Emotional memory

in people

with frontal lobe lesions

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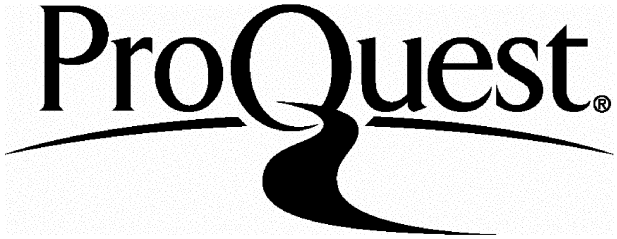

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ABSTRACT

Studies have consistently shown that emotionally arousing events are better learned and remembered than neutral events. There is wide consensus that this emotional memory advantage is linked to the cognitive and physiological effects of emotional arousal, and that the amygdala plays a key role. However the role of other brain structures is less well understood. The present study aimed to explore the role of emotional responsiveness in emotional memory, by studying a clinical population in whom emotional responsiveness itself is altered.

The performance of six people with frontal lobe lesions was compared with that of twelve matched controls, on five emotional memory tasks. Results suggested that emotional memory effects depend upon both how memory is assessed, and the nature of the emotional stimuli. For highly arousing negative stimuli, preserved superiority for emotional material was shown in the frontal group. However frontal participants showed significantly greater difficulty, compared to controls, where valent (but not specifically arousing) stimuli mediated the memory-enhancing effect. This effect was most evident 1) where memory was assessed implicitly, and 2) on a source memory task, where performance of the frontal group was disrupted for positive stimuli. On a test assessing retrieval of autobiographical memories, the frontal group showed greater difficulty in recalling memories, especially in response to negative cue words.

These findings are discussed in the context of contemporary literature on emotional memory, in both clinical and normal populations. The contribution of this study to understanding the role of the frontal lobe in aspects of emotional memory is considered and both clinical and research implications are explored.

CHAPTER 1 - INTRODUCTION

The focus of this thesis is emotional memory in people with frontal lobe lesions. This introductory chapter is in three parts. Firstly the concept of emotional memory will be explained, and research looking at emotional memory in people with and without brain injury will be described. The second section outlines the effects of frontal lobe lesions and the theoretical models proposed to explain these effects. Finally the rationale for looking at emotional memory in people with frontal lobe lesions is presented.

1. EMOTIONAL MEMORY

Emotions play a key role in all aspects of our lives, influencing attention, perception, and behaviour, and people remember emotionally significant experiences in their own lives in exceptional detail, with the recall of these events seeming both vivid and enduring. It makes intuitive sense that emotionally arousing events are better remembered than those that do not elicit an emotional response. Such an effect is evident at its extreme in those who experience or witness a traumatic event whereby the memory of that event can be experienced as 'inscribed' on the brain. The enhancing effect of arousal serves to ensure that details of those situations eliciting strong positive or negative emotions are stored, and can be used to guide behaviour in the future. Emotional arousal, by signalling stimuli that might need to be remembered, therefore provides an adaptive way of making sense of the external world.

Research has consistently supported this idea, showing that events with strong emotional associations are better learned and remembered than similar neutral events (e.g. Bower, 1992). Cahill and McGaugh (1996) demonstrated that people show superior declarative memory for emotionally vivid segments of a story, relative to neutral segments. Similar enhancing effects have been shown in studies comparing memory for emotional and non-emotional pictures (Bradley, Greenwald, Petry & Lang, 1992; Hamann, Ely, Grafton & Kilts, 1999). A study of children found a similar effect, showing better recall for stories describing emotional rather than non-emotional behaviours (Davidson, Luo & Burden, 2001).

Whilst an interaction between emotional arousal and memory is empirically evident, and clearly makes evolutionary sense, the exact mechanism by which memory is enhanced by emotion is less clear. Historically psychological accounts have implicated cognitive mechanisms to explain this effect, suggesting that emotional stimuli are better remembered because they focus attention and are rehearsed to a greater extent than non-emotional material (e.g. Neisser & Harsch, 1992 cited in Hamann, 2001). It is also postulated that emotion facilitates memory by providing a schema or category that may enhance recall (Phelps, LaBar, Anderson, O'Connor, Fulbright & Spencer, 1997). It seems that these accounts alone do not, however, fully explain the research findings and contemporary accounts link emotional memory to mechanisms that involve both the cognitive and physiological effects of emotional arousal. It is postulated that in emotionally stressful learning situations, an endogenous neurobiological system becomes active, to ensure that the strength of the memory for an event is, in general,

proportional to its importance (Cahill & McGaugh, 1998). Two elements are thought to be important to this system: the amygdaloid complex and stress hormones released during emotional events. Evidence for the role of these two elements will be discussed in the next two sections and the implications of this evidence for understanding the brain mechanisms underpinning emotional memory will then be explored.

1.1 Neural brain mechanisms

It is widely suggested that the amygdala is a critical brain structure in emotional memory. The amygdala has been shown to be important in emotional processing in general. For example it is known that the amygdala is important in the recognition of emotions from facial expressions (Broks et al, 1998), and patients with amygdala lesions show selective deficits in the identification of fearful or angry expressions (Adolphs, Tranel, Damasio, & Damasio, 1994; Adolphs, Tranel & Damasio, 1998). In terms of memory processing it is postulated that the amygdala does not act as a site of memory storage, but serves to influence memory storage processes in other brain regions e.g. the hippocampus and related circuitry (Cahill & McGaugh, 1998). It is suggested that emotional arousal has an effect upon memory through the release of stress hormones that interact with the amygdala and impact upon encoding and consolidation. The position of the amygdala in the brain, with widespread efferent connections, makes this a viable hypothesis, and several strands of evidence support this view. These will be summarised below.

1.1.1 Animal studies

Early animal studies identified what became known as Kluver-Bucy syndrome (Kluver & Bucy, 1937) following the bilateral removal of the medial temporal lobes of monkeys. The monkeys were described as showing an emotional deficit or "psychic blindness", and an apparent lack of fear response to previously threatening stimuli. Subsequent studies identified the amygdala as the structure within the medial temporal lobe which seemed to underpin this deficit (Weiskrantz, 1956). Recent animal studies have provided further support for the role of the amygdala in fear conditioning in animals; for example following amygdala lesions in rats (Phillips & LeDoux, 1992) learning of conditioned responses was found to be impaired. In particular the amygdala was found to play a significant role in learning where stimuli were both emotionally arousing and unpleasant/aversive (Cahill & MacGaugh, 1990; Davis, 1992). Studies of rats also found that the amygdala has an effect upon the allocation of attentional and information processing resources (Holland & Gallagher, 1999). These studies seem to point to the importance of the amygdala in processing stimuli relating to danger and threat, but might also indicate a more complex role in learning, and responding to, emotional stimuli.

1.1.2 Human studies

Implicit/unconscious processing

Extending these animal studies to explore the amygdala in humans has similarly found good evidence for a critical role in implicit responses to emotional stimuli. Morris, Ohman & Dolan (1998) used scanning techniques to study the role of the amygdala in

healthy participants. They presented angry faces to participants for a brief period of time such that they were not consciously perceived. Amygdala activation was shown even when participants were not consciously aware of viewing them. Several other studies have also found that the amygdala can respond differentially to emotional stimuli that subjects are unable to explicitly recall (e.g. Fried, MacDonald & Wilson, 1997; Whalen, 1998).

Patients who have undergone amygdala resection have been found to show little or no conditioned response to aversive stimuli (LaBar, LeDoux, Spencer & Phelps, 1995; Tranel & Hyman, 1990). A study of a patient with Urbach-Weithe syndrome (a rare congenital disorder which leads to mineralisation of the amygdala whilst sparing the hippocampal formation) found that the patient failed to show a conditioned skin-conductance response to stimuli paired with an aversive loud noise (Bechara et al, 1995). This lack of conditioned response is shown despite excellent declarative memory for details of the experimental experience. By contrast amnesic subjects without amygdala damage show evidence of intact fear conditioning responses, despite impaired declarative memory for the experiment itself (Bechara et al, 1995).

Explicit processing

The effect of amygdala damage upon explicit emotional memory has been explored in a range of studies. There is evidence to suggest an absence of enhanced memory for emotional material in this population (Adolphs, Cahill, Schul & Babinsky, 1997). In another study, a patient with Urbach-Weithe syndrome showed a normal pattern of

memory for neutral pictures and story content, but failed to show additional enhanced memory for emotionally salient pictures (Cahill et al, 1995). Further studies, using a range of episodic memory tasks with two patients with amygdala damage, found similar evidence of a lack of enhanced memory for emotional material on certain tasks (Babinsky et al, 1993; Markowitsch et al, 1994).

However there is evidence to suggest that the amygdala is not implicated in enhancing episodic memory for emotional material in certain types of memory tasks. Studies have shown that people with amygdala damage sometimes show deficits on emotional memory tasks, yet they show normal enhanced memory for emotional material in other circumstances (Markowitsch et al, 1994; Phelps, LaBar, & Spencer, 1997). It has been suggested that the amygdala is only involved in emotional learning when there is an actual emotional response i.e. an arousal response. Phelps, LaBar, Anderson, O'Connor, Fulbright, & Spencer (1998) explored the role of arousal in a study comparing memory for emotionally valenced words, which did not evoke a specific arousal response, with memory for taboo words, which did evoke physiological signs of arousal. A patient with amygdala damage showed enhanced memory for emotionally valenced words similar to matched controls, but impaired recognition memory for arousal stimuli. Emotionally valent stimuli have emotional meaning (i.e. can be considered to be positive or negative to a degree) but do not evoke the same magnitude or quality of physiological arousal. This seems to point to a more complex role for the amygdala in emotional memory. It seems that the amygdala is crucial to mediating enhanced memory for

arousing stimuli, but emotional enhancement of memory may still be shown to emotionally-valent stimuli even when the amygdala is not intact.

Phelps et al (1998) hypothesised that on tasks where emotional memory is intact, in spite of amygdala damage, emotion may be serving as a retrieval cue, in the same way as other category information. Similar enhanced memory for emotionally valenced words was shown in a study of undergraduate students (Doerksen & Shimamura, 2001). In this study it is suggested that the emotionally valenced words engage organisational processes which facilitate memory. Contrary to Phelps et al (1998), who suggests these are semantic clustering effects, they suggest that emotionally-valent words trigger personally relevant memories and this 'autobiographical clustering' facilitates the enhanced memory effect (Doerksen & Shimamura, 2001). Whilst the exact process remains subject to some debate, this fits with hypotheses that the enhancing effects of emotion work in part by activating cognitive mechanisms such as attention and elaborative encoding to enhance memory for the emotional stimuli (Hamann, 2001). In this way a person with amygdala damage can show enhanced memory on such tasks, but does not show enhanced memory on tasks where the arousal mediated amygdala system is primarily implicated.

1.1.3 Emotional memory in memory-impaired groups

There is evidence for preservation of fear conditioning in amnesic patients, despite impaired declarative memory for their experimental experience (Bechara et al, 1995). Lesions of other structures that can cause amnesia, such as the hippocampus, do not

proportionally impair emotional memory. Enhanced declarative memory is associated with emotional arousal in people with amnesic syndromes, despite impaired memory for neutral material (Hamann, Cahill, McGaugh & Squire, 1997, Ikeda et al, 1998). Mori et al (1999) found that Alzheimer patients were able to remember a highly emotional autobiographical episode (earthquake in Japan) and the quality of remembering was positively correlated with amygdala volume. A recent study of emotional memory in a group of patients with Korsakoff's syndrome (Shah, 1999 unpublished dissertation) found that enhancement of memory for emotional material was dependent upon the way in which memory was assessed. Emotional memory effects were shown on implicit but not explicit tasks, and on a test of autobiographical memory, superiority of memory for negative autobiographical experiences was shown.

Other studies of people with memory impairments have produced seemingly conflicting results. For example a study of recall and recognition memory for photographs in early Alzheimer's disease (AD) found emotional reactions to be normal in the AD group, but emotional memory enhancement was blunted (Hamann, Monarch & Goldstein, 2000). These findings might be explained in part by the intensity of amygdala damage (Mori et al, 1999). Comparison with studies of patients with bilateral amygdala lesions also suggests that the impact of emotional arousal is normal in amnesia, in the absence of damage to the amygdaloid region (Hamann, Cahill, McGaugh & Squire, 1997). This provides further support for the critical role of the amygdala in emotional memory, and for the preservation of enhanced emotional memory where conscious declarative memory is impaired.

1.1.4 Neuroimaging studies

Studies utilising brain-imaging techniques have allowed further insights into emotional memory. Amygdala activation while viewing of emotional films was found to be correlated with retention of the films (Cahill et al, 1994), and such a correlation was not observed for emotionally neutral films. Subsequent studies showed a similar correlation between stronger amygdala activation and superior memory for emotional stimuli (Hamann et al, 1999; Canli, Zhao, Desmond, Glover, & Gabrielli, 1999).

Imaging studies have also allowed exploration of hypotheses relating to the aspects of stimuli which activate the amygdala mediated memory system; for example, is it valence or arousal characteristics which are important in this system, or a combination of both? Canli, Zhal, Brewer, Gabrieli and Cahill (2000) found that amygdala activation and subsequent memory were only correlated for the most emotionally intense stimuli, and suggested that this might indicate that a stimulus would have to exceed a certain level of emotional arousal before amygdala activation modulates memory. In this study there was also evidence that amygdala activation correlates with subjective rating of emotional intensity, and memory performance was only improved for those stimuli rated as the most intense. This study also supported findings of previous studies which suggest that at the point of encoding amygdala activation is independent of stimuli valence (Hamann et al, 1999). In sum this evidence seems to point to the amygdala activation being predictive of subsequent memory where a high level of emotional

intensity is evoked at encoding and this supports the findings of experimental studies (e.g. Phelps et al, 1998).

1.2 Neurobiological mechanisms

1.2.1 Stress hormones

Stress hormones are activated by emotional situations and serve an immediate adaptive function in preparing the body to respond. These hormones also aid future responses by enhancing declarative memory for the emotional experience. Evidence for this is found in studies which show that stimuli are better remembered the more emotionally arousing they are (e.g. Bradley, Greenwald, Petry & Lang, 1992; Hamann, Cahill & Squire, 1997) and in numerous animal studies which implicate the neuropharmacological response to stress in the modulation of learning (McGaugh et al, 2000). Manipulation of arousal levels in humans, either pharmacologically (Cahill, Prins, Weber & McGaugh, 1994) or through the use of a specific context (Cahill & McGaugh, 1996) leads to increased recall of emotional material. In sum this evidence supports the hypothesis that increased arousal serves as a signal, to enhance encoding of material into declarative long-term memory. However the exact neurobiological mechanism by which this takes place is less well understood.

