychopaths. Large P500s were unexpected, considering it is a simple perceptual task.
	ERPs (P500 latency): No significant effects	

Table 11 Continued:

Task	Significant Results or Trends	Description and Interpretation
Nonverbal Visual Search	Performance (errors):	
	No significant effects	The two groups were similar in performance
	ERPs (N100 amplitude)	
	P3/P4; H .... $p < .08$ G X H .... $p < .02$	The greater right-sided than left-sided N100 peak is more evident for the psychopaths, suggesting their right parietal lobes were more responsive to the tones than for the nonpsychopaths
Memory for Tones Task	Performance (percent accuracy)	
	Negative correlation between: REA and Factor 1 .... $p < .04$ REA and PCL - R .... $p < .05$	Psychopathic traits are associated with an unusual left ear advantage on this task
	ERPs (P300 amplitude)	
	P3/P4; H .... $p < .08$ E† X H .... $p < .08$	Right parietal activity is greater than left parietal activity, but the difference is greater for left ear tones (which would project contralaterally to the right side) than for right ear tones
	ERPs (P300 latency)	
	F3/F4; E .... $p < .05$	The frontal lobes took longer to process right ear tones than left ear tones, especially for psychopaths
	P3/P4; G X H .... $p < .09$	Psychopaths produced later P300s over the right hemisphere than did the nonpsychopaths
	E X H .... $p < .01$	For left ear tones, responses occurred later over the right than the left hemisphere. For right ear tones, responses occurred later over the left than the right hemisphere. This suggests that the information takes some time to transfer across to the contralateral hemisphere.

* C = Condition

† E = Ear

The emotional face task, which matched the emotional word task in design, illustrated that psychopaths tended to be a little more accurate and a little slower than the nonpsychopaths at identifying which of two faces was more emotional. Nonpsychopaths were somewhat faster at identifying the more emotional face when it was in the LVF than when it was in the RVF, presumably because the information reached the more efficient right hemisphere more directly and quickly. Psychopaths, however, were less lateralized in terms of reaction time, suggesting that both hemispheres could access the necessary resources to make the decision as quickly. Perhaps in psychopaths both hemispheres contain the necessary neural structures to process the information, or the two hemispheres are highly interconnected for this type of cognitive processing. Again, these results do not replicate Day and Wong's (1995) study. They found no group by visual field interactions for either performance measure. Perhaps because I could more carefully control stimulus presentation time and measurements of reaction time (being computerized), trends in group differences were found.

The electrocortical results provide us with some more interesting information. Right visual field faces evoked larger and earlier P300 peaks than left visual field faces, opposite to what one might expect, since these stimuli are supposedly more difficult to analyze. However, the nonpsychopaths appear to process the emotionality of faces equally as quickly in the frontal lobes, regardless of the side of presentation. This suggests the main effect of visual field on P300 latency is mostly (or entirely) due to the tendency for the psychopaths to process LVF faces much later or more slowly than RVF faces, stimuli that should be easier to process, assuming more direct access to the more spatially and emotionally "skilled" right hemisphere cortical areas. Recall that the psychopaths tended to respond more slowly when the emotional faces were on the left than the nonpsychopaths (according to the performance results), suggesting that this version of the task is more difficult for the psychopaths, requiring more time to process the information. Because the psychopaths tended to emit smaller and later P300 peaks at frontal and temporal sites, and larger, earlier peaks at parietal sites relative to nonpsychopaths, this suggests that this was merely a perceptual task for them. The nonpsychopaths, in contrast, utilized the more rostral areas which are presumably more efficient than the posterior cortex at emotional processing. While this task does not draw out strong group differences in lateralized cortical activity, it does illustrate some interesting rostral-caudal patterns of activation.

The mental rotation task showed that psychopaths and nonpsychopaths were very similar in visuospatial performance, as expected. Also, the more difficult version evoked larger P300 responses than the easy condition. However, an unexpected increase in frontal activation for the psychopaths was found, suggesting that they utilized frontal resources for this perceptual task. The opposite was true for nonpsychopaths, as they tended to produce larger parietal (especially P4 or right parietal) responses, as expected. The nonpsychopaths appeared to process mental rotation (nonverbal and nonemotional) tasks using right parietal resources primarily, while the psychopaths drew on frontal resources! This unusual pattern was somewhat replicated for P500, a measurement of more elaborative processing. One would not expect much elaboration on this spatial task, but psychopaths showed marginally greater P500 amplitude at all three brain areas than the nonpsychopaths. The trend approached significance for the difficult version of the task at parietal areas.

The nonverbal visual search task yielded much different results than its matched version in Study 1. Psychopaths tended to make more right- than left-sided errors, and the nonpsychopaths more left- than right-sided errors. Thus, psychopaths tended to direct more attention to the left side of the page, and nonpsychopaths to the right side, although these findings were not statistically significant. However, it is interesting that I previously found that that those at risk for alcoholism, on the basis of antisocial personality and family history, had a pattern of errors very similar to the psychopaths in the present study, while low-risk controls had a pattern of errors very similar to the nonpsychopaths (Mills, 1989). In the present study, over the right parietal hemisphere, psychopaths elicited more negative N100 peaks than the nonpsychopaths, indicative of greater response to the tones. Nonpsychopaths' two hemispheres were equally unresponsive to the tones, suggesting they were able to ignore the tones and concentrate on the task. It is clear that the psychopaths' tendency to respond to the tones over the right parietal brain site did not hamper their overall performance. We could speculate that the psychopath's right parietal hemisphere is not being as greatly taxed as one would expect during this spatial task. Perhaps the areas responding to the tones and the areas involved in the cognitive processing of visual search do not communicate with each other, or do not interfere with each other.

Finally, the memory for tones task showed that psychopaths processed nonverbal left hemisphere information in an unusual way. An unusual left ear advantage was correlated with psychopathic characteristics. These results replicate those Nachshon (1988) found when he compared violent and nonviolent offenders on this task. Nachshon's nonviolent offenders (the presumably less psychopathic men) had a REA of 8.4 percent (56.7 versus 48.3) which is similar to the present study's nonpsychopathic offenders' REA of 9.4 percent (55.6 versus 46.2). His violent offender group had a LEA of 15 percent (65 versus 50) while in the current study, the LEA for the psychopaths was a smaller LEA of 3.1 percent (59.9 versus 56.8). However, if one includes the violent offenders with the murderers in his sample, it appears that his results match the present psychopaths' responses closely (with a LEA of approximately 5 percent, 60 versus 55). It is interesting that Nachshon's results were stronger, considering how he divided his groups.