Enhancement of memory for emotional material has been shown in studies that have used pharmacological manipulations to stimulate the noradrenergic system. For example administering the drug yohimbine, which inhibits re-uptake of noradrenaline, results in increased recall and recognition of emotional phases of a story, compared to

participants administered a placebo (O'Carroll, Drysdale, Cahill, Shajahan, & Ebmeier, 1999). However a subsequent study using a different noradrenaline re-uptake inhibitor produced contradictory findings (Papps et al, 2001). In this study two different doses of the drug were compared to a placebo and it was expected that the higher the dose, and therefore the more noradrenaline available in the brain, then the greater the enhancing effect of emotion on memory. However the opposite effect was observed with the high dose group performing worst on recall and recognition tasks. These findings indicate the need to explore other possible brain mechanisms that might be implicated. One possible explanation of these findings is that arousal mediated memory is being enhanced in a dose-dependent way, such that there is an optimum level of arousal which enhances memory (Papps et al, 2001). It is suggested that higher levels of arousal may serve to impair memory (Introini-Collison & McGaugh, 1986).

Lesions of the amygdaloid complex have also been found to block the memory enhancing effects of stress hormones (Cahill et al., 1995; Adolphs et al., 1997). This suggests that emotional arousal enhances memory through the release of stress hormones which interact with the amygdala in some way. Stress hormones are, however, not able to easily cross the blood-brain barrier and so cannot enter the brain, i.e. these hormones could not influence brain structures directly (Blake, Varnhagen, & Parent, 2001). It is therefore thought that these effects are mediated by a secondary, indirect mechanism. It is hypothesised that one possible mechanism is the release of glucose into the blood (Blake et al, 2001). This is consistent with evidence that glucose administration improves memory, in both young and elderly people (Manning, Parsons, Cotter, & Gold,

1997 cited in Blake et al., 2001), and in a group of patients with Alzheimer's Disease (Benton & Owens, 1993 cited in Blake et al., 2001). Blood glucose levels were also increased after viewing a slide show accompanied by an emotional narrative (Parent et al, 1999). This study also showed that administering glucose to a greater level seemed to prevent the enhancing effects of the emotionally arousing narrative on memory, and this finding might fit with evidence of extreme emotion suppressing or distorting memory for an event (see below, Section 1.2.2.). A subsequent study showed memory was enhanced for emotionally arousing pictures in parallel with increases in blood glucose (Blake et al, 2001).

1.2.2 Effects of high level of arousal on memory

There is some indication that high levels of emotional arousal impair memory as opposed to having an enhancing effect (e.g. Kihlstrom, 1995). Clinical reports indicate that an amnesiac syndrome may be induced by a highly stressful, traumatic event (Christianson & Safer, 1996). An experimental study similarly showed that participants viewing a very violent film had poor memory for the details of the film (Loftus & Burns, 1982). High levels of stress and cortisol have also been correlated with impaired memory (Lupien & McEwen, 1997; Introini-Collison & McGaugh, 1986). These findings seem to contradict evidence which suggests that increased arousal enhances memory.

To account for these findings it has been suggested that the effect of emotion on memory follows an inverted U-curve (Yerkes-Dodson law) whereby low and high levels of

emotion impair memory whilst moderate levels enhance memory performance (Kassin, Ellsworth & Smith, 1989). However several studies show evidence of accurate and detailed memories following highly stressful events (e.g. Yuille & Tollestrup, 1992; Christianson & Hubinette, 1993). Such an effect is also shown in the phenomena of 'flashbulb memories', which are memories for personal circumstances when shocking information is received (Brown & Kulik, 1977). These memories are experienced to be enduring and resistant to decay. This suggests the effect of emotional arousal upon memory follows a more complex pattern.

It is suggested that different memory structures in the brain are affected differently by emotional arousal; for example the hippocampus is affected by stress in a different way to the amygdala (Brewin, 2001). Hippocampal function is enhanced by a certain level of emotional arousal but is impaired under high levels of stress (Metcalfe & Jacobs, 1998) whilst amygdala function seems to be enhanced generally by increased stress level (Pitman, Shalev & Orr, 2000, cited in Brewin, 2001). This idea is consistent with the suggestion that some aspects of memory might be enhanced whilst others are impaired and might explain clinical reports of impaired declarative, autobiographical memory for highly emotional events.

Some studies also show an effect of enhanced memory for central details of an emotional situation, but poor memory for peripheral details (e.g. Steblay, 1992; Burke et al., 1992). Emotional arousal might serve in this way to direct attention and subsequent encoding resources to emotionally-relevant aspects. It has been suggested that this

'attentional narrowing' (Christianson, 1992) to take in emotional stimuli occurs at the expense of memory for contextual information (i.e. item-source memory trade-off) (Jurica & Shimamura, 1999). However, a recent study looking at memory for emotionally valenced words found that both item, and source, memory were enhanced for emotional items (Doerksen & Shimamura, 2001). The authors propose a role for emotional valence in engaging both attentional and organisational processes important for source memory. The effect of emotion in impairing or distorting memory, therefore, remains subject to some debate.

1.3 Emotional memory mechanisms

The research evidence summarised in this chapter so far seems to support an account of specific emotional memory mechanisms that act to enhance memory for emotional events. In summary, during an emotional event stress hormones are released that activate specific neurobiological mechanisms. These mechanisms interact with the amygdala and activation of the amygdala serves to influence storage of emotional memories in other brain regions involved in long-term memory. Attention of memory theorists has increasingly turned to the processes of consolidation and retrieval, and in the case of emotional memory, to consider the possibility of post-encoding mechanisms that also contribute to mediating enhanced memory.

1.3.1 Consolidation

Consolidation is described as the process that occurs after initial encoding where a memory is slowly fixed in the mind and made more permanent (McGaugh, 2000).

Subsequent recall is a function of both how well something is initially learned, and also how well it is consolidated. The consolidation process takes time to complete. It is therefore suggested that the enhancing effects of emotion on memory might also take time to develop and will increase over time (Hamann, 2001).

It is widely accepted that the amygdala mediates an enhancing effect at encoding, when arousal is elicited, but recent evidence also suggests a role in consolidation. Evidence from animal studies found that electrical stimulation of the amygdala in rats, after learning a conditioned response to aversive stimuli, led to severely disrupted retention (Goddard, 1972). This might suggest that whilst amygdala mediation had taken place at initial encoding, disruption of the process of consolidation served to reduce retention. In the Phelps et al (1998) study described above control participants showed increased recall over time for taboo as opposed to neutral words. The patient with amygdala damage did not show this recall advantage over time for arousal stimuli. Scanning studies have also shown the amygdala is activated during REM sleep (Maquet et al, 1996). Given that sleep has been postulated to have a role in the consolidating and reorganising of memory, it is possible that some of the amygdala's modulation of emotional memory takes place during this time.

1.3.2 Retrieval

The neural systems subserving the retrieval of emotional memories are subject to debate. It is not clear to what extent these neural systems differ from those that underpin the retrieval of episodic memories per se. There is some evidence to suggest that the

amygdala is activated during the retrieval of emotionally salient autobiographical memories (Fink et al, 1996). However a subsequent study did not replicate this effect, showing activation of the amygdala during encoding of emotional films, but not at recall (Reiman et al, 1997). This would be consistent with the idea that the amygdala has a time-limited role in forming declarative memories for emotional events.

Dolan et al (2000) compared retrieval for emotional and non-emotional material in a scanning study. They found that the right anterior temporal cortex and the left amygdala region were activated in retrieval of emotional memories but not in non-emotional episodic memory retrieval. This suggests that whilst the amygdala has time-limited effects during the process of encoding, there may also be specific neural systems involved in the retrieval of emotional memories. This may involve a role for the amygdala, distinct from that at encoding and consolidation. Dolan et al (2000) suggest that the role of the amygdala at retrieval may be to index memories in some way, with a representation of their past significance.

2. THE FRONTAL LOBES

The frontal lobes constitute one third of the mass of the entire brain and have reciprocal interconnections with virtually every part of the nervous system (Stuss & Benson, 1986). A wealth of research suggests that they play a crucial role in higher order cognitive functioning and in regulating overall brain function (Luria, 1973). Numerous studies have attempted to explicate the specific functions subserved by this area of the brain and some of these studies will be summarised below. Early studies looked at the region in

its entirety and frontal pathology was labelled 'frontal lobe syndrome'; more recent studies have attempted to subdivide this region and take account of the effects of different locations, and aetiologies, of lesions. An attempt will therefore be made to look broadly at the impact of damage to the frontal region but to look also at what is known about the specific regions that subserve different functions.

2.1 Effects of frontal lobe damage

2.1.1 Changes in emotion and social behaviour

Patients with lesions in this area of the brain are characterised by altered emotion and social behaviour, and have been described as appearing to have flattened affect, or emotional shallowness. This is shown in reduced social sensitivity, misinterpretation of the moods of others, an apparent lost sense of responsibility and a lack of concern for social rules (e.g. Lishman, 1968; Blumer & Benson, 1975; Eslinger & Damasio, 1985; Damasio, 1994). Lesions have also been linked to personality changes such as increased irritability, disinhibition, impulsiveness and euphoria (e.g. Stuss & Benson, 1986).

These personality changes have largely been linked to orbitofrontal and medial frontal regions with lesions to the dorsolateral prefrontal cortex more likely to lead to deficits in cognitive reasoning, abstract thinking, and problem solving (Fuster, 1997). In people with lesions to the orbitofrontal cortex, formal reasoning and problem-solving abilities are often intact, whilst social reasoning and behaviour seem to be impaired.

One of the most famous cases to illustrate these personality changes is that of Phineas Gage (Harlow, 1848, 1868), who following a penetrative head injury appeared to show good recovery, demonstrating intact language, learning and memory abilities. However his personality was reportedly profoundly changed, and he seemed to show little sense of social conventions. Damasio et al (1994) used modern imaging techniques to determine the probable location of lesion in this case and suggested that this damage was likely to have involved the ventromedial region of both of frontal lobes, while sparing the dorsolateral region. This has led to hypotheses that emotion and social conduct regulation depend upon the ventromedial cortex (Damasio et al, 1990; Saver & Damasio, 1991).

A case study of a patient with a right orbitofrontal injury (Nies, 1999) described similar change in emotion and social behaviour post-injury. In this case self-report indicated a lack of emotional responsiveness and alteration in the regulation of emotional states. A case reported by Dimitrov, Grafman, and Hollnagel (1999) of a man injured during the Vietnam War demonstrated significant personality changes many years later. These included bluntness of affect, lack of tact, and a difficulty in making and maintaining relationships with others. His cognitive abilities on standard tests seemed to fall largely in the normal range (with the exclusion of certain tests of executive function) but he was found to be significantly impaired on tests of his emotional responses.

2.1.2 Physiological responses

In the case described above significant differences were found in physiological responses to emotional stimuli, when compared to both normal controls and to patients with damage to other areas of the brain (Dimitrov et al, 1999). The patient described showed hyporesponsivity to gruesome slides, which would normally evoke a significant skin conductance response (SCR). Impairment of SCR to psychological stimuli has been reported in several studies (e.g. Tranel & Damasio, 1994; Zahn et al, 1999), although the ability to generate physiological responses per se remains in tact. Blair and Cippolotti (2000) found hyporesponsivity to images of threatening objects, and to emotional facial expressions, in a man with significant damage to the orbitofrontal cortex. It is suggested that this diminished sensitivity to emotional or socially relevant stimuli might in part explain the observed bluntness of affect in this population. This will be explored further in the theoretical models described below.

2.1.3 Cognitive effects

The cognitive effects of frontal injury are varied and mostly dependent upon the location of injury. It is noted that people with frontal injury sometimes have normal neurological and neuropsychological examinations, with impairments becoming more evident later in the rehabilitation process (Eslinger et al, 1995; Dimitrov et al, 1999). In particular where damage is localised to the orbitofrontal region cognitive abilities may remain in tact, with impairments largely being evident when higher level social judgements are called upon. It is noted for clarity that the differentiation of cognitive effects and social/personality change is an artificial one. These different effects are likely to be

inter-linked and aspects of cognitive dysfunction may explain personality change at another level of explanation, and vice versa.

Executive function

The prefrontal region is the part of the brain most implicated in 'executive function'; the aspect of functioning concerned with the processing and control of complex thought and action. Executive function is conceptualised as having four components; volition, planning, purposive action and effective performance (Lezak, 1995). People with frontal lobe lesions may show impairments in aspects of executive function, although there is much variation amongst studies and considerable debate about how this variation might best be explained. Impairments described in this literature include perseveration, concrete thinking, disorganisation, response inhibition and problems with sustained attention and planning (see Lezak, 1995).

Memory

There is also considerable debate about the role of the frontal lobes in memory functioning. It is suggested that whilst people with frontal lesions may show impaired performance on memory tests, this is often secondary to difficulties with attention, problem solving and response inhibition, which impinge upon test performance (Nies, 1999). Other researchers would suggest that the frontal lobes are implicated more directly in aspects of memory, and report evidence that frontal lobe damage disrupts free recall, cued recall and recognition memory (Wheeler et al, 1995, 1997; Shimamura et al, 1991). It seems likely that frontal damage is associated with certain specific types of

memory impairment. For example frontal damage has been linked to impairments in the ability to remember facts for a short period of time (i.e. working memory) (Goldman-Rakic, 1987; Smith et al, 1995; Courtney et al, 1997). Meta-memory has also been linked to the frontal region (Janowsky, Shimamura & Squire, 1989a) and functional imaging studies have supported a role for the frontal lobes in remembering and retrieval (Fletcher et al, 1997; Nyberg, Cabeza & Tulving, 1996 cited in Wheeler et al, 1997). It is also suggested that the linking of contextual details to memory for events is also subserved in some way by the frontal lobe, as evidenced by studies which show impairments in source memory (Janowsky, Shimamura & Squire, 1989b). This is consistent with suggestions that memory for content is not impaired in frontal injury whilst memory for contextual information is affected.

In particular memory for temporal context (i.e. memory for when events took place in time) and temporal order is affected by orbital frontal injury (e.g. Milner et al., 1991). It is suggested that mechanisms in this region contribute to marking events and memories in such a way that they can be maintained in a temporal order and the past can be distinguished from the present (Wheeler, Stuss & Tulving, 1997). This concept also allows an individual to have an 'awareness of self as a continuous entity over time' and this 'autonoetic awareness' has been linked to the frontal lobes (see Wheeler et al., 1997). It is suggested that damage to this area may affect the ability to access and mentally represent these personal experiences. The capacity to self-reflect and use subjective experiences to inform behaviour is therefore impeded.

2.2 Factors that are hypothesised to contribute to overall social deficit

2.2.1 Empathy

Empathy is defined as the "ability to perceive and think beyond our own needs, goals and desires, to include those of others as necessary for the emergence of mental models, schemas and other forms of working knowledge about others and ourselves in relation to each other" (Eslinger, 1998). This empathic understanding of, and response to, other people is thought to be impaired in people with focal frontal damage (Eslinger, 1998), as shown by lowered scores on measures of empathy. It is suggested that impairments in empathic responding may in part underpin social deficits observed in frontal groups and that this part of the brain is specialised for emotional and cognitive aspects of empathy.

2.2.2 Theory of mind

A concept related to the empathy construct is that of Theory of Mind (TOM); the ability to make inferences about the mental states of others. This ability is crucial to social interaction with others. Several strands of evidence implicate frontal areas in TOM tasks, such as neuroimaging evidence for frontal activity during TOM tasks. Clinical and experimental data suggest that people with frontal damage have difficulty in representing the mental states of others (e.g Stone et al, 1998; Price et al., 1990). There are however criticisms of experimental TOM tasks that require only visual perspective taking, since this may not actually necessitate the representation of the mental states of another (Leslie & Frith, 1988). Subsequent case studies have also described individuals with frontal damage who show unimpaired performance on TOM tests, in which participants are asked to comment on why story characters behave as they do (e.g. Saver

& Damasio, 1991; Blair & Cipolotti, 2000). These findings suggest that whilst some people with frontal injury may have difficulty in representing the mental states of others, others do not show impairment on TOM tasks, yet still show difficulty in modulating emotional and social behaviour.

2.2.3 Identifying other people's facial and emotional expressions

It is suggested that impairments in recognising emotional expressions in others might in part explain the social deficits shown in people with frontal injury (Hornak, Rolls & Wade, 1996). On tests of emotional expression recognition a ventral frontal damage group were found to be significantly impaired and this impairment was found to be correlated with disinhibited and socially inappropriate behaviour (Hornak et al, 1996). Similar difficulties in recognition of emotion were found in the case study described by Blair and Cipolotti (2000), in particular in the recognition of angry, fearful and disgusted expressions. Difficulty in identifying expressions of emotion in others would impede appropriate responding, and in particular might mean individuals failing to inhibit behaviour that might be inappropriate to another's emotional state.

2.3 Psychological models explaining emotional and social behaviour change

Brothers (1995, 1997) proposes the idea of the frontal lobe as a 'social editor' which is specialised for processing of social information and of the intentions of others in social situations. The rest of the brain therefore perceives social information, such as gestures and facial expressions, and reports this information to this unitary system for responding

to social signals. The social editor then has the role of attributing intention to gestures and facial expressions to make sense of social situations and guide responding.

Eslinger et al. (1995) postulate a similar concept of the frontal lobes as a social executive, for processing different types of social information. They describe four aspects of social behaviour within their model: Social self-regulation, Social self-awareness, Social sensitivity, and Social salience. Deficits in different aspects of interpersonal behaviour are shown in different ways; for example difficulties in social self-regulation might be shown in a limited appreciation of social boundaries or a difficulty inhibiting impulsive responses. Within this model 'social salience' refers to the cognitive and autonomic processes that regulate emotional state. Whilst this framework provides an account of how different aspects of social and emotional behaviour might be affected, and a way of talking about deficits, it does not inform discussion as to the mechanisms which might underlie the social executive.

Grafman (1989, 1995) describes the frontal lobes as containing social schema knowledge organised in Managerial Knowledge Units (MKU's). These are knowledge structures composed of events, actions and ideas, which will be activated in response to specific stimuli. The activation of social schema knowledge therefore serves to inhibit aberrant social behaviour and guide appropriate responses. It is suggested that damage to the prefrontal cortex could lead to the decomposition of these knowledge structures, such that schemas are not activated in response to novel situations (Grafman, 1989). Loss of access to these knowledge structures might then lead to impairments in social

and emotional responses, and aberrant behaviour would no longer be inhibited. This model has however not been empirically tested to a great extent. Dimitrov et al (1996) found that whilst some patients with frontal lobe lesions had difficulty with tasks of rating appropriate responses to social situations, the degree of difficulty was correlated with level of overall intellectual functioning. This might suggest that cognitive ability was the mediating factor as opposed to disproportional impairment in social knowledge. Saver and Damasio (1991) described a patient with intact social knowledge on certain tasks, despite deficits in social behaviour. Blair and Cipolotti (2000) also found that their patient was able to access knowledge about morals and societal conventions in order to complete a task of rating transgressions from these norms, although he was notably unable to distinguish levels of severity within these transgressions.

2.4 The frontal lobes and emotional learning

Damasio (Damasio, Tranel & Damasio, 1990) also postulates a role for the prefrontal cortex in storing social judgement abilities. However they conceptualised this knowledge base as linked to the autonomic system and as a part of a wider, distributed network responsible for processing, and responding to, social information. Damasio (1994) described this link with the autonomic system as a 'somatic marker' system, which provides a way of tagging events and knowledge with a somatic state (i.e. an autonomic nervous system response). In this way autonomic states are activated in response to specific situations to aid decision making and guide responding. This allows a process of learning about the emotions/somatic states activated in certain situations and stores these links for use in future situations.

Damasio et al suggest the following evidence to support this position. The frontal cortices receive projections from all sensory modalities and are the source of projections from frontal regions to central autonomic structures. In this way the frontal lobes play an important role in autonomic regulation. In people with ventromedial frontal lesions, autonomic responses to socially meaningful stimuli are found to be impaired (Saver & Damasio, 1991; Damasio et al, 1994; Bechara et al, 1996; Zahn et al, 1999). In particular it was found that people with ventromedial frontal lesions did not show autonomic responses to social stimuli when viewed passively. Patients with ventromedial frontal lesions also perform poorly on a card game task that involves learning about rewarding and punishing packs. For example participants are given the opportunity to learn that certain packs are more likely to lead to loss in the long-term and others more likely to lead to reward. Healthy participants were found to learn which packs led to maximum gain, and skin conductance responses prior to choosing from high-risk packs indicated that they had an anticipatory somatic response, i.e. in anticipation of a negative outcome. Patients with ventromedial frontal damage failed to consistently avoid 'high risk of punishment' packs despite showing SCRs when 'punishment' was actually received. They failed to show anticipatory SCRs when taking from disadvantageous packs, which indicates that the 'somatic marker' was not acting as a warning signal. In other words the somatic state did not seem to be linked to the situational information, thus was not activated as a warning signal in subsequent situations.

Rolls (2000) similarly suggests a role for the frontal lobe in emotional learning. In particular he suggests involvement in learning from emotional feedback, and modifying behaviour in response to feedback (Rolls, 2000). Animal studies and functional imaging studies have indicated that this is a critical area for stimulus-reward learning. Studies have shown impairments in people with frontal lesions on tasks in which an alteration of behavioural strategy is required in response to changes in environment reinforcement contingencies (Rolls et al., 1994). It is suggested that these aspects of emotional learning may be the basic components of higher order emotional and social behaviour and personality changes in this clinical population may be related to a similar type of dysfunction (Rolls, 1990, Damasio, 1994). In social interaction there is a need to decode and respond to social signals and failure to respond appropriately could lead to negative outcome. It is therefore proposed that inappropriate social behaviour, in people with frontal lesions, reflects difficulty in altering behaviour appropriately in response to negative (or positive) outcome. Further studies have found a correlation between impairment on such emotional learning tasks and personality changes, such as difficulty responding to positive and negative social feedback (Rolls et al, 1994).

3. RATIONALE FOR CURRENT STUDY

It is clear that considerable research has already been undertaken to gain an understanding of the concept of emotional memory. However there remain many unanswered questions. It is intended that this study will add to current understanding of emotional memory, and its underlying brain mechanisms. The development of a coherent, integrative account of emotional memory clearly has significant implications

for understanding, and treatment of, depression, post-traumatic stress disorder and other psychological conditions in which emotional memories are implicated. Developing a greater understanding of the role of the frontal region of the brain also has significant clinical relevance to the field of neurorehabilitation, informing the process of developing individualised, theoretically-based strategies to allow people to best manage their difficulties and maximise their independence.

3.1 Why might the frontal lobes be important to consider in emotional memory?

Whilst there is clearly strong evidence to implicate a role for the amygdala in modulating emotional memory, there is also empirical evidence to suggest that other neural structures may also be playing a role. For example, Tranel and Damasio (1993) describe a study of an amnesic patient with a total lesion to the amygdala and hippocampus, yet who was able to learn an affective valence. Studies of people with frontal lesions, without damage to the amygdala, have shown evidence of impairment in learning emotional information. For example, as described above, in a card game where participants are required to learn strategies to maximise reward and avoid 'punishment', people with frontal lobe lesions do not seem to show conditioned skin conductance responses (SCRs) in anticipation of negative outcome (Bechara, Damasio, Damasio & Anderson, 1994; Bechara, Tranel, Damasio & Damasio, 1996). This impairment in acquiring a conditioned fear response might be expected, given empirical evidence, in the case of amygdala damage but in these patients amygdala function was intact. Whilst there are several possible explanations of the poor performance of frontal participants on this task, including general deficits in working memory, impaired decision making, or a

high level of risk-taking behaviour, this finding that anticipatory physiological responses are not acquired seems to suggest a particular difficulty in emotional learning. This might therefore indicate a role of the frontal region in aspects of emotional memory. Damasio (1994) proposes that for patients with frontal lesions these impairments indicate difficulty in activating emotional representations (i.e. visceral response), and hence in making associations between a situation and its emotional consequences. This could indicate that emotional memory mechanisms, which would ordinarily serve to modulate these associations, are impaired in some way. This might implicate the frontal area directly in processes of encoding, consolidating or retrieving aspects of emotional memories, or indirectly in interaction with processes modulated by the amygdala.

Evidence from imaging and animal studies seem to further indicate a role for medial frontal areas in emotional memory. The multitude of bi-directional interconnections between the frontal cortices and both the amygdala and the hippocampus supports a case for the importance of frontal areas in emotional memory. The caudal orbitofrontal cortex in particular receives strong inputs from the amygdala (Price, Carmichael & Drevets, 1996). Recent brain-imaging studies have suggested that the amygdala complex and the orbitofrontal cortex interact functionally during emotionally arousing situations (Hamann, Ely, Hoffman & Kilts, 2002; Cahill et al, 1996). Windmann and Kutas (2001) report electrophysiological evidence of the involvement of frontal regions during the recognition of emotionally valenced stimuli, and they postulate an executive or organisational role for the frontal cortex in the retrieval of emotional memories. Given

the range of evidence this study will look at emotional memory in a group of people with frontal lobe lesions.

3.2 Emotional responsiveness and emotional memory

Contemporary accounts of emotional memory identify the importance of arousal in activating memory enhancing mechanisms (e.g. Canli, 2000). Extensive study of people with frontal lobe lesions has shown that emotional responsiveness is impaired. This is evidenced by studies which show hyporesponsivity to arousal stimuli (Dimitrov et al., 1999) and clinical observations of flattened or blunted affect (Blair & Cippolotti, 2000). This is in contrast to studies of amygdala damage where there is some evidence to suggest that emotional responsiveness itself is unimpaired. For example subjects with amygdala damage often exhibit normal cognitive (Cahill et al, 1995; Adolphs et al, 1997; Hamann et al, 1997) and physiological (Bechara et al, 1995) reactions to emotional stimuli, despite having impaired long-term memory for the stimuli. This suggests that the amygdala may not be necessary to experience emotional intensity itself but is critical to emotional learning. The present study therefore intends to study performance on a range of emotional memory tasks in a group of people in whom it is suggested emotional responsiveness itself is impaired.

3.3 Understanding of social behaviour change in frontal lobe injury

Case studies document significant personality and social behaviour change post-frontal injury. Several models have been put forward to explain and account for this change, one of which is the suggestion that this area of the brain has a role in learning from

emotional feedback, and modifying behaviour (Rolls, 2000). Studies have found a correlation between impairment on emotional learning tasks and personality changes, such as difficulty responding to positive and negative social feedback (Rolls et al, 1994). It is however suggested that the impairment in emotional mechanisms which contribute to guiding decision-making on emotional learning tasks, is distinct from the mechanisms that enhance memory for emotional material (Bechara et al., 2000).

Only one unpublished study, reported in Bechara et al (2000), has explored this hypothesis. This study compares memory for emotional and neutral pictures, in patients with ventromedial frontal lesions and in healthy controls. Bechara et al report that enhanced recall of the emotional pictures was shown in both groups, and concluded that emotional modulation of memory is therefore intact in this frontal group. A full account of the study is however not given and some of the details of the methodology are unclear. For example it is not evident how 'recall' of the visual images was measured, or how emotional and neutral pictures were matched. Drawing the conclusion that emotional memory mechanisms are unimpaired in a frontal group, on the basis of these findings, is also questionable, since only one aspect of the emotional modulation of memory is sampled. Contemporary accounts of emotional memory suggest that multiple mechanisms, at both encoding and consolidation, contribute to memory-enhancing effects. In this case highly arousing negative stimuli have been utilised (i.e. pictures of raped and mutilated bodies) and the enhanced recall for such stimuli might indicate that certain aspects of these mechanisms are intact under conditions of high arousal, when measured by a recall task. The effects of a lesser degree of emotional arousal, or of

emotional valence (without significant arousal), on memory, in people with frontal lesions, therefore remain unclear. Performance on a recognition task, which requires an accurate representation to discriminate those previously viewed, or on an implicit memory task might similarly produce different findings. Previous studies with both healthy and brain-injured groups have found varying results within groups on implicit and explicit tasks, and on tasks comparing memory for arousing with memory for emotionally valent items (Phelps et al, 1997; Phelps et al, 1998).

Other studies have not specifically studied enhancement of memory for emotional material in people with frontal lesions, but imply that the mechanisms of encoding of emotional material are altered in some way in this population, and that the process of linking experiences with somatic states is impaired (Damasio, 1994). It might therefore also be expected that memory for emotional material in a frontal group would not show the same degree of enhancement as in a healthy population (i.e. contrary to Bechara et al's findings). It is therefore intended within this study to explore this hypothesis further, looking at the performance of people with frontal lesions on a range of emotional memory tasks. Given the limited empirical study of this area to date, this exploration could contribute to a greater understanding of the models that are postulated to account for social behaviour change in this group. This understanding might therefore help to inform rehabilitation and treatment of people with frontal lobe lesions, and aid understanding, and interpretations of the changes observed.

3.4 Experimental assessment of memory for emotional and neutral material

As is evident in reviewing the studies that have been carried out in both brain-injured and healthy people, how emotion affects memory will depend on the type of task used to assess memory. Memory for neutral material differs depending upon whether implicit or explicit tasks are employed, or, within explicit tasks, whether free recall, cued recall or recognition tasks are used. Similarly any differences, between people with frontal lesions and healthy controls, in emotional memory will depend on the same factors. It is therefore important to use a range of tasks to fully investigate possible differences. The present study employed 5 tasks to tap into different aspects of emotional memory. The following brief account of each test gives an indication of the aspects of the emotional modulation of memory which are measured in each case.

The Good guy/Bad guy test

This is an adapted version of the Good guy/Bad guy test used by Johnson et al (1985). The version used in this study is included because it assesses memory for emotional material in several different ways, including both explicit and implicit tasks.

Firstly, it assesses the effect of emotional valence on recognition memory by comparing recognition of faces accompanied by a 'good' or 'bad' character profile, with those not accompanied by a descriptor. Secondly, the test measures free and cued recall for the 'good' or 'bad' information given about the characters. Finally the test includes an implicit memory task in which participants are asked to rate, prior to the recall test, each of the characters on three personality characteristics. This rating tasks assesses the

extent to which the emotionally valent descriptors given might guide judgements about each of the characters, independent of actual recall of the descriptors themselves.