Unfortunately, the electrocortical results for the memory for tones task were rather inconclusive. However, some nonsignificant trends suggest that psychopaths utilize more right frontal resources to process the tones than do nonpsychopaths. Likewise, it takes their frontal, temporal and right parietal lobes somewhat longer to process right ear tones (the tones they found more difficult to remember accurately) than those of the nonpsychopaths, all suggestive of reversed asymmetry in psychopaths.

Thus, it is evident that unusual patterns in cortical organization can be found for a wide variety of lateralized verbal and nonverbal tasks in criminal psychopaths, and that they are able to perform as well as or more efficiently than nonpsychopaths. Hence, their "mask" is firmly in place, covering their aberrant cortical functioning. Can we look to models of cerebral asymmetry and other psychopathology to understand this paradox?

General Discussion

Based on interesting patterns in group differences in both performance and electrocortical responses on verbal and nonverbal, and emotional and neutral tasks, we can speculate on the differences in brain organization between psychopaths and nonpsychopaths. First, nonpsychopathic inmates usually performed and responded in expected, normal ways. This supports the vast majority of past research with this population. Not only does this tell us that the tasks elicited "normal" reactions and were suitable tools to investigate lateralized brain activity, but that the unusual responses of psychopaths are likely due to their pathology, and not to factors such as institutionalization or drug abuse. Thus, if we consider the results from all seven tasks, we can say in broad terms that psychopaths utilize their brains for cognitive activity in unusual ways. We can also say that their performance does not suffer, and they are able to compensate.

Looking at the patterns in the data carefully, it is not possible to pinpoint one area of the cortex that is particularly "underused" or "underdeveloped". Thus, at least in terms of global cortical areas, psychopaths do not appear to have significant localized brain damage. The differences in cortical utilization suggest that sometimes there is diminished asymmetry (both sides of the brain are more active and involved than expected), increased asymmetry (both sides of the brain are not involved as expected in the processing or receiving of information), or reversed asymmetry (unexpected areas of the brain are involved). In many cases, cortical responses (and performance) are somewhat slower for the psychopaths relative to the nonpsychopaths, suggesting an inefficiency in processing. Finally, emotional tasks seem to be processed in merely perceptual, unelaborated ways. The most conservative suggestion is that, while the cortices of psychopaths and nonpsychopaths are far more alike than different, the cortex of the psychopath is organized in a somewhat more diffuse manner, with odd inter- and intra-hemispheric communication.

Perhaps a "diffuse" organization enables the psychopath to "overfocus" his or her attention at times, as there is less interference from competing neural circuits. This may also explain their reduced ability to incorporate affect with verbal and nonverbal perception. The lack of right frontal activation for emotional tasks and a trend for frontal activation for spatial tasks may account for the specific emotional deficit in psychopathy, in that the more rostral brain areas are not "wired" to process emotion. Finally, a diffuse organization of neural circuits may result in deficient behavioural inhibition, and may explain their apparent reduced ability to make rational and reflective decisions (which would require the integration of a wide variety of information).

No current model of cerebral asymmetry explains the puzzle of the psychopath well. The possibility that psychopaths have less specialized, more diffusely connected cortices can be examined from the perspective of Tucker and Williamson's (1984) model of cerebral asymmetry. Recall that the two hemispheres have specialized "modes" and supposedly work in concert (with the corpus callosum acting as a gate), capitalizing on the activity of one or the other depending on current environmental needs. Recall also that their model would predict that psychopaths are imbalanced in favour of more left hemisphere activity in terms of cognition, but that it predicts the opposite imbalance in terms of personality style. A diffusely organized brain would mean that psychopaths would not follow one pattern or the other, either in terms of information processing or interpersonal style. Geschwind and Galaburda's (1987) complicated model is more difficult to apply. Recall that it predicts that neural development of particular brain areas affects development in other cortical areas during fetal development. Exposure to excessive prenatal testosterone may result in underdeveloped left posterior and right anterior brain areas, and a compensatory development of right posterior areas, rendering the individuals less or abnormally lateralized for some cognitive skills. The current study generated some evidence for (unusually) less right frontal activity in favour of more right parietal activity in psychopaths. However, this was for the two emotional tasks only, and so only partially supports the model. It is more easily explained that these tasks are performed as though they are merely perceptual for psychopaths. What is of more interest is the possibility that areas of the brain that analyze and/or incorporate emotional information (i.e., the right anterior cortex) do not fully develop in psychopaths, and adjacent and homologous areas increase in development instead (perhaps allowing the frontal lobes to process spatial information, and the right parietal lobe to conduct verbal categorization). Regardless of the model applied, it may be that as the brain of the psychopath forms, cortical specialization and/or intercommunication develops in unusual ways.

Of course, one can examine brain organization in ways other than the left-right dimension. The cortex communicates with the subcortical structures such as the thalamus and the limbic system, structures important for orienting attention and processing emotional information (e.g., Gainotti, Caltagirone, & Zoccolotti, 1993). Although beyond the scope of this dissertation, one must not minimize the possibility that subcortical structures are dysfunctional in psychopaths.

The rostral-caudal dimension of cortical organization is of relevance, especially in light of some recent research examining frontal lobe activity in psychopaths. However, results have been mixed. In 1982, Gorenstein published a study in which he administered several neuropsychological tests to psychiatric patients and university students, tests that had been shown to differentiate those with frontal lobe damage specifically. He concluded that the "psychopaths" (although his diagnostic procedures were questionable) suffered from frontal lobe deficits, resulting in their inability to modulate dominant response sets and inhibit behaviour. Lueger and Gill (1990) replicated Gorenstein's results using two of the same frontal lobe tasks with conduct-disordered adolescents and a matched control group. However, groups were not equated on age, and there was no mention of assessment for organic brain disorders or head injury. Hare's (1984) criticisms of Gorenstein's methodology (that his diagnostic procedures merely identified those with antisocial personality disorder, and demographic variables such as age, education, and substance abuse were not well-controlled between groups) can be applied to Lueger and Gill's study as well. Hare

(1984) administered the tasks which differentiated Gorenstein's two groups to carefully diagnosed psychopathic and nonpsychopathic prison inmates. He did not replicate Gorenstein's results. In 1987, Sutker and Allain examined other frontal lobe skills (such as abstraction, planning, and flexibility) in a non-criminal population of "psychopaths" and nonpsychopaths. They did not find support for Gorenstein's conclusions either, although they grouped their subjects in a similar manner (i.e., they labeled those who were clearly antisocial as "psychopathic"). Gillstrom (1995) administered several tests of abstract thinking (believed to be dependent upon intact frontal lobes) to psychopaths and nonpsychopaths, and found that only interpretation of proverbs was deficient in psychopaths. She suggested that frontal pathology may account for this finding. Intrator et al. (1994) recently measured regional cerebral blood flow during a lexical decision task in psychopathic and nonpsychopathic drug abusers, and found that psychopaths had reduced blood flow in frontal areas relative to nonpsychopaths during the processing of emotional words. It is difficult to understand these varying results.