The Cahill Test

This test compares memory for neutral and emotional events, using a story paradigm. It has been widely used in a range of studies; including with normal subjects, a patient with an amygdala lesion (Cahill et al, 1994; 1995) and in a study of patients with Korsakoff's syndrome (Shah, 1999). Performance on this task in people with frontal lesions has not been reported in the literature to date.

Emotional priming test

This is an incomplete word-stem priming task, utilising pairs of emotional and neutral words that begin with the same word stems. Participants first view all the words and are subsequently asked to complete the word stems. This test therefore compares the influence of neutral and emotional material on an implicit memory task.

Autobiographical memory test

The Autobiographical Memory test (AMT) (Williams & Broadbent, 1986) examines memory for autobiographical events with positive, negative and neutral words given as cues. It looks at whether emotionally valent cue words affect the ease of recall of a specific memory, by measuring latency time and specificity of the memory. It has been widely used in studies of different clinical populations but has again not been used to date in people with frontal lesions. Inclusion of this explicit memory task allows another

aspect of emotional memory to be sampled, by looking at the participant's own personal memories. This is in contrast to the other tests, which measure learning of novel information, presented in the experimental setting.

Emotional picture test

This test developed by Brignell (2001) measures both recognition memory and source memory for positive, negative and neutral pictures. Participants initially view the pictures, half of which are shown in the colour purple and half in green. During the subsequent memory test participants are shown black and white pictures and asked to identify those pictures previously viewed and their associated colour (source memory). This test therefore provides a way of looking at the influence of emotionally arousing and emotionally valent picture content on an explicit memory test, and the influence of emotion on memory for source information.

3.5 Research questions

Given limited research in this area to date it is difficult to justify specific hypotheses about how the performance of people with frontal lobe lesions may contrast with that of healthy controls, on emotional memory tasks. Rather the current study aimed to address three main research questions:

- Do people with frontal lobe lesions show a similar degree of enhanced memory for emotional (as compared to non-emotional) material, as seen in healthy controls?

- Does performance on emotional memory tasks in this population depend upon how emotional memory is measured, i.e. is there a difference between performance on implicit and explicit tasks?

- Given findings which suggest altered emotional responsiveness in people with frontal lesions, is there a difference in their performance on tasks in which stimuli are intended to elicit an emotional arousal response, and on tasks in which stimuli have emotional valence, but do not specifically elicit an arousal response?

CHAPTER 2 - METHOD

1. Design

This study uses a case control design to compare emotional memory in people with frontal lobe lesions to control participants.

2. Participants

Two groups of participants are included in the study, a group of people with frontal lobe injuries, and a group of control participants. Both groups are matched for age, gender, education and intellectual functioning.

Frontal lobe group

Participants with right, left and bilateral frontal lesions were recruited through the department of neuropsychiatry at St.Thomas' Hospital. All participants were confirmed to have focal frontal lesions using scanning procedures.

Control group

Control participants were recruited by opportunity sampling, through their involvement in previous research projects and via an advertisement in a local paper. The control participants were offered a payment for taking part in the study.

Rationale for participant numbers

Emotional memory has not previously been studied in this population and hence it was not possible to carry out a formal power analysis. This study was however modelled on a previous study looking at emotional memory in people with Korsakoff's syndrome (Shah, 1999), in which the performance of 6 people with Korsakoff's syndrome, on a range of emotional memory tasks, were compared to that if 12 healthy controls. In this study significant findings were found on the measures utilised. Research of this nature tends to employ small samples due to the difficulty of recruiting a suitable and well-matched sample, but such research has still been found to make a significant contribution to the field.

3. Procedure

Obtaining informed consent

Ensuring informed consent is always an issue in research and is particularly pertinent in working with people with frontal lobe lesions. To try to ensure that consent was as informed as possible the following procedures were followed. All participants were first contacted by telephone, for a preliminary discussion about the research project and what might be involved in taking part. All but one of the participants contacted by telephone expressed an interest in being part of the study, and a meeting was arranged to consider this further. Written information (as outlined on the consent form – see Appendix 1) was then sent to each participant, prior to the first meeting, along with contact details of the researcher to whom any questions or concerns could be addressed.

At the first meeting all participants were asked to read the information sheet (if they had not already done so), before choosing whether or not to take part. Involvement in the study was discussed with each participant by the investigator, to clarify (as far as is possible) his or her understanding of the written information given. Participants were given the opportunity to ask questions and reminded that they could choose to finish their involvement with the project at any time. The researcher reiterated that involvement in the study would require attendance at two appointments, and the timing of both appointments was confirmed before proceeding. If the participant continued to express interest they were then asked to sign a consent form (see Appendix 1). Ethical approval for this study was given by St. Thomas Hospital Research Ethics Committee (see Appendix 2).

Tests were administered individually to participants over two sessions. The duration of each session was approximately two hours, with a planned five-minute break after one hour. For each participant, sessions took place two days apart and both sessions were held in the same setting.

A brief interview was carried out in the first instance to collect demographic information. It was hoped that this preliminary interview would facilitate the development of rapport and reduce the participant's anxiety. It is however acknowledged that for some participants this might not be the case and that discussion of schooling and academic attainment is not a neutral subject.

The tests were administered in the following order. Order of administration was kept constant for all participants, and follows the same order of administration as Shah's study. Those tests that were included in addition to Shah's battery were administered at the end of the second session, such that order effects would remain constant and comparisons to the previous study might be made.

Session 1

1. First presentation of 18 Good guy/Bad guy faces and rating at time 1 by participants.
2. Second presentation of Good guy/Bad guy faces, accompanied by information for selected faces. Rating at time 2 by participants.
3. Presentation of slides from Cahill test and accompanying pre-recorded narrative. Participants rate emotionality of the story and are asked whether they found any of the pictures shown distressing.
4. Presentation of words and non-words from emotional priming test.
5. Autobiographical Memory Test.
6. Word-stem completion of emotional priming test.
7. NART
8. Participants complete HADS questionnaire

Participants were thanked for their time and reminded of the time for the next appointment. An opportunity for asking questions and making comments was given.

Session 2

1. Recognition test from the Good guy/Bad guy test; 50 faces are presented which includes 18 'target' faces.
2. Rating at time 3 of faces by participants.
3. Recall test, including free recall, cued recall and forced choice recall sub-tests.
4. Multiple choice recall test of slides and narrative from Cahill Test.
5. FAS test of verbal fluency.
6. Story recall test (immediate) from AMIPB.
7. Visual Reproduction test (immediate recall) from WMS-R.
8. Ravens Standard Progressive Matrices (sets A,B,C,D and E)
9. Trail making test.
10. Design fluency test.
11. Presentation of pictures from the emotional pictures test
12. Subjective emotion questionnaire.
13. Recognition and source memory test for the emotional pictures test

Participants were then thanked for their participation in the study and given an opportunity to make comments or ask questions. Travel expenses were reimbursed if necessary and control participants were given payment for their time.

4. Emotional memory measures

4.1 Good Guy/Bad Guy Test

This test is an adapted version of the experiment described by Johnson et al (1985) and assesses memory for emotional material in several different ways. Participants are shown a series of faces that are accompanied by either a 'good', 'bad' or no descriptor. Recognition of faces with emotional descriptors is then compared with recognition of those without a descriptor. The test also examines free and cued recall for descriptive information. Rating of the faces on the specified characteristics, and giving preference ratings, provides a measure of the impact of emotional valence on implicit memory.

Participants are told that they are going to be asked to look at some pictures of faces. They are shown the rating sheets (Appendix 3) and asked to rate each of the faces according to the three specified characteristics: honesty, kindness and likeability. An opportunity to ask questions about the rating sheet or procedure is then given. The form consists of a five point rating scale for each of the characteristics, as in the Johnson et al study. In this study, as in Shah (1999), only three characteristics are included whilst Johnson et al (1985) used twenty. This modification is undertaken to reduce administration time and hence allow more faces to be included. The three characteristics chosen were selected since they were considered to be more general as compared to some of those included in the original study, and were thought to encompass some of the more specific characteristics used by Johnson et al (1985).

Participants are shown eighteen faces, one at a time, for a period of 5 seconds and asked to make a judgement for each characteristic, for each face as described above (rating at time 1). Participants are then immediately shown the eighteen faces again. For control participants each face was presented for a period of 5 seconds, whilst frontal participants viewed each face for 30 seconds. Different exposure times were utilised firstly, to ensure that control participants did not perform at ceiling level, which would make the effects of emotion on memory difficult to discriminate, and secondly, to minimise the likelihood of more general memory, or attentional, impairments confounding results in the frontal group. In other words, to maximise the possibility that the two groups might be broadly matched in terms of recognition memory for the faces, and hence the effect of different types of information on retention can be better discriminated. The exposure times chosen were based on the findings of Shah (1999) and the procedure was piloted initially with control participants, to ensure that this manipulation had the desired effect upon retention (as compared to Shah's control group).

During this second presentation biographical information is given for six out of the eighteen faces. Participants are told that they will be played some information on a tape about some of the faces shown. For three of those faces information is given which describes the person in the picture as a 'good' person (good guys) and the other three are described as bad or unpleasant (bad guys) (see Appendix 4 for the biographical information given). Participants are asked to rate the characters immediately after hearing the information, following the same rating procedure (rating at time 2). For a further three faces participants are asked to rate the faces without hearing any

biographical information ('neutral characters'), and are asked to attend to the other nine faces for the specified time without rating. All faces are presented for the same total amount of time. Faces are presented to each participant in the same random pre-determined order to control for primacy and recency effects. This pre-determined order follows that used in Shah's study (1999).

Two days following the first and second presentations the participant is asked to undertake the following tasks.

Recognition memory

Participants are shown fifty faces, eighteen of which are those shown in the first session whilst the remaining 32 faces have not been seen before. Faces are again presented in a random pre-determined order. Participants are asked to identify those faces they have seen before.

Rating at time 3

Participants are then shown the nine faces that were rated at time 2; the 3 'good guys', the 3 'bad guys' and the 3 neutral characters about whom no information had been given. Participants are then asked to rate the faces in the same way as previously, in order to determine if ratings remained consistent with ratings at time 2 and with the biographical information, i.e. higher rating for good guys, lower for bad guys.

Recall test

Finally the 9 faces are presented in a random pre-determined order and for each face participants are asked what they can remember about the character (free recall test). For those faces which had previously been accompanied by biographical information, three cued recall and three forced recall (Yes/No) questions are also asked (see Appendix 4 for transcript of questions).

4.2 Cahill test

This is a test designed to compare memory for an emotionally arousing story with memory for a neutral story. Participants view a set of pictures, and two different stories are created by varying the narration that accompanies the pictures. 'Normal' subjects show enhanced memory for the emotionally arousing story (Cahill & McGaugh, 1996), and this effect has been shown in a wide range of studies (e.g. Cahill et al, 1994; 1995; 2001; Shah, 1999). Within the present study, only the emotionally arousing narrative was utilised, as described by Shah (1999). Previous studies have shown clear differences between the emotional and neutral versions and it would not be possible with the small patient sample included in this study to make within-sample comparisons of the two versions. The emotionally arousing story consists of three phases. The first phase is neutral (about a mother and son leaving home to visit the father's workplace), the second phase is emotionally arousing (the boy is hit by a car and critically injured) and the third phase is neutral (the mother goes to pick up her other child). It is therefore possible to make within-subject comparisons between memory for the emotional and neutral phases of the story.

In the first session participants are shown a set of 11 pictures which are accompanied by a narrative (see Appendix 5). Each picture is presented to control participants for a period of 3 seconds and to frontal participants for 20 seconds. As in the Good guy / Bad guy test different exposure times were selected for the two groups, based upon Shah's results, to maximise the possibility that both groups would perform at a similar level and therefore variation in retention of different types of information can be better discriminated. These modified exposure times were piloted with control participants to ensure that the desired effects upon retention were shown. After hearing the story participants are asked to rate how 'emotional' they felt the story was, on a scale of 0-10, where 0 is 'not at all emotional' and 10 is 'extremely emotional'. Participants were further asked if they had found any of the pictures shown to be distressing on a scale of 1-4, where 1 is 'not at all distressing' and 4 is 'extremely distressing'.

In the second session, 48 hours after viewing the pictures, participants are asked some multiple-choice questions about the story. For each question four possible answers are given (see Appendix 6) and the participant is asked to indicate the correct answer. A number of questions (between 5 and 9) are asked about the narrative and visual aspects of each slide in the story. The following standard instructions are given to all participants.

"You should answer each question even if you are forced to guess. You will have to guess on many of them because we have designed the questions to be difficult. There

will be 5-9 questions per slide and I will tell you at what point the questions refer to the next slide. Sometimes a question will tell you that you were right or wrong on the previous question, if you were right, great, if you were wrong just keep going on."

Participants are then asked the questions and their answers recorded. The percentage of correct answers to each slide is calculated.

4.3 Autobiographical memory test

This is a widely used test of explicit memory for events (Williams & Scott, 1988), in which participants are given positive, negative and neutral cue words, and asked to retrieve a specific personal memory. The methodology employed by Williams and Scott (1988) has been employed in several subsequent studies (e.g. Williams & Dritschel, 1988; Whitely, 1998; Shah, 1999) to look at autobiographical memory. Latency time and specificity of memory are recorded to examine whether emotional cue words aid recall of specific memories.

Participants are given 18 cue words in three categories, 6 positive words (e.g. happy), 6 negative words (e.g. guilty) and 6 neutral words (e.g. bread) (see Appendix 7 for full list of cue words). Participants are given the following standard instructions:

"I am interested in your memory for events that have happened in your life. I am going to read you some words. For each word I want you to think of an event that happened to

you which that word reminds you of. The event could have been an important or a trivial event."

"The event you recall should be a specific event. So if I said the word 'good' it would not be okay to say 'I always enjoy a good party' because that doesn't mention a specific event. It would be okay to say 'I had a good time at Jane's party on Friday'."

4.4 Emotional priming test

This is a word-stem, priming task that provides a way of looking at implicit memory for emotional stimuli. Participants are shown 55 words, 32 of which are real words and 23 of which are non-words. The set of 32 real words consists of 16 pairs of words (see Appendix 8 for word list). Each pair starts with the same 3-letter word-stem and contains the same number of letters. In each pair one of the words is a 'neutral' word and one an 'emotional' word. The 55 words are presented in a pre-determined random order.

During presentation of the words participants are asked to give an indication of how certain they are that the presented word in an English word. The options 'definitely an English word', 'probably an English word', 'unsure', 'probably not an English word' or 'definitely not an English word' are listed on a card and participants are asked to point to an option for each word. This task is intended to ensure that the participant attends to each word that is presented.

Twenty minutes later participants are presented with 24 word stems (see Appendix 9) and asked to think of a word to complete them. This includes the 3-letter stems of the 16 neutral/emotional word pairs presented previously, in addition to 8 new word stems. The word stems are presented in pre-determined random order. Participants are informed that the number of dots after each word-stem indicates how many letters should complete the word. Participants are not made aware that this task is related to the previous task of identifying the 'Englishness' of the presented words. The 8 new word stems are included to reduce the likelihood that the participant recognises the connection between the two tasks.

Responses are coded as either 'E', if the participant completes the word stem with the emotional word, 'N' if the neutral word is used and 'O' if completed with another word.

4.5 Emotional pictures task

This task, developed by Brignell (2001), assesses two different aspects of the effect of emotion on memory. Firstly, it assesses recognition memory for emotional and neutral pictures, and secondly, it provides a measure of source memory for the colour in which pictures are presented. Hence it provides a way of looking at the effect of emotionality upon participants' ability to both discriminate old from new pictures, and to link contextual details (i.e. picture colour) to item memory. The test has been used to date in healthy controls and to explore the effects of a range of different pharmacological manipulations (Brignell, 2001).

A total of 67 pictures are shown in the study session, of which 2 at beginning and 1 at the end do not appear in the test session, and are intended to control for primacy and recency effects. Of the remaining 64 pictures, half are emotionally valenced (16 positively valenced and 16 negatively valenced) and half are neutral images. The pictures used in the test were selected by Brignell from the International Affective Picture Scale (IAPS – Lang, Ohman & Dolan, 1988) on the basis of their valence ratings. Neutral pictures have mean valence ratings in the range 4.25-5.75 (on a scale of 0-9), negative pictures have valence ratings less than 2.5 and positive pictures have valence ratings greater than 7.5.

During the test session the monochromatic images are presented coloured in either green or purple (see Appendix 10 for examples), with half of each category of picture presented in green, and half in purple. The pictures are presented on a Microsoft PowerPoint package and are shown for 3 seconds, followed by a white screen for 1 second. In this task, in contrast to the Cahill and Good Guy/Bad Guy test, exposure times were kept constant across both groups. Memory on this task is assessed solely by a recognition test, as opposed to the additional recall components of both the Cahill and Good Guy tests. Since this is arguably a less cognitively demanding aspect of memory performance it was felt to be justifiable, in this instance, to test the frontal group under the same conditions as the controls. The pictures are presented in pseudo-random order, with a maximum of 3 neutral or 2 emotional pictures in succession, and a maximum of 2 pictures of either colour shown in succession. Participants are instructed to look at each

picture as it appears on the screen, to think about what is going on in each picture and to try to remember the colour that each picture is shown in.

During the recognition test, which takes place after an interval of 10 minutes, participants view 128 pictures shown in black and white. The pictures include the 64 pictures shown in the test session (i.e. excluding the primacy/recency buffer images), and 64 unseen pictures, each one matched on the basis of physical appearance and emotionality to a picture in the test set. Participants are asked to indicate whether the picture shown was previously seen in purple or green, or if it is a new picture.

5. Other assessments

5.1 National Adult Reading Test (NART)

The NART-R (Nelson, 1982) gives an estimate of pre-morbid intellectual functioning. The test consists of 50 non-phonetic words that the participant is asked to read aloud from a printed card. It is widely used to estimate pre-morbid IQ and has been extensively standardised. Studies show a high degree of inter-rater reliability ($r>0.9$; e.g. O'Carroll, 1987), good test-retest reliability ($r>0.88$; Spreen & Strauss, 1998) and moderate to high correlations are shown between NART scores and other measures of general intellectual ability (between 0.4 and 0.8; cited in Spreen & Strauss, 1998).

5.2 Hospital Anxiety and Depression Scale (HADS)

The HADS (Snaith & Zigmond, 1983) is a self-report measure designed to assess levels of anxiety and depression. It consists of 14 items, half of which relate to symptoms of

anxiety and the other half to symptoms of depression. The scale produces scores between 0 and 21 for both anxiety and depression. Studies of the psychometric properties of the measure report good internal consistency (0.93 for anxiety and 0.90 for depression), good concurrent validity when compared to other psychiatric ratings of these symptoms (anxiety, r=0.54; depression, r=0.79) and report good test-retest reliability for both total and subscale scores (Roberts et al., 2001). A score of above 9 indicates a higher level of anxiety and depression than would be expected in the normal population and is therefore considered to be outside the 'normal range'.

5.3 Story Recall (immediate) - Adult Memory and Information Processing Battery

The Story Recall sub-test from the Adult Memory and Information Processing Battery (AMIPB) (Coughlan & Hollows, 1985), assesses current verbal episodic memory function. Participants are required to listen to a short passage of prose. Immediately after listening to the passage participants are asked to recall as much as they can about the story. Two points are scored for every idea correctly recalled and one point for ideas partially recalled. Scores can therefore range from a minimum of 0 to a maximum of 56 and the percentile range in the general population can be calculated from the scores obtained. This sub-test has been widely standardised, and studies describe high interscorer agreement (r>0.95) and test-retest reliability of 0.47 (Spreen & Strauss, 1998).

5.4 Visual Reproduction (immediate) - Weschler Memory Scale (WMS-R)

The Visual Reproduction task is a sub-test of the WMS-R (Weschler, 1983). It is a test of short-term visual memory. Participants are required to look at 4 geometric designs one at a time for 10 seconds each. Immediately after the presentation of each design the participant is asked to draw what they can remember of the design. The drawings are then scored for accuracy following detailed criteria, and a maximum score of 41 may be obtained. This test has been widely standardised and the percentile range can be calculated from the scores. Studies suggest this subtest has high interscorer reliability ($r>0.97$) and a reliability coefficient overall of 0.87 (Spreen & Strauss, 1998).

5.5 FAS Verbal Fluency Test

The FAS test (Benton & Hamsher, 1989) is a test of verbal fluency. It provides a measure of participant's ability to plan and generate appropriate performance strategies. In this test participants are required to think of as many words as they can, beginning with the letters F, A, and S respectively. One minute is given for each letter and the researcher records the participant's responses. Prior to commencing the test, participants are told that proper nouns, repetitions and words that are the same but have different endings (e.g. eat and eating), will not be counted. Reliability studies suggest near perfect interscorer reliability (>0.95) and test-retest reliability ranging from 0.70-0.88. Concurrent validity has been established in several studies and the test shows high sensitivity to frontal lobe damage (Ruff et al, 1994 cited in Spreen & Strauss, 1998).

5.6 Raven's Standard Progressive Matrices

Raven's Standard Progressive Matrices (Raven, Court & Raven, 1985) provides a measure of non-verbal reasoning ability. It consists of 60 pictorial puzzles divided into 5 sets (A, B, C, D and E). Each puzzle has a piece missing and the participant is asked to select, from the options provided, the piece that fits the gap in the puzzle. All participants are asked to attempt all items on the test. The test is widely standardised and scores give an index of intellectual functioning. Good test-retest reliability is reported ($r>0.8$) and concurrent validity studies show a modest correlation (approx. 0.7) with convential tests of intelligence (Spreen & Strauss, 1998).

5.7 Trail Making Test

The Trail-making test (Reitan, 1958) is a test of executive functioning and planning. The test consists of two parts, A and B. In part A participant are instructed to join a series of 25 numbered circles in sequential order, and the time taken is recorded. In part B participants are instructed to join up numbers and letters in order, going from 1 to A, A to 2, 2 to B, B to 3 and so on. Again the time taken is recorded. In both parts A and B practice items are administered to clarify understanding of the instructions. The test is well-standardised and gives an indication of the participant's ability to shift between different concepts and modify performance in response to instruction. Interrater reliability is reported to be 0.94 for Part A and 0.90 for Part B and test-retest reliabilility is cited to be between 0.64 and 0.94 (Spreen & Strauss, 1998).

5.8 Design Fluency Test

The Design Fluency test (Jones-Gotman & Milner, 1977) is a non-verbal analogue to verbal fluency tasks. It has been shown to be sensitive to right frontal lobe damage. The test consists of two conditions: a free response condition and a fixed response condition. In the free response condition participants are instructed to generate as many different designs as possible in a 5-minute period. In the fixed condition the participant is required to generate as many different designs that all contain exactly 4 specific components. In both conditions participants are instructed that designs will be recorded as errors if they repeat a previous design, or if a design that they produce is recognisable as a nameable object. Participants are asked to avoid 'scribbling'. Examples of both acceptable designs and errors are shown to the participant.

The Design Fluency Test has been criticised for lacking clearly defined scoring criteria and psychometric data and studies have suggested that the reliability of the scoring criteria can be increased, by increasing the structure of the task itself i.e. by including only the 'fixed condition' (Ruff, Light & Evans, 1987). However it has been shown that the unstructured component of the test, the 'free condition', is generally more sensitive than the fixed (Lezak, 1995). A recent study therefore suggests that increasing standardisation in the scoring criteria, rather than the task itself, allows the best compromise of reliability and sensitivity of the task (Harter & Hart, 1999). The expanded scoring criteria are hence utilised in this study and both the 'free' and 'fixed' conditions included. These expanded criteria increase both inter-rater, and test-retest

reliability (interrater reliability ranging from r=0.81 to r=1.00, for the different aspects of the test; test-retest reliability from r=0.69 to r=0.91) (Harter et al, 1999).

5.9 Modified Card Sorting Test (Nelson, 1976)

This test is a modified version of the Wisconsin Card Sorting Test (WCST), which is a widely used measure of frontal functioning, devised to give an indication of abstract reasoning abilities and the capacity to shift flexibly between different concepts. In this version of the test the participant is given 48 cards on which are printed between one and four symbols (either triangles, stars, crosses or circles), in one of four colours (red, green, yellow or blue). Four stimulus cards are then placed in front of the participant, on which are printed the following symbols - one red triangle, two green stars, three yellow crosses and four blue circles. The task for the participant is to place each of the cards in the pack, one by one, under the four stimulus cards, according to a principle that the participant must deduce from the pattern of the examiner's responses to the participant's placement of the cards. Whichever category the participant chooses first is designated "correct" by the examiner who then proceeds to tell the participant whether or not each choice is correct, until the participant has achieved a run of six correct responses. At this point the participant is told that the rule has changed and to "find another rule". This procedure is continued until six categories are achieved or the pack of 48 cards is used up.

The number of categories obtained is recorded. Scores are also calculated for the total number of errors made, and for the number of perseverative errors (i.e. where the

participant persists in sorting cards according to the preceding rule as opposed to the current one despite feedback that this is incorrect). This version of the test utilises a simplified set of cards, which serves to reduce ambiguity in the test, thereby simplifying the task for the participant, reducing administration time and clarifying the nature of errors for the examiner. The test is well-standardised and has good test-retest reliability (Purdon & Waldie, 2001).

5.10 Subjective Emotion Measure

This questionnaire (see Appendix 11) is a measure of change in the participant's subjective experience of emotions since their illness or injury (frontal group), or over the past year (controls). The questionnaire is based upon that used by Hornak et al (1996) and Rolls et al (1994). Participants are asked whether they have experienced, since their illness or injury/over the past year, any general change in their ability to experience emotion. They are then asked about any change in the intensity or frequency of the following emotions: sadness, anger, fear, disgust, excitement and happiness, and if they have been aware of any difficulty in their expression of these emotions. The final section of the questionnaire asks participants if there has been any change in the likelihood of other people misinterpreting their moods and feelings, and if they had difficulty misinterpreting the moods and feelings of others. Studies show a strong correlation ($r = 0.76$) between the degree of subjective altered emotional experience and the degree of behavioural change observed following illness or injury (Hornak et al, 1996; Rolls et al, 1994).

5.11 Demographic information

An interview was used to collect demographic information. Participants were asked about their schooling and qualifications, and to provide a brief career history.

CHAPTER 3 - RESULTS

Overview

In this chapter, the scores of the experimental and control groups on a range of background measures will first be explored. Performance on each of the measures of emotional memory will then be analysed in turn.

Statistical analyses

Normality checks were carried out before proceeding with the analysis. For those variables which showed significant deviations from normality, and which did not respond to transformations, non-parametric tests were employed. The main statistical tests utilised were therefore t-tests, analysis of variance and the non-parametric Mann Whitney U test. Two tailed tests were utilised except where there were strong *a priori* hypotheses about the direction of an effect, for example when comparing the performance of the frontal group and controls on standardised measures of frontal functioning. In these instances one-tailed tests were used.

1. Participants

18 participants took part in the study, 6 (33%) with lesions of the frontal lobe and 12 (67%) healthy controls. 5 of the 6 frontal participants were outpatients at the Neuropsychiatry department of a large teaching hospital and 1 of the frontal group was seen whilst an inpatient in a neuropsychiatric unit. All of those seen as outpatients lived independently, 3 with partners and 2 alone. Healthy controls were recruited by

opportunity sampling, through their involvement in previous research projects and via an advertisement in a local paper.

All the patients included in the frontal group showed behavioural changes consistent with frontal lobe damage, as evidenced by clinical reports. The site of damage to the brain was confirmed by Magnetic Resonance Imaging (MRI) or by Computerised Tomography (CT) scans, where a MRI scan was not possible. All participants (in the frontal group) were confirmed, by examination of scan images and formal scan reports, to show damage to frontal areas of the brain. Detail of the predominant location of damage, of each of the frontal participants, is summarised in Table 1. Impairment in frontal lobe functioning was further indicated in neuropsychological assessment reports. It is noted that (as shown in Table 1) there is considerable variation within the group in the time since the frontal injury took place. Whilst this clearly could be a relevant variable it was not explored statistically due to the small subject numbers, and wide range of time periods, which would have made such an analysis meaningless. To clarify the inclusion of each of the patients in a frontal group, clinical observations and the findings of physical investigations will be summarised below.

Table 1 – Summary of clinical details of each participant in the frontal group

Case	Sex	Age	Pathology	Scan	Lesion site	Time since injury
A	Male	59	Tumour	MRI	Right	15 years
B	Male	60	Cortical atrophy	CT	Right	1.5 years
C	Male	59	Head trauma	CT	Bilateral	1 year
D	Male	49	Abscess	MRI	Right	1.5 years
E	Female	67	Frontal infarct	MRI	Left	6 years
F	Male	34	Meningioma	CT & MRI	Bilateral	3 years

1.1 Clinical observations and physical investigations

A brief clinical account will be given of each of the frontal participants (A-F). Further information about each of the participants is given in Appendix 12.

Participant A

This participant underwent a transfrontal operation to remove a pituitary tumour. Subsequent to this, a MRI scan showed a large lesion in the right frontal pole, with a greater degree of medial rather than lateral involvement. Clinical reports describe increased irritability, labile mood and outbursts of anger.

Participant B

B has a diagnosis of frontal dementia (a variant of fronto-temporal dementia). Clinical reports describe disinhibition, irritability, apathy and blunted emotional expression. It is reported that B began to express bizarre ideas and showed inappropriate laughter. His clinical presentation is best explained in terms of damage to frontal areas of the brain

and a CT scan confirmed this showing "pronounced cortical atrophy, particularly marked in the frontal region". Recent cognitive testing indicates that performance on executive tests is disproportionally impaired relative to memory and other cognitive tests.