In a recent study by LaPierre, Braun, and Hodgins (1995), the authors point out that one must distinguish between dorsolateral prefrontal functions from orbitofrontal and ventromedial frontal functions. They proposed that the conflicting results from previous research have been at least partly due to overly global investigations of frontal activity. LaPierre et al. (1995) used the PCL-R to diagnose their inmate sample, and administered a variety of neuropsychological tests. Those tasks that tap primarily orbitofrontal and/or ventromedial frontal functioning differentiated the groups most strongly, with psychopaths showing significant deficits. The other tasks tapping dorsolateral frontal and posterior brain functions did not differentiate the groups. The authors point out that these regions are known to be more intimately connected with the limbic system than the dorsolateral frontal areas, and are believed to be more important for behavioural inhibition, aggression, and social and self-awareness. This speculation is supported by a recent article by Damasio, Grabowski, Frank, Galaburda, and Damasio (1994). They reexamined the skull of Phineas Gage, a young man who seemed to "acquire" psychopathy after a tamping iron was blasted through his frontal lobes in the mid 1800s. He did not lose consciousness, and his intellect and motor skills remained intact, but he had a significant personality change, losing his sense of reverence and responsibility. The reexamination of his skull indicated that the tamping iron likely lesioned the ventromedial regions of both frontal lobes, sparing the dorsolateral areas.

In the present study, there were some trends for psychopaths to utilize more posterior brain areas while the nonpsychopaths had greater electrocortical activity in the frontal and temporal areas, particularly for verbal and emotional tasks. This would support the proposition that psychopaths have "dysfunctional" frontal lobes, and utilize posterior regions. Thus, the tasks remain perceptual and superficial, as they do not (or cannot) incorporate more elaborative processing which relies on more anterior brain areas. However, this does not explain the tendency for the psychopaths to show somewhat *greater* frontal activity for a task that is visuospatial and perceptual, the mental rotation task. This provides more support for the possibility that the brains of psychopaths are organized in a more diffuse and disconnected manner, with areas being less specialized than in nonpsychopaths.

In most respects the current study supports other examinations of cerebral asymmetry in psychopaths, as I have found support for reversed or reduced asymmetry for most tasks. However, can we equate the unusual patterns in the present study with other psychopathologies? It is clear that psychopaths are not merely the "same" as psychotic, alcoholic, manic, or brain damaged individuals, as the overall pattern of cognitive processing does not match any of these disorders, despite some similarities in symptomology. This fact supports other suggestions that psychopathy is a distinct taxon (Harris, Rice, & Quinsey, 1994), with distinct neurological pathology separate from these other disorders, regardless of some probable overlap in etiology. It would be interesting to discover whether the psychopath's unusual patterns of cerebral asymmetry is "plastic" or reversible as it appears to be in those with mood disorders (Bruder et al., 1994; Johnson & Crockett, 1982). If odd patterns are reversible or changeable with time, it might suggest that biases in attentional and/or biochemical balance among brain areas account for the unusual patterns of cognitive processing. If they remain stable, deficits might be assumed to be structural. Future research could examine this question.

There are some weaknesses in this study that warrant mentioning. The sample size was somewhat small and certainly statistical power could have been improved. Most similar studies with psychopaths include more than 12 subjects per group, to as high as 20 or 30. However, due to the complexity of ERP research, as well as the quantity of data generated, it is not unusual to include only 10 to 15 subjects per group in psychophysiological studies. Also, the local prison population has become wary of our research, and many were unwilling to participate, making data collection much more difficult than anticipated. Related to this, it would have been preferable to only involve nonpsychopaths who scored 20 or below on the PCL-R in order to separate the groups more on these characteristics (and exclude the low-middle range scorers who often exhibit some psychopathic personality traits). Regardless, because the nonpsychopaths performed as one would expect, and the unusual trends in psychopaths' responses support other research, a greater sample size likely would have strengthened the present results.

A second limitation of this investigation was the sample used. A male prison population is a narrow sample, and most carefully conducted studies have not looked beyond this. This population is also riddled with substance abuse, low socioeconomic status, head injuries, and long-term institutionalization. We know little of how other groups of psychopaths would perform on these tasks, making it imperative that we examine brain organization in female, noncriminal, and adolescent populations before drawing strong conclusions as to brain functioning and organization in psychopathy per se.

Third, research in institutions such as prisons is difficult to control. Environmental variables such as air quality, lighting, and background noise are almost impossible to modify and control across testing sessions. However, as order of subject participation was random, there is no reason to suspect that these variables influenced one group more than another. However, an enhanced ability to focus one's attention would help the psychopaths to screen out things like background noise more easily than nonpsychopaths could. Therefore, future research would ideally be conducted in a sound-proof room with controllable quality of lighting and air temperature. Random subject variables such as current drug intoxication and motivation were not assessed, and may have varied between groups. The repeated measures design is only a partial safeguard for these factors. The two substance abuse measures illustrated that reported drug use did not differ between groups, but this is not a measure of intoxication. Ideally, urine samples would ensure equality between groups, but this was not feasible. Regarding motivation, psychopaths seemed more motivated than did the nonpsychopaths. Anecdotally, they were more likely to inquire about the prizes for first and second place (and won three out of four prizes). Enhanced motivation (and/or superior ability to focus their attentional resources) may explain their tendency to perform better in terms of accuracy for six out of seven tasks, but reaction times suggested that they did not find the tasks easier. Also, a group difference in motivation would not explain unusual asymmetry of performance or brain activity, but could influence effort and arousal.