Participant C

This participant was admitted to hospital following a fall, with evidence of head trauma. Reports suggested strong evidence of frontal lobe involvement and a CT scan showed large bilateral subdural hematomas (areas of localised swelling) with intra-cranial bleeding within the tissue of the right frontal lobe. Post-injury C was described as inert, having trouble initiating and showing poor insight into extent of his difficulties. A subsequent MRI scan showed bilateral frontal atrophy secondary to earlier lesions and assessment one year post-surgery revealed strong evidence of impairment on frontal/executive tests.

Participant D

This participant developed a right-sided fronto-parietal abscess following a tooth infection. D is described as showing significant personality and emotional change post-injury. Reports suggest labile mood, impulsivity, frequent aggressive and violent episodes and an "arrogant manner". He had also begun to show obsessional features, collecting magazines and tokens. Scores on the Behavioural Assessment of Dysexecutive Syndrome (BADS) indicate particular difficulties in plannning, adherence to rules and higher order executive skills. MRI scanning showed localised widening of

the frontal horn and an EEG indicated frontal changes, largely on the right hand side. Scan reports suggest the left frontal lobe to be intact.

Participant E

E showed significant behavioural change as a result of a frontal infarct (i.e. area of dead tissue resulting from the obstruction of blood supply to the region). Initial reports describe E as disinhibited, very talkative and somewhat emotionally inappropriate. Over time she reportedly became more apathetic and emotionally unresponsive. The MRI scan showed a large infarct in the left frontal cortex.

Participant F

This participant underwent neurosurgery to remove a frontal meningioma (i.e. an encapsulated brain tumour growing from the protective tissue encasing the brain). F was reported to be emotionally labile with increasing irritability and periods of low mood. Clinically he was observed to show flattened affect with little variation in facial expression. It is also reported that he lost his sense of smell. Neuropsychological assessment identified difficulty with sequencing and planning tasks, and impairments in a cognitive estimation test. A CT scan post-surgery indicated a large frontal lesion and a more recent MRI scan supported this finding, and showed bilateral frontal damage.

1.2 Demographic details

The age range was 34-67 years (mean 54.83, ±11.72) in the frontal group and 34-73 years (mean 54.67, ±12.70) in the controls. There was no significant age difference

between the two groups (t(16)=-0.027, p=0.98 n.s.). 5 of the frontal participants were male and 1 female. In the control group, 7 participants were male and 5 female.

7 of the control group were in current employment, 1 was unemployed and seeking work and the remaining 4 had retired from work. None of the frontal participants were working at the time of the study, although all had been in employment in the past.

1.3 Premorbid intellectual functioning

The average age for leaving school for the frontal group was 17.5 (s.d. 1.22, range 15-18) and for the control group was 16.33 (s.d. 1.23, range 14-18). There was no significant difference in the age that participants left school (t(16)=1.899, p=0.076 n.s.).

In the frontal group 2 participants reported leaving school with no qualifications, however 1 of the 2 returned to education at a later date and attained 3 O'levels. 4 participants in the frontal group had 2 or more A'levels and 2 of these 4 went on to complete a degree. In all, 5 out of the 6 frontal participants underwent further professional training (e.g. nursing, accounting, police training).

6 of the participants in the control group reported leaving school with no qualifications, but half of these reported returning to education to attain further professional qualifications (e.g. banking certificate). 4 of the controls acquired 2 or more O'levels and 4 completed 2 or more A'levels. 2 of these 4 went on to complete degree level education, and 1 a further degree. In the control group 8 out of 12 participants underwent

professional training of some sort (e.g. nursing, banking, teaching). The groups appeared to be well-matched in terms of educational background and there was no significant difference in the total number of years in education, between the two groups ($t(16)=0.892$, $p=0.39$ n.s.).

Pre morbid IQ was estimated from scores obtained on the NART. In the frontal group the average estimated pre-morbid IQ was 113.17 (s.d. 10.23, range 100-121) and in the control group the average estimate was 117.92 (s.d. 6.44, range 108-126). A non-parametric Mann-Whitney U test was carried out (due to some deviation from normality on this variable) and there was found to be no significant difference in estimated IQ scores between the two groups ($Z=-1.18$, $p=0.24$ n.s.).

1.4 Current cognitive functioning

Current intellectual functioning: The average score for the standard progressive matrices in the control group was 44.58 (s.d. 9.71, range 28-57). This average score falls at the 25th percentile. In the frontal group 2 of the participants were unwilling to complete all sections of the Ravens matrices task, completing only sections A, B and D. For the remaining 4 participants the mean score was 45.0 (s.d. 8.98, range 35-54). Again this average falls at the 25th percentile. There was no difference between the performance of these 4 frontal participants and the control group ($t(14)=0.08$, $p=0.94$ n.s.). For the purposes of including the remaining 2 frontal participants, scores on items B and D were compared. For the frontal group the average score for items B and D was 19.83 (s.d. 2.86, range 16-24); for the control group the average score was 19.25 (s.d.

4.05, range 11-23). There was no significant difference in scores between the groups ($t(16)=0.31$, $p=0.76$ n.s.).

Verbal memory: The story recall test from the Adult Memory and Information Processing battery was administered as a measure of immediate verbal recall. Out of a possible total score of 56, the mean score for the frontal group was 27.83 (s.d. 14.15, range 10-48). For the control group the average score was 34.83 (s.d. 9.22, range 18-45). The difference between these mean scores was not significant ($t(16) = -1.27$, $p=0.22$, n.s.).

Visual memory: On the Visual Reproduction subtest from the Wecshler Memory Scale (WMS-R), scores obtained were converted to percentile scores. The average percentile score for the frontal group was 75.0 (s.d. 32.59, range 25-96) and for the control group the average was 67.33 (s.d. 24.13, range 30-98). There was no significant difference between the performance of the frontal and control groups on this test ($t(16) = 0.57$, $p=0.58$, n.s.).

1.5 Tests of frontal functioning

On these standardised tests of frontal functioning it was predicted that the frontal group would obtain lower scores than the control group, and hence one-tailed tests were utilised to test the significance of an effect in the anticipated direction.

Verbal fluency: The average scores for the FAS test of verbal fluency for the frontal group was 37.17 (s.d. 10.63, range 25-56) and for the control group was 47.5 (s.d. 14.34, range 20-69). There is a 10-point difference between these scores, with the frontal group performing worse than controls as would be expected. This difference showed a trend towards significance ($t(16) = -1.56$, $p=0.07$).

Figural fluency: On the design fluency test scores were compared on both the free and fixed conditions. In the free condition participants may create designs containing any number of lines whilst in the fixed condition all drawings must consist of only 4 lines. In the free condition the frontal group obtained a mean novel output score of 8.17 (s.d. 3.49, range 4-12) and a mean percentage of perseverative responses of 35.6 (s.d. 30.31, range 0-88). The control group had a mean novel output of 17.2 (s.d. 5.33, range 10-27) and a mean percentage of perseverative responses of 10.63 (s.d. 14.18, range 0-43). The control group showed significantly greater novel output than the frontal group ($t(14)=-3.68$, $p=0.001$). The frontal group made significantly more perseverative responses than the controls ($t(14)=2.26$, $p=0.02$).

In the fixed condition, the frontal group had a mean novel output score of 6.17 (s.d. 3.13, range 2-11) and an average percentage of perseverative responses of 51.56 (s.d. 32.66, range 0-85). The control group had a mean novel output score of 18.9 (s.d. 5.01, range 11-28) and a mean percentage of perseverative responses of 25.25 (s.d.13.74, range 0-45). As in the free condition the controls had significantly higher novel output ($t(13)=-$

5.51, $p<0.001$). There was a trend towards a higher percentage of perseverative responses in the frontal group (unequal $t=1.87$, d.f.=6.2, $p=0.055$).

Trail-making test: Performance on the trail-making test was measured by the number of seconds taken to complete parts A (numbers only) and B (numbers and letters). On Part A, the average number of seconds for the frontal group was 81.33 (s.d. 32.16, range 46-129). Controls completed part A in an average time of 44.17 (s.d. 22.73, range 25-98). Controls were performing significantly better than the frontal group ($t(16)=2.85$, $p<0.01$).

On part B the average time taken for the frontal group was 159.17 (s.d. 67.40, range 100-267) whereas the average for the controls was 83.58 (s.d. 32.75, range 44-134). A non-parametric Mann-Whitney U test was carried out, due to some deviation from normality on this variable, and controls were performing significantly better than frontal participants ($Z=-2.53$, $p<0.01$).

The difference between completion time for parts A and B was also calculated. The mean difference for the frontal group was 77.83 (s.d. 57.12, range 11-181) and for the control group was 39.42 (s.d. 22.71, range 13-90). Controls were found to be performing significantly better than frontal participants ($t(16)=2.07$, $p=0.03$).

Modified Card Sorting Test (Nelson, 1976): The Modified Card Sorting Test was administered to frontal participants by a different researcher as a part of another research

project. Additionally, data was collected on this test for 5 of the controls and hence scores on this test (for the 6 frontal participants and 5 controls) are reported.

Three scores were calculated and compared across the two groups, namely the number of categories completed, the total number of errors and the number of perseverative errors.

Table 2 – Mean (s.d.) scores for modified card sorting test across the two groups

	Categories completed	Total no. of errors	No. of perseverative errors
Frontal	4.50 (1.64)	16.50 (11.66)	3.33 (3.83)
Control	6.00 (0)	1.00 (1.41)	0.20 (0.45)
Z	2.12*	2.49**	1.70 trend

* = $p<0.05$ ** = $p<0.01$

Due to the lack of variance within the control group on the 'categories completed' variable non-parametric tests (Mann Whitney U) were employed for these scores. For consistency and due to concerns about the normality of the distribution, non-parametric tests were used to look at the differences between the groups on the other scores in this test.

The control group completed significantly more categories during the test than the frontal group ($z=2.12$, $p=0.04$). There was found to be a significant difference between the two groups on the total number of errors, with controls making significantly fewer errors than the frontal group ($z=2.49$, $p<0.01$). The difference between the number of

perseverative errors in the two groups showed a trend towards significance (z=1.70, p=0.06).

1.6 Mood

Hospital Anxiety and Depression Scale (HADS): Individual subscale scores, for both anxiety and depression, were obtained from the HADS. On the anxiety subscale the average score for the frontal group was 9.00 (s.d. 6.07, range 2-18) and for the control group the average score was 7.08 (s.d. 4.17, range 0-15). There was no significant difference between groups on the anxiety scale ($t(16) = 0.792$, $p=0.44$ n.s.). A score of 9 or above is considered to be in the clinical range of anxiety symptoms. 3 of the 6 (50%) frontal participants and 4 of the 12 (33.33%) control participants scored above 9 on this subscale.

On the depression subscale the average score for frontal participants was 7.00 (s.d. 4.90, range 1-14) and for the control participants the average score was 3.92 (s.d. 4.21, range 0-15). There was no significant difference between the groups on the depression scale ($t(16) = 1.39$, $p=0.18$ n.s.). 2 of the 6 (33.33%) frontal participants and 2 of the 12 (16.67%) controls obtained scores above 9, and would therefore be considered to show depressive symptomatology in a clinical range.

Subjective emotional change questionnaire: Scores were calculated, according to the scoring criteria described by Hornak et al (1996), for general subjective emotional change, and for both subjective experience, and expression, of each of the specified

emotions. Frontal participants were asked to rate subjective emotional change since their frontal injury, and controls rated subjective emotional change over the past year. Both groups rated change on a four-point scale (no change to extreme change). Positive scores were given for changes in either direction (increase or decrease) in any of the five emotions. A slight change scored 0.5, a definite change scored 1.0 and an extreme change scored 1.5.

There was a trend for frontal participants to report a greater subjective change overall, in their ability to experience emotion ($t(16) = 1.86$, $p=0.08$). In particular frontal participants reported significantly greater change in the intensity and frequency of anger ($t(16) = 2.65$, $p=0.02$), but there were no significant differences between the groups for the other five specified emotions (i.e. sadness, fear, disgust, excitement, happiness). The frontal group also indicated significantly greater difficulty in expressing emotions overall ($t(16) = 2.14$, $p<0.05$). Finally frontal participants reported significantly more difficulty 'interpreting the moods and feelings of others' ($t(16) = 2.16$, $p<0.05$) and felt, significantly more than controls, that other people had difficulty interpreting their moods and feelings ($t(16) = 4.12$, $p<0.001$).

Scores for overall subjective emotional change across both groups were positively correlated with scores on the depression subscale of the HADS ($n=18$, $r=0.56$, $p=0.02$). For the control group alone, a positive correlation was similarly shown between these two variables ($n=12$, $r=0.61$, $p=0.04$). This was not the case for the frontal participants where there was not found to be a correlation between depression and subjective

emotional change (n=6, r=0.29, p=0.58). This suggests that in the control group those participants reporting depressive symptoms are also those describing subjective emotional changes over the past year. In the frontal group it does not seem that increased depressive symptoms fully explain reports of subjective emotional change.

2. The Good guy / Bad guy test

It was hypothesised that the frontal group would perform as well as control participants on tasks of recognition and recall overall. It was, however, suggested that superiority for emotional material, which was predicted in the control group, would be seen to a lesser degree in the frontal participants and that in the rating task they would show poorer retention of emotional material.

2.1 Ratings

In order to test the above hypotheses the ratings given by participants of each of the 'characters' were first analysed. During the study participants were asked to rate three characters accompanied by 'good' information ('good guys'), three accompanied by 'bad' information ('bad guys') and three 'neutral' characters about whom no information was given. For each character there was a maximum score of 12 (if rated at 4 for each characteristic) and a minimum score of 0 (if rated at 0 for each characteristic). For the purposes of analysis these ratings were added together at each time point to give an overall rating score for each character type at each of 3 time points (e.g. overall good rating at time 1, overall good rating at time 2, etc.).

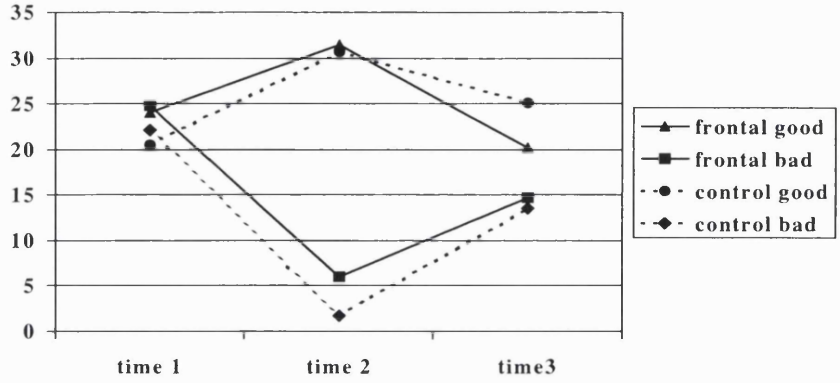
Table 3 shows the means of ratings for the good and bad characters at each time point. These scores are also shown in Figure 1. This graph shows that both groups seem to respond to information about the characters given at time 2, and their ratings change at this point in the expected direction, for both good and bad characters. As would be expected, there was no significant difference in ratings, between groups at time 1, for either the good ($t(16) = 1.84$, $p=0.08$) or the bad ($t(16) = 1.23$, $p=0.24$) characters, therefore analysing ratings at time 2 and 3 was considered valid.