A fourth limitation of this study was that ERP data were the only measure of cortical activation. They provide excellent control over temporal measures of cortical activity (the "when" of processing), but poor spatial acuity (the "where" of processing). Thus, one cannot draw strong conclusions about how active specific brain areas are. More advanced (but expensive and intrusive) technology may allow us in the future to capitalize on both the timing and location of cognitive processing.

This was the first study of which I am aware that combined lateralized performance and electrocortical measures simultaneously in a variety of neurocognitive tasks in psychopaths. Future directions could take several tacks. It is now fairly clear that psychopaths are strongly lateralized for simple verbal tasks and less lateralized for more complex verbal processing. More investigations of lateralized emotional and nonverbal tasks may aid us in drawing stronger conclusions about how they process other sorts of information. As already mentioned, expanding this research to other psychopathic populations would be fruitful as well. Likewise, an incorporation of tasks that can add to this model for rostral-caudal and cortical-subcortical dimensions would be worthwhile. Perhaps then we can develop a model of psychopathic cortical organization. These tasks (and a resulting model) could be compared with findings in other psychopathologies that are related in symptomology to psychopathy (e.g., psychosis, mania, narcissistic personality disorders, those with ventromedial frontal brain lesions) to help in drawing conclusions about the etiology of psychopathy.

There are some clinical implications for the results of this research. Regarding assessment, psychopaths may remain elusive to mental health professionals untrained in the assessment and diagnosis of this serious personality disorder. This is because these professionals may subscribe to the cultural myth that the prototypical psychopath is highly intelligent, and yet bizarre or fiendish. Research of the present sort suggests, again, that psychopaths can appear intellectually normal, and yet process a variety of information in a concrete and superficial manner. Unaware professionals can easily be fooled by their charming ways and seemingly normal or advanced intellect, making appropriate training in assessment and diagnosis imperative. The implications for treatment are similar. It has long been obvious that psychopaths are untreatable using current treatment methods (e.g., Hare, 1992; Meloy, 1988). Current treatment programmes in correctional facilities may make them merely better at manipulation (Rice, Harris, & Cormier, 1992) and yet those conducting the treatment often do not differentiate between psychopaths and nonpsychopaths in selection for treatment groups. Superficial, diffuse, and concrete processing of information may render psychopaths incapable of making personal connections with what the therapist and other group members are discussing. The material will remain irrelevant for them, other than using it to their benefit to continue to fulfill greedy and callous needs. Those administering treatment may train psychopaths so well, that they themselves will be fooled into believing the inmates or patients have truly changed. Treatment programmes must consider psychopaths' neurological deficits when implementing procedures to help them think in more prosocial ways. Perhaps then we can remove the mask of sanity these people wear.

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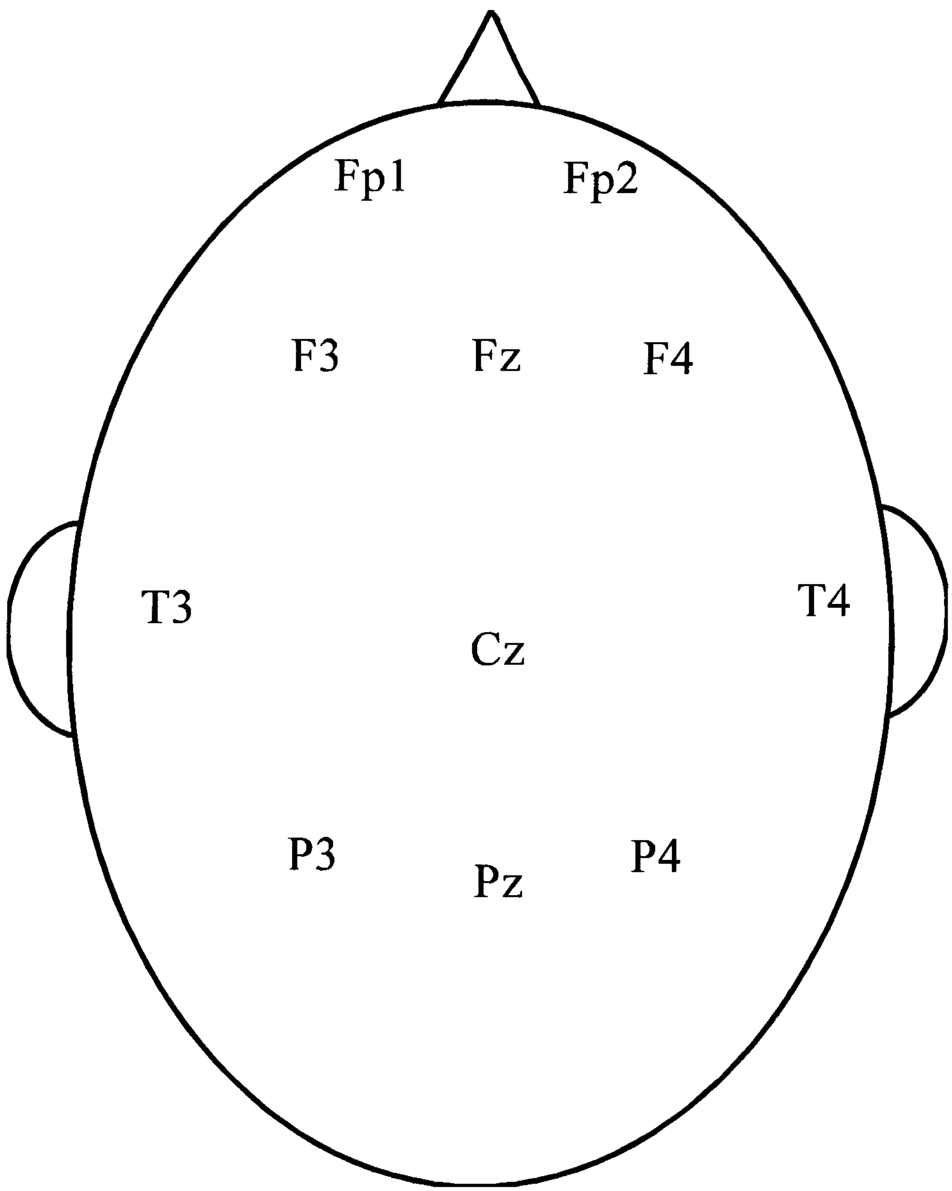
Appendix A: Diagram of Electrode Placement



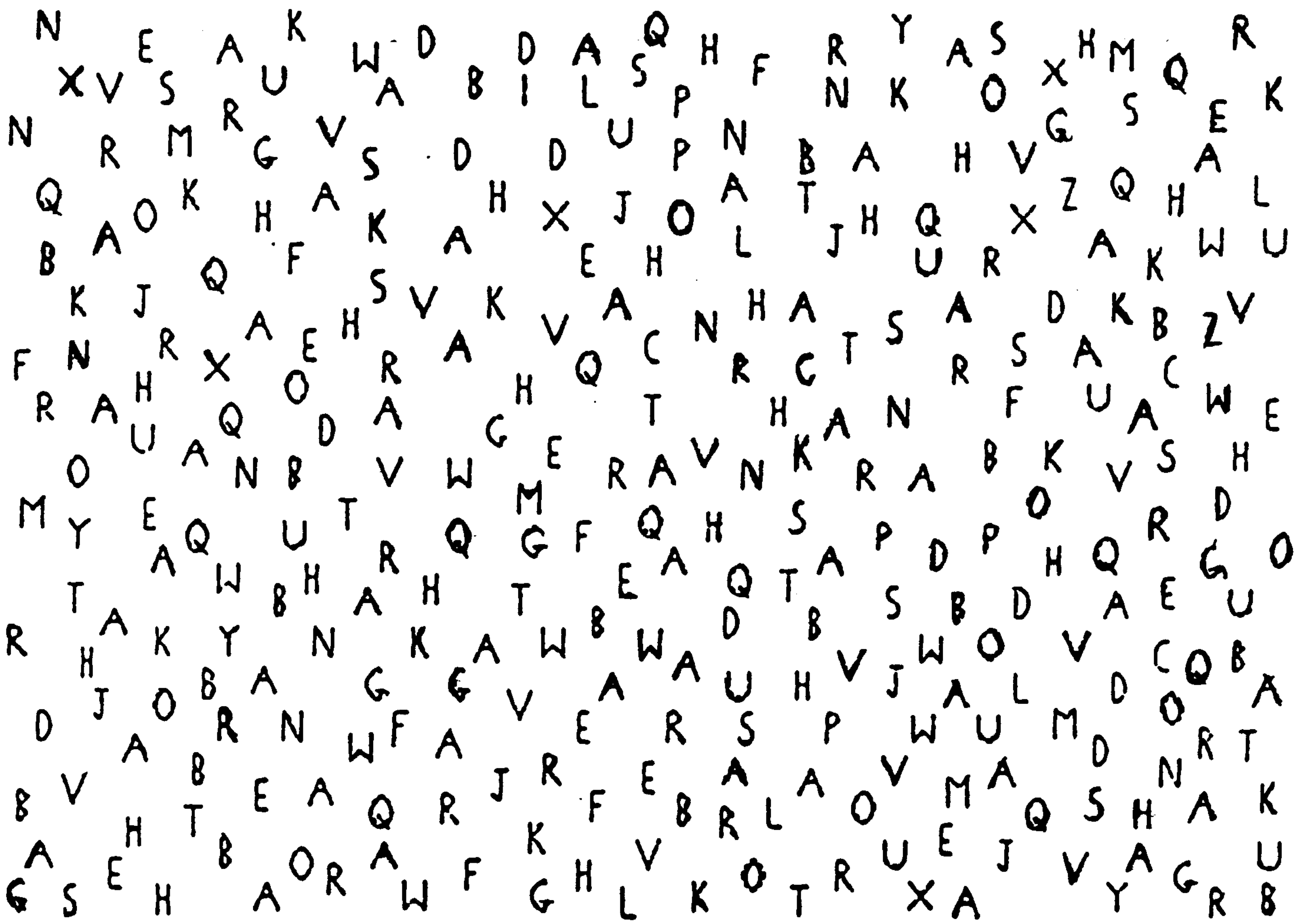
Appendix B: Stimuli for Emotional Word Task

Emotional Words	Nonemotional Words
agony	angle
anger	ankle
chaos	array
crime	board
death	code
demon	elbow
devil	item
fire	link
gore	metal
grief	month
greed	oats
hate	paper
jail	plain
noose	plank
panic	sauce
shame	shoes
shock	stone
slave	truck
tomb	unit
venom	vapor

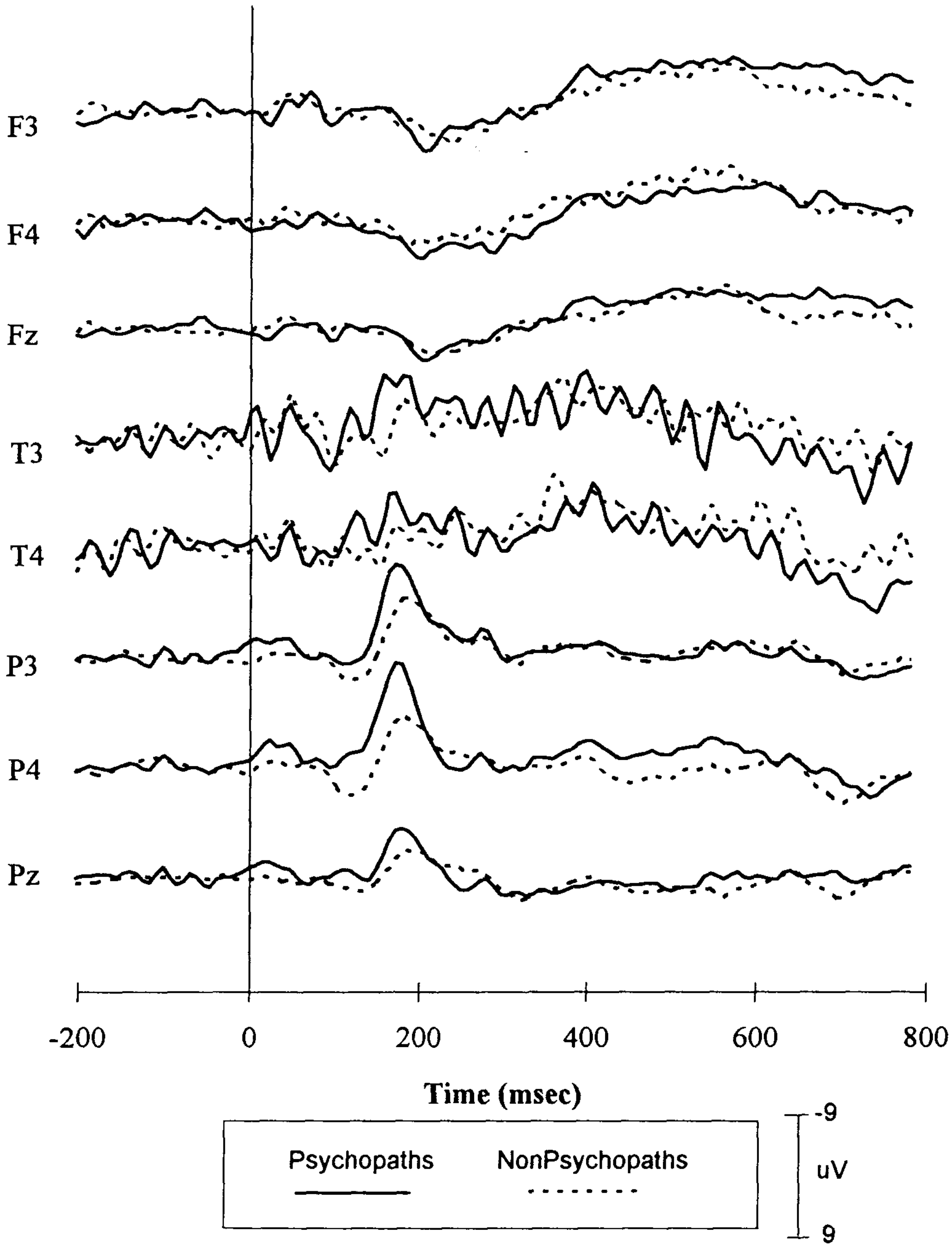
Appendix C: Stimuli For Nonemotional Word Task