Table 3 – Mean (s.d.) ratings for emotional characters at times 1, 2 and 3 for each group

Group	TIME 1		TIME 2		TIME 3	
	good	bad	Good	bad	Good	bad
Frontal	24.00 (5.40)	24.83 (3.97)	31.50 (4.93)	6.00 (6.84)	20.17 (5.04)	14.67 (7.42)
Control	20.50 (2.78)	22.08 (4.68)	30.75 (5.43)	1.75 (2.22)	25.17 (6.95)	13.58 (7.80)
T	1.84 n.s.	1.23 n.s.	0.28 n.s.	1.48 n.s.	-1.56 n.s.	0.28 n.s.

For time 2 df =5.53 since variances were unequal across the groups. df = 16 for times 1 and 3.

Figure 1: Mean ratings of 'good' and 'bad' characters for each group at each time point



Results were compared by calculating the difference between ratings for good and bad characters (good minus bad) at each time point. This gives a measure of how well participants were distinguishing between good and bad characters. Investigation of individual difference scores within the frontal group found there was substantial variation amongst the scores, with one frontal participant (A) showing a difference score of 27 points at time 3 and the remaining 5 participants showing difference scores ranging between –3 and 5. Excluding participant A from the analyses showed a significant difference, across the two groups, between the mean difference scores (i.e. difference between good and bad ratings) at time 3 ($t = -1.94$, $p=0.04$, one-tailed). A 2 X 3 (group X time) Analysis of Variance (again excluding participant A) found a significant main effect of time ($F(2,30) = 42.56$, $p<0.01$) and a trend towards a significant main effect of group ($F(1,15)=4.43$, $p=0.052$).

Effects of character valence

The effects of good and bad character information were explored separately across the groups. Firstly, to look at 'good' characters, a 2 X 3 repeated measures ANOVA was carried out, with 'time' (good ratings at time 1, 2 and 3) entered as the within subjects factor and 'group' as the between subjects factor. There was a significant main effect of time ($F_{(2,32)} = 23.10$, $p<0.01$) and a significant interaction between group and time ($F_{(2,32)} = 4.33$, $p=0.02$). The same analysis was carried out for the bad characters and revealed a significant main effect of time ($F_{(2,32)} = 48.63$, $p<0.01$) but the time by group interaction was not significant.

Neutral ratings

The mean ratings for the neutral characters at each time point are reported in Table 4. There were no significant differences between the two groups, in their ratings of neutral characters, at any of the 3 time points (Time 1, $t(16)=-1.05$, $p=0.31$; Time 2, $t(16)=0.46$, $p=0.65$; Time 3, $t(16)=0.43$, $p=0.68$).

Table 4 – Mean (s.d.) ratings for neutral characters at times 1, 2 and 3

Group	TIME 1		TIME 2		TIME 3	
Frontal	16.50	(3.94)	18.50	(3.56)	17.67	(5.39)
Control	19.00	(5.08)	17.50	(4.70)	16.58	(4.93)
T	-1.05 n.s.		0.46 n.s.		0.43 n.s.	

df = 16 in all cases.

2.2 Recognition test

In the second session participants were given a recognition test consisting of the 18 target faces, which they had been shown in session 1, and 32 distractors that had not

previously been seen. The 18 target faces included the good, bad and neutral characters. Participants could score a maximum of 18 true positives (i.e. recognising they had seen the picture before) and 32 true negatives (i.e. recognising that they had not seen the picture before). Incorrect answers therefore consisted of 'false positives' and 'false negatives'. An overall score for recognition ('total correct') was calculated by subtracting incorrect answers from correct recognitions. The means and standard deviations of these recognition scores are shown in Table 5. An independent samples t test showed there was no significant group difference in overall recognition scores ($t(16) = -1.31$, $p = 0.21$ n.s.).

Table 5 – Mean (s.d.) recognition scores for frontal and control participants

Response type	**FRONTAL**		**CONTROL**	
True positive	17.33	(0.82)	17.17	(1.19)
True negative	25.00	(9.72)	29.00	(2.76)
False positive	0.67	(0.82)	1.00	(1.60)
False negative	7.00	(9.72)	2.83	(2.69)
Total correct:	34.67	(18.49)	42.33	(6.54)

N.B. Maximum total score = 50

A repeated measures 2 X 2 Analysis of Variance was carried out to see if there was any difference in the recognition of the 6 good and bad characters as compared to the 12 'neutral' faces, about whom no information had been given. 'Group' (frontal/control) was entered as the between subjects factor, and ' character' was entered as a within subjects factor with 2 levels, valent (good and bad combined) and non-valent (neutral). There was no significant main effect of valence ($F(1,16) = 0.25$, $p=0.62$) and no interaction between valence and group ($F(1,16) = 2.29$, $p=0.15$). Recognition does not

therefore seem to vary as a function of valence in either group and both groups are performing similarly in terms of recognition.

2.3 Recall tests

A recall test was given to participants in session 2, consisting of free and cued recall, and forced choice items. The information about each of the characters consisted of 22 'ideas'. In the free recall test a point was given for each 'idea' correctly recalled and half a point scored for giving the gist of an idea without recalling the specific details. The frontal group recalled a mean of 6.58 ideas (s.d.10.66, range 0-27.5) and the control group a mean of 7.17 ideas (s.d. 6.89, range 0-19.5). There was no significant difference in the number of ideas recalled between the two groups ($t(16) = -0.14$, $p=0.89$).

There were 3 cued recall questions per character and one point was scored for each correct answer. Since there were 6 characters the maximum score participants could attain overall was 18. The frontal group scored a mean of 5.83 overall (s.d. 2.79, range 2-10) and the control group a mean of 7.42 (s.d. 3.09, range 3-11). A t test showed no significant difference in cued recall between the two groups ($t(16) = -1.06$, $p=0.31$). There were 3 forced choice recall questions for each character and therefore a maximum potential score of 18. The frontal group attained a mean score of 11.83 (s.d. 2.40, range 9-16) and the control group had a mean of 14.00 (s.d. 1.91, range 10-17). This difference between the two groups showed a trend towards significance ($t(16) = -2.09$, $p=0.053$).

2.4 Valence of information

A 2 X 2 repeated measures Analysis of Variance was conducted to look at the interaction between the valence of character information and recall scores. Free, cued and forced choice recall scores were added together for both the good and the bad characters (i.e. to give overall recall scores for good and bad characters). 'Group' was entered as a between subjects factor and 'valence of information' as a within subjects factor with 2 levels (good and bad). There was no interaction between group and valence ($F(1,16) = 0.54$, $p=0.47$). There was, however, a significant main effect of valence ($F(1,16) = 16.81$, $p=0.001$), with both frontal and control participants showing better recall for 'good' character information as compared to 'bad'. Mean recall scores in the frontal group for the good and bad characters were 13.83 (± 7.63) and 10.42 (± 6.97) respectively. In the control group mean recall score, for information about the good characters was 16.67 (± 6.48) and 11.92 (± 4.64) for the bad characters. Paired samples t tests confirmed that differences between 'good' and 'bad' recall were significant for both the frontal ($t(5) = 6.17$, $p<0.001$) and control ($t(11) = 3.49$, $p<0.001$) groups. There was no significant difference between the two groups on their total recall scores ($t(16) = -0.74$, $p=0.47$).

2.6 Summary of the results of the Good Guy/Bad Guy test

- Difference between ratings of good and bad characters was used as a measure of ability to discriminate good from bad characters at each of the time points. There was significant variation in performance on the rating task within the frontal group,

with one participant showing significantly better discrimination than the remaining 5 participants. Exclusion of this participant from the analysis showed a trend towards a main effect of group i.e. trend for frontal participants to show poorer ability to discriminate good from bad characters at time 3. This is indicative of a trend for poorer retention of emotional material in the frontal group.

- This difference seems to arise because the frontal group retained positive character information less well compared to controls, whilst for the 'bad guys' both groups showed a similar level of retention at time 3.

- On explicit memory tests (recognition, free recall, cued recall and forced choice recall) there were no significant differences between the performance of frontal and control participants and hence differences on the rating task cannot be explained in terms of differences in target memory.

- There was no significant difference between the groups in recognition scores for valent (good and bad) and non-valent characters (i.e. those not accompanied by character information), with valence having little effect on recognition performance in either group. The valence of character information was found to have a significant main effect on total recall scores (for each valence category), with both groups scoring higher on recall tests for the 'good guys' in contrast to the 'bad'.

3. The Cahill test

It was hypothesised that the two groups would be matched on recall memory overall and that control participants would show enhanced memory for the emotional, as opposed to neutral, story phases. It was hypothesised that the frontal group would not show the same degree of superiority of memory for emotional material.

3.1 Scores on different phases of the test

The mean percentage of questions answered correctly, for each of the three phases of the story, were calculated and these are shown in Table 6 and Figure 2

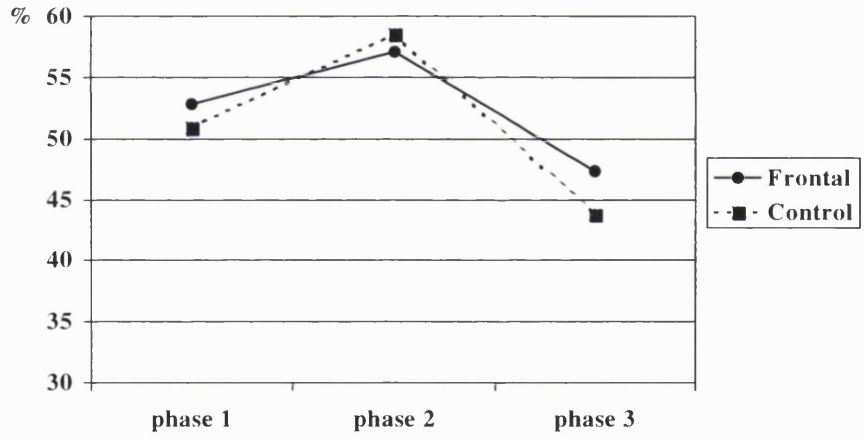
As can be seen from the graph, both groups performed similarly on this task, seeming to show better memory for the emotional (middle) story phase as opposed to the two neutral story phases. A repeated measures 2 X 3 Analysis of Variance was carried out to look at this profile, examining the interaction between 'participant group' and 'story phase' (beginning neutral, emotional, end neutral). There was a significant main effect of phase $F(2,32) = 5.04$. $p=0.01$ but no significant interaction between group and phase ($F(2,32) = 0.22$, $p=0.81$ n.s.) or main effect of group ($F(2,32) = 0.05$, $p=0.81$). A post hoc paired samples t test confirmed that memory for the emotional phase was significantly better than for the neutral phases combined ($t(17) = 2.24$, $p=0.04$). It is noted that although both groups seem to be performing similarly overall, there was substantially more variation amongst the performance of the frontal group than the controls (see Table 6).

Table 6 – Mean (s.d.) percentage of questions answered correctly for each phase of the story by each group and mean valence ratings given by each group

GROUP	Neutral (phase 1)	Emotional (phase 2)	Neutral (phase 3)	VALENCE RATINGS
Frontal	52.80 (12.14)	57.07 (23.42)	47.34 (17.58)	4.33 (3.01)
Control	50.89 (11.32)	58.51 (7.52)	43.84 (14.98)	6.08 (1.56)
T	0.33, n.s.	-0.20, n.s.	0.44, n.s.	-1.34 n.s.

df = 16 for phases 1, 2 and 3. For ratings an unequal variance test was used, therefore df = 6.39

Figure 2 - Mean percentage of questions answered correctly by frontal and control groups for each story phase



Scores were also compared across the two groups for Picture 8 (the boy after surgery), which is known to be the most arousing of the 11 stimuli and which has been found to explain the majority of the enhanced emotional effect in the emotional phase overall. The mean recall of the frontal group on this picture is 72.00 (s.d. 35.92, range 0-100) whilst for the control group mean recall is 88.75 (s.d. 14.85, range 50-100). A non-

parametric Mann Whitney U found the difference between these means was not significant ($z = -1.35$, $p = 0.18$). Again it is noted that there is considerably more variation in the frontal group. Inspection of the individual scores however shows that only one participant (participant E) within the frontal group does not seem to show an emotional memory effect, scoring 0% on this slide. The remaining 5 frontal participants show the expected peak in memory recall for picture 8.

3.2 Valence rating of the story

After viewing the pictures and hearing the story participants were asked to give a valence rating, indicating how emotional they thought the story was, on a scale of 0 to 10, with 0 being not at all emotional and 10 being extremely emotional. The mean valence ratings given by each group are shown in Table 6. The mean valence rating for the frontal group is lower than for the control group but this difference was not significant (unequal $t = -1.34$, $p=0.23$, d.f. 6.39). Again there was substantially more variation amongst the scores of the frontal group (range 1-9) compared to that seen in the control group (range 3-8). Only one control participant rated the story as less than 5 on the emotionality scale whilst 4 out of the 6 frontal participants gave the story a valence rating of less than 5.

3.3 Summary of the results of the Cahill test

- There was no significant interaction between group and story phase (i.e. emotional or neutral), and no overall effect of group, indicating that both groups were performing at a similar level, in terms of recall for all three phases.

- There was a significant main effect of valence, with significantly higher scores shown on the emotional phase in both groups.

- In terms of response to slide 8, the most emotionally arousing stimulus, there was a difference between the scores of the two groups but this was not significant. The standard deviation within the frontal group for slide 8 was significantly greater than that shown in the control group and one of the frontal participants did not show the expected enhanced memory effect.

- The valence ratings of the frontal group were lower on average than those given by the controls but this difference was not statistically significant.

4. Emotional Priming Test

Performance on implicit memory tasks has generally been found to be intact in groups with organic brain injury. However it was hypothesised that frontal participants might show a somewhat reduced priming effect to emotional words, compared to that seen in controls.

4.1 Type of word-stem completion frequencies

Word stem completions were coded as either 'emotional', 'neutral' or 'other'. Words were coded as 'emotional' where a primed emotional word was given, as 'neutral' for primed neutral words and as 'other' where the word given had not previously been presented. Where participants failed to give a response this was coded as 'none'. For each of the participants the frequency of each type of response was calculated. Since there were few 'none' responses in the two groups (i.e. Frontal group, mean=0.5, s.d.=0.55; Controls, mean=1.00, s.d. 1.41) this type of response was excluded from further analysis. The mean frequencies for each type of response in the two groups are summarised in Table 7.

Table 7 – Mean (s.d.) number of each type of wordstem completion and ratio of emotional to neutral wordstem completions for each group

	Type of wordstem completion			
Group	**Emotional (E)**	**Neutral (N)**	**Other**	**Ratio (E:N)**
Frontal	3.17 (1.17)	4.33 (1.75)	8.00 (2.37)	0.43 (0.16)
Control	3.42 (1.56)	5.83 (1.27)	6.08 (0.79)	0.36 (0.14)

In order to explore the effect of word valence on subsequent word completions (i.e. the priming effect of word valence) the ratio of emotional to neutral primed words was calculated for each participant (see Table 7). There was no significant group difference between the mean ratios of emotional and neutral words (unequal t = 0.85, p=0.43, d.f. 9.23).