COD
HID
HEX
COB
BED
BID
BOX
COO
DID
DIE
BOB
DOE
EBB
EKE
HOE
ICE
KID
ODE

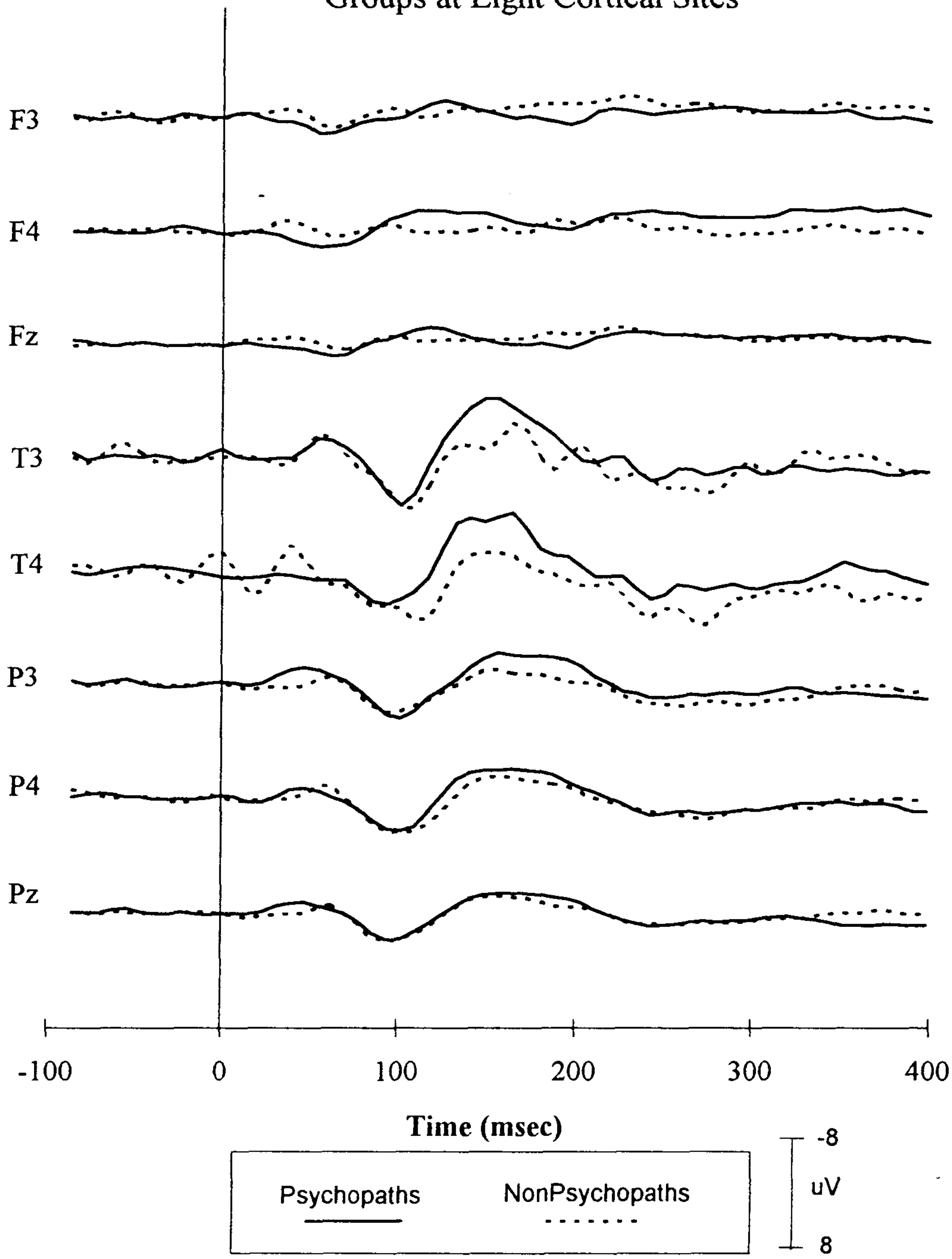
Appendix D: Stimuli for Verbal Visual Search



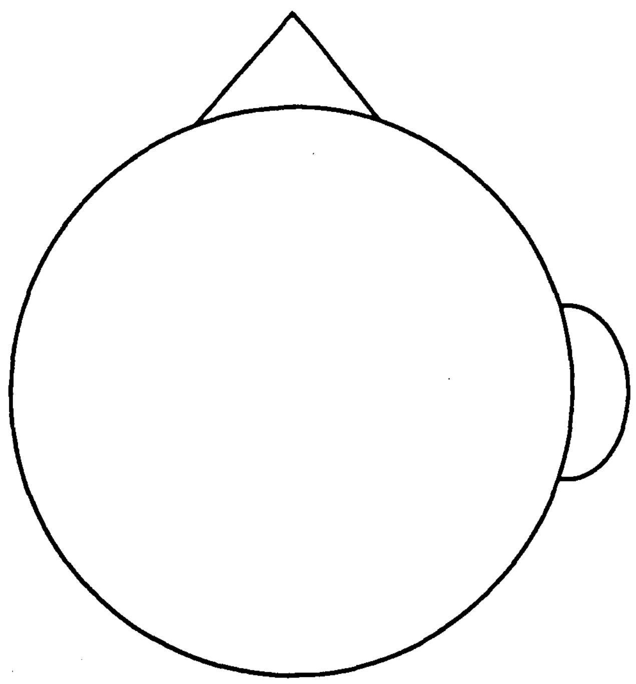
Appendix E1: Non-Emotional Word Task ERPs for Both Groups at Eight Cortical Sites



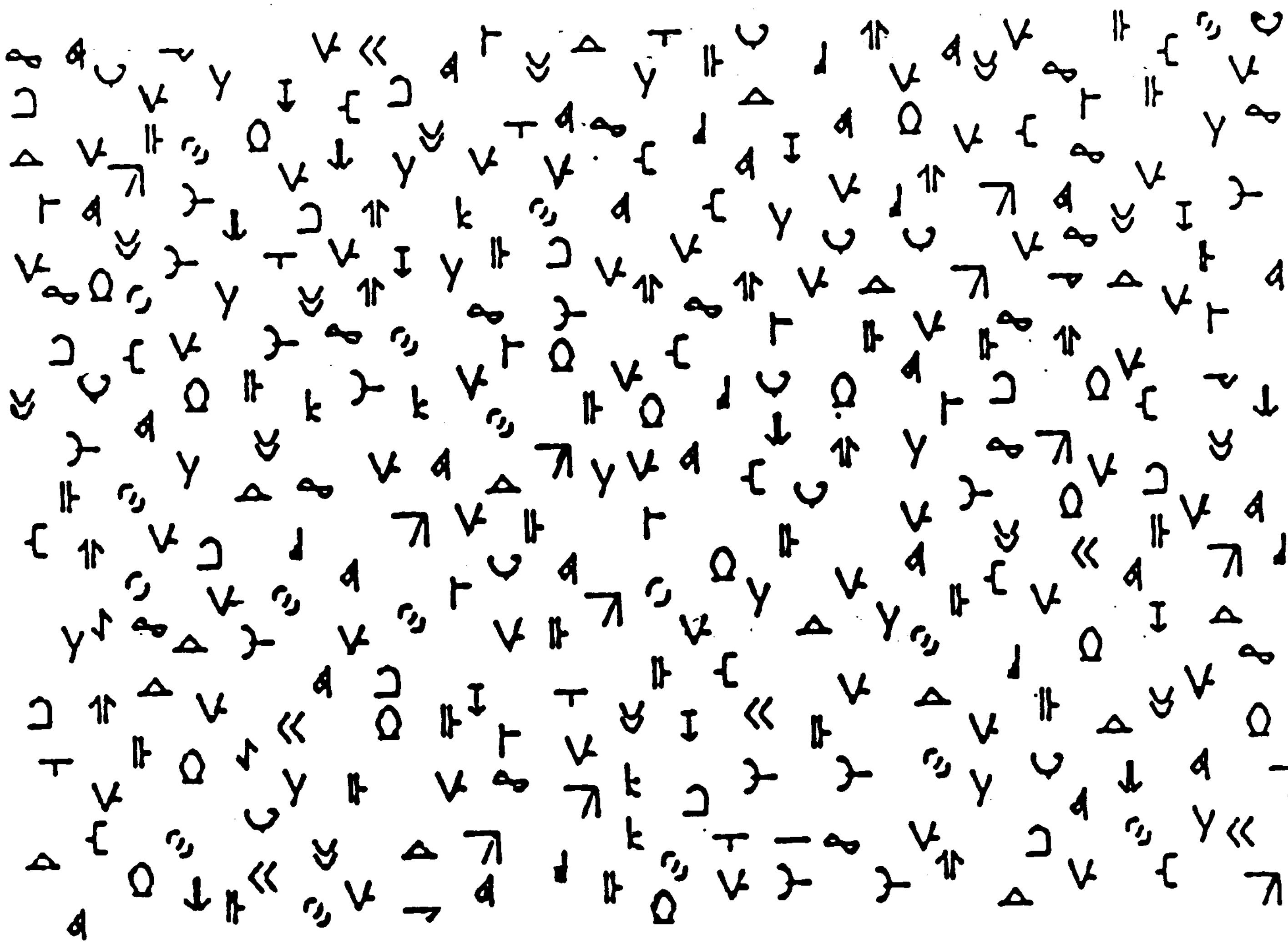
Appendix E2: Verbal Visual Search ERPs for Both Groups at Eight Cortical Sites



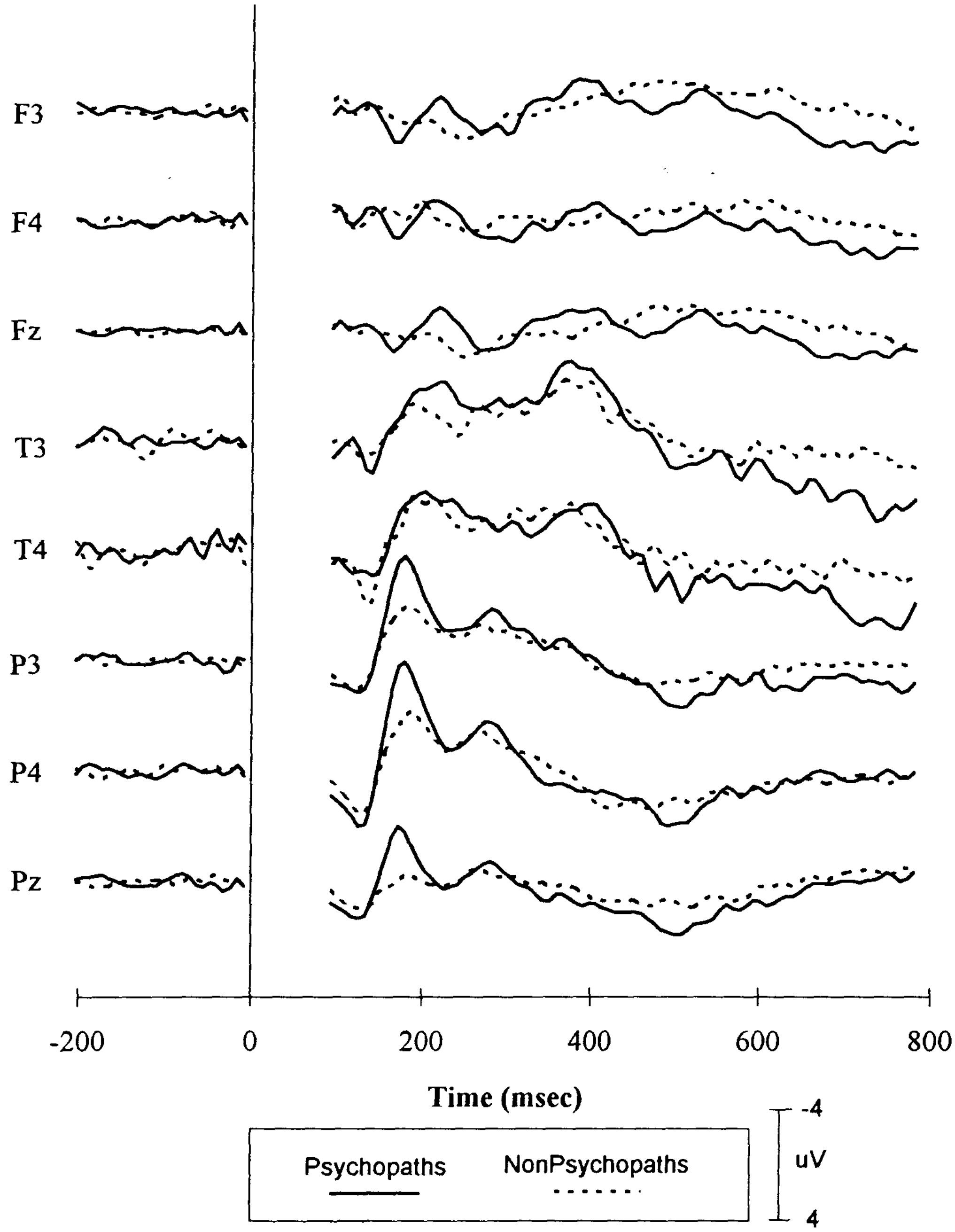
Appendix F: Stimuli for Mental Rotation Task



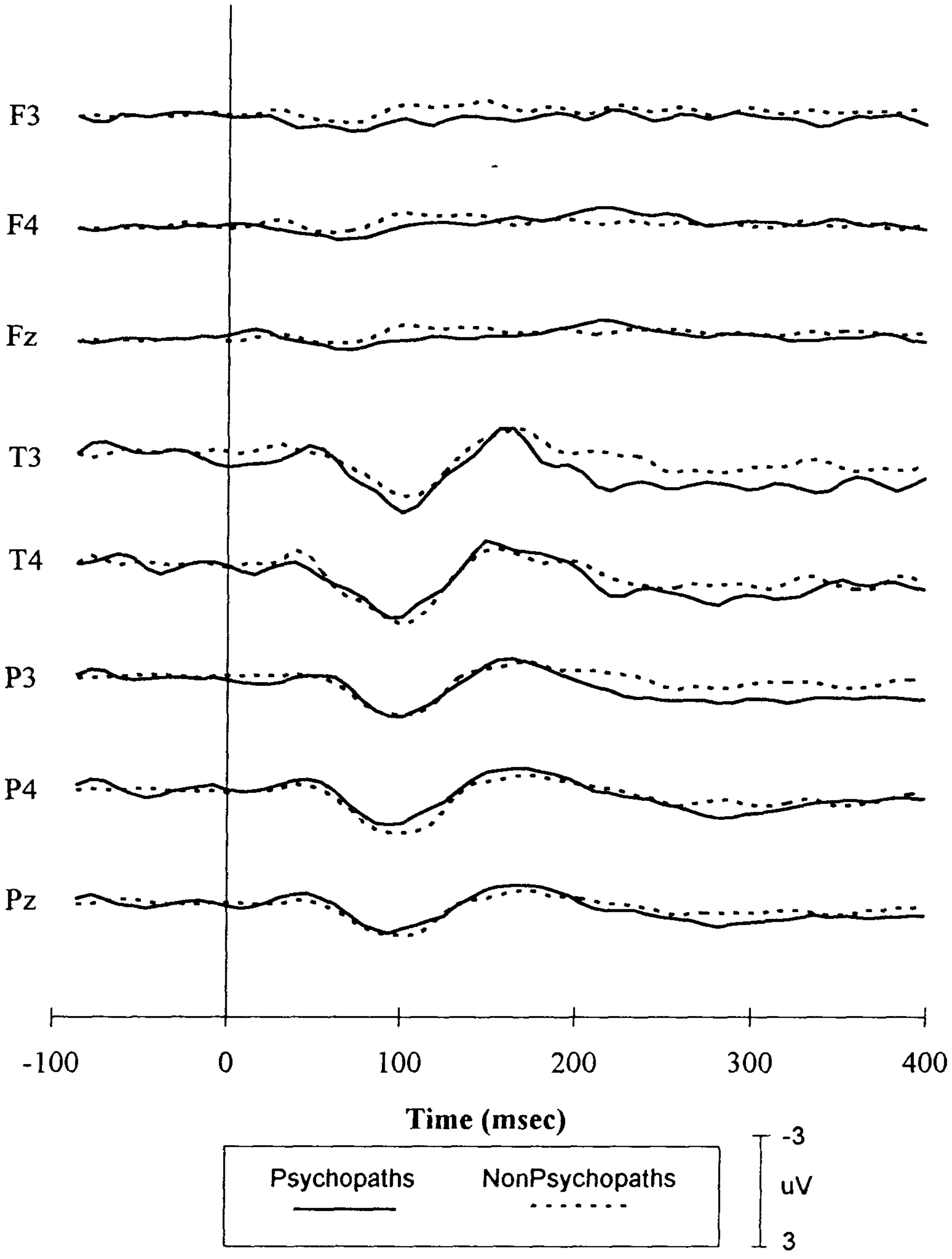
Appendix G: Stimuli for Nonverbal Visual Search



Appendix H1: Mental Rotation Task ERPs (Difficult Condition)
for Both Groups at Eight Cortical Sites



Appendix H2: Non-Verbal Visual Search ERPs for Both Groups at Eight Cortical Sites



Appendix H3: Memory for Tones ERPs for Both Groups at Eight Cortical Sites