A repeated measures 2 X 2 ('valence' X 'group') ANOVA showed a significant main effect of valence ($F(1,16) = 8.77$, $p<0.01$) and an overall effect of group ($F(1,16) = 4.93$, $p=0.04$) but no interaction ($F(1,16) = 1.07$, $p=0.32$). A paired samples t test confirmed that there was a significant difference overall between the number of neutral and emotional word stem completions ($t(17)=-3.50$, $p=0.003$), with neutral completions being significantly more likely than emotional ones. T tests showed a trend for frontal participants to respond with fewer neutral primes than controls overall ($t(16) = -2.09$, $p=0.053$), but there was no difference between the number of emotional word responses given by the two groups ($t(16) -0.34$, $p=0.74$). This suggests that whilst both groups were performing similarly in the number of emotional word responses produced, the frontal group was responding with proportionally fewer of the neutral word primes (i.e. responding with 'other', unseen words instead).

4.2 Summary of results of the emotional priming test

- There was no significant difference between the two groups in terms of the ratio of neutral to emotional primed words.

- There was no significant interaction between type of wordstem completion and group, but there was a main effect of valence and of group overall. Both groups were performing similarly in terms of the number of emotional wordstem completions but control participants produced proportionally more neutral words than frontal participants.

- Neutral words were more frequently produced than emotional words.

5. Autobiographical memory test

It was hypothesised that, on this test, both groups would be matched in terms of ease of recall and specificity for neutral words. In the control group it was suggested that emotional words would enhance ability to access memories. The hypothesis that emotional words will enhance memory recall to a lesser extent in the frontal group will be tested.

5.1 First memory responses

All participants were able to produce either a specific, generic or extended memory, in response to the majority of the cue words in this test. As there were 18 cue words the maximum potential score of each participant for each type of memory response was 18.

The mean number of each type of memory response, to the 18 cue words, for the two groups is shown in Table 8. As the table shows, there were no significant differences between the two groups in the type of first memory response given. Whilst there seems to be a pattern of frontal participants responding with fewer specific, and more generic, memories than controls overall this pattern was not found to be significant (see Table 8). There were few extended memory responses in either group, and given this small number this type of memory response has not been included in further analysis. This is in line with other studies which have similarly found the number of extended memories to be negligible and have therefore excluded them from the analysis (Shah, 1999;

Whitely, 1998). There was no significant difference, between the groups, in the number of omissions made ($t(16) = -0.10$, $p=0.92$). It was therefore deemed valid to focus upon only analysing specific and generic responses.

Table 8 – Mean (s.d.) number of each type of first memory response given by each group

Memory type	FRONTAL		CONTROL		t tests
	Mean (s.d.)	Range	Mean (s.d.)	Range	
Specific	7.50 (3.94)	4-14	9.08 (2.84)	4-14	t = -0.98 n.s.
Generic	8.00 (4.05)	1-12	6.42 (3.12)	3-12	t = 0.92 n.s.
Extended	0.83 (0.75)	0-2	0.75 (0.75)	0-2	t = 0.22 n.s.
Omissions	1.67 (1.03)	1-3	1.75 (1.91)	0-5	t = -0.10 n.s.

The number of specific and generic memory responses were calculated, for the positive, negative and neutral cue words respectively. Since the number of specific and generic responses given in total varied considerably across individual participants these scores were calculated as the percentage of the total number of specific (or generic) responses, given by each participant, in each of the cue word valence categories.

The mean percentages of specific and generic memories in each cue word valence category are shown, for each participant group, in Table 9. The mean frequencies of specific memories for each cue word valence category are also shown in Figure 3 and for generic memories in Figure 4.

Table 9 - Mean (s.d.) percentage of specific and generic first memory responses given in each cue-word valence category

	FRONTAL		CONTROL	
	Specific	Generic	Specific	Generic
Positive	41.12 (8.54)	22.05 (12.18)	29.68 (15.32)	29.74 (14.78)
Negative	19.67 (10.08)	35.92 (18.56)	27.72 (9.00)	41.28 (13.84)
Neutral	39.21 (18.25)	42.03 (30.14)	42.60 (13.04)	28.98 (15.09)

Figure 3 - Mean percentage of specific memory responses for each cueword valence category

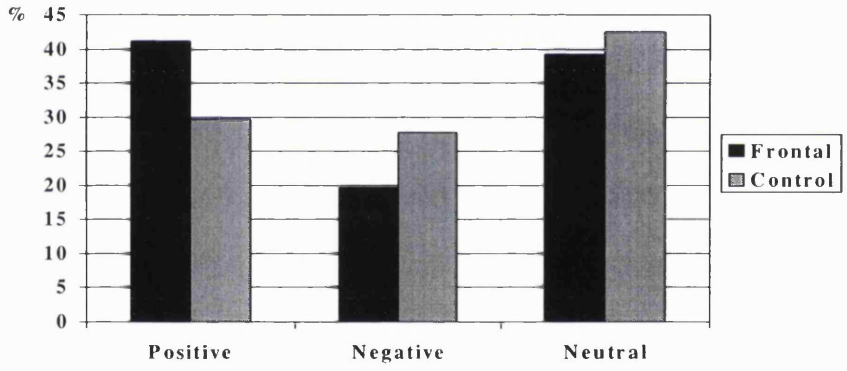
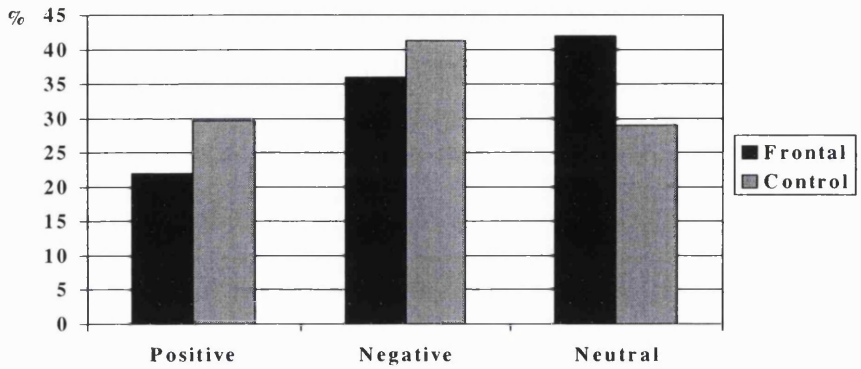


Figure 4 - Mean percentage of generic memory responses for each cueword valence category



A 2 X 2 X 3 repeated measures ANOVA was carried out to investigate interactions between 'group', 'type of memory response' (specific or generic) and 'cueword valence category' (positive, negative or neutral). The effects of depression were controlled for by entering 'HADS depression score' as a covariate in the analysis. There was a significant 3 way interaction between the three factors ($F(2,30) = 3.76$, $p=0.035$). There was no overall effect of group ($F(1,15) = 0.72$, $p=0.41$) and no overall effect of valence ($F(2,30) = 1.18$, $p=0.32$). There was a significant main effect of response type ($F(1,15) = 6.13$, $p=0.03$) and a significant interaction between response type and valence ($F(2,30) = 4.05$, $p=0.04$). Inspection of the means suggests that there was a similar pattern of response for both groups for negative cue words, with a higher proportion of generic than specific responses. For positive and neutral words the two groups were found to differ, with the frontal group producing a higher proportion of specific memories to positive words and the control group producing a higher number of generic memories. This pattern is reversed for neutral words where the control group produced more

specific than generic memories and the frontal group produced more generic than specific.

Paired sample t tests carried out within each group found that for the frontal participants, specific memories were significantly more likely for positive than negative words ($t(5) = 13.16$, $p<0.01$) and conversely generic memories were significantly more likely for negative than positive words ($t(5) = -3.87$, $p=0.012$). In the control group the pattern of generic memories did not differ significantly between the positive and negative words ($t(11) = 0.32$, $p=0.76$) and likewise there was no significant difference in the proportion of positive and negative specific responses ($t(11) = -1.64$, $p=0.13$).

5.2 Latency to specific memory response

The time taken to respond to the cue words with a specific memory response was measured (latency score), regardless of whether this was the first memory recalled or whether a prompt was required. Two prompts were allowed per cue word and therefore a participant may have produced 2 generic memories before a specific memory response was generated. Some of the participants did not produce a specific memory to every word, even with prompting, in these cases a latency score of 30 seconds was recorded, since this was the time limit for each item. The mean and standard deviations of latency scores are reported in Table 10 for each of the cue word valence categories.

A 2 X 3 ANOVA was carried out to investigate whether there was an effect of group and cue-word valence category on latency, again entering depression as a covariate. There was no significant main effect of cueword type ($F_{(2,30)} = 1.79$, $p=0.18$) and no

significant interaction between group and cueword valence, indicating that the effect of valence on response latency does not vary as a function of group ($F_{(2,30)} = 0.37$, $p=0.69$). There was however a trend towards a significant main effect of group ($F_{(1,15)} = 4.49$, $p=0.051$), with people with frontal lesions taking longer to retrieve memories, for each cueword type, than controls. Post-hoc t tests revealed that there was a significant group difference in latency to remembering specific memories for negative words ($t(16) = 2.35$, $p=0.03$), with the frontal group showing longer response latencies than controls. There was also a trend towards group differences for positive and neutral cue words, although these differences did not quite reach statistical significance (positive: $t(16) = 2.07$, 0.06; neutral: $t(16) = 2.03$, 0.06).

Table 10 – Mean (s.d.) latency times to specific memory response for each cueword valence category

Group	POSITIVE	NEGATIVE	NEUTRAL
Frontal	21.30 (7.11)	25.07 (4.05)	19.92 (4.63)
Control	14.74 (5.96)	18.07 (6.64)	15.60 (4.07)

5.3 Subjective valence

Participants were asked to give a rating of the emotional valence of each of their cue-word responses. They hence gave a rating for each memory on a scale from –10 (very unpleasant) to +10 (very pleasant). The mean subjective ratings for each group are shown in table 11.

A 2 X 3 ANOVA (group X cue-word valence category) showed a significant main effect of cue-word valence category ($F_{(2,30)} = 77.84$, $p<0.01$) as would be expected. The between subjects effect of group was not statistically significant but showed a trend towards a difference in performance between the two groups ($F_{(1,15)} = 3.69$, $p=0.07$). There was no significant interaction between cueword valence and group ($F_{(2,30)} = 1.20$, $p=0.32$). Inspection of the mean ratings for the groups suggested that frontal participants were rating memory responses to neutral cuewords more negatively than controls, but this difference was not statistically significant ($t(16)=-1.10$, $p=0.29$).

Table 11 – Mean (s.d.) subjective valence reported by each group, for each cueword valence category

Group	POSITIVE	NEGATIVE	NEUTRAL
Frontal	7.15 (2.07)	-5.56 (2.19)	-0.18 (4.11)
Control	6.55 (1.47)	-5.43 (2.32)	1.85 (2.39)

5.4 Time ago of remembered events

Each participant reported how long ago the event they recalled had taken place. The mean number of years since events took place was calculated for each participant, with events that had happened less than a year ago being given a score of 0. Means were also calculated for each cueword valence category and these are reported in Table 12 for each group.

A 2 X 3 ('group' X 'cueword valence category') repeated measures Analysis of Variance was carried out. There was no significant interaction between group and valence category ($F(2,30) = 0.83$, $p=0.45$), and no main effect of either valence category ($F(2,30) = 0.15$, $p=0.87$) or group ($F(1,15) = 1.74$, $p=0.21$).

Table 12 - Mean (s.d.) number of years ago that recalled events took place, for each group in each cueword valence category

Group	POSITIVE	NEGATIVE	NEUTRAL
Frontal	15.41 (9.30)	11.62 (13.83)	15.18 (14.15)
Control	8.51 (8.86)	10.38 (8.52)	7.26 (5.10)

5.5 Summary of results from the autobiographical memory test

- There were no significant differences between the two groups in the overall pattern of first memory response type (i.e. number of specific and generic responses across all 18 cue words).

- There was however a significant 3 way interaction between group, specificity of response and valence, which seemed to reflect a difference between the two groups in their responses to positive and neutral cue words, but a similar response pattern for negative words. After controlling for depression the frontal group gave more specific responses to positive cue words, and fewer specific responses to neutral words, than the control group.

- There was a significant interaction between response type and valence, with the direction of effect being a higher proportion of generic memories for negative words. T tests found this pattern was significant within the frontal group but not within the control group.

- There was no significant effect of cueword valence on latency to specific memory responses, but there was a trend towards an overall effect of group with frontal participants showing longer response latencies overall. Frontal participants showed significantly longer response latencies to negative words than controls, and a trend towards longer latencies for positive words and neutral words.

6. Emotional picture task

It was hypothesised that recognition overall would be matched across the two groups but that control participants would show greater superiority for emotional material on the recognition task. Since this test has not been widely used to date, specific hypotheses about the performance of the frontal group on the source memory task are precluded.

6.1 Recognition

Participants were shown 128 pictures in the recognition test, 64 of which had been shown previously. This included the 16 negative, 16 positive and 32 neutral pictures already seen. Participants could therefore score a maximum of 64 'hits', correctly identifying a picture they had seen before and 64 'correct rejection' responses. Scores for false identification of pictures not previously viewed were also calculated (false alarms).

Signal detection analysis was used to give a measure of old/new discrimination, such that recognition bias for emotional pictures could be investigated. The techniques used for this analysis are based upon those described by Snodgrass & Corwin (1988). Signal detection theory describes a model of measuring recognition memory which postulates that items presented in a recognition task lie along a continuum of familiarity or memory strength i.e. old items having higher familiarity than new. In order to identify an item as 'old', participants must set a hypothetical level or criterion at which a stimulus elicits a sufficient degree of familiarity to be considered previously seen. Two scores were therefore calculated from hit and false alarm rates: a discrimination index (d'), a measure of the participant's ability to discriminate between old and new items, and a bias index (C), a standard measure of the point in the distribution at which the criterion for recognition is set. These were calculated using the following formulae:

$$d' = Z_{FA} - Z_H \text{ (FA = false alarm score, H = hit score)}$$

$$C = Z_{FA} - d'/2 \text{ (FA = false alarm score)}$$

Mean values of the discrimination index (d') for each group are shown in Table 13. A 2 X 3 repeated measures ANOVA was carried out to look at discrimination with 'emotion' entered as the within subjects factor with 3 levels (d' positive, d' negative and d' neutral) and 'group' entered as the between subjects factor. There was no significant main effect of emotion ($F_{(2,30)} = 0.75$, $p=0.48$) or overall effect of group ($F_{(1,15)} = 0.13$, $p=0.72$), and the interaction between emotion and group was not significant ($F_{(2,30)} = 0.16$, $p=0.85$).

Table 13 – Mean (s.d.) values of discrimination index (d') for each group, in each valence category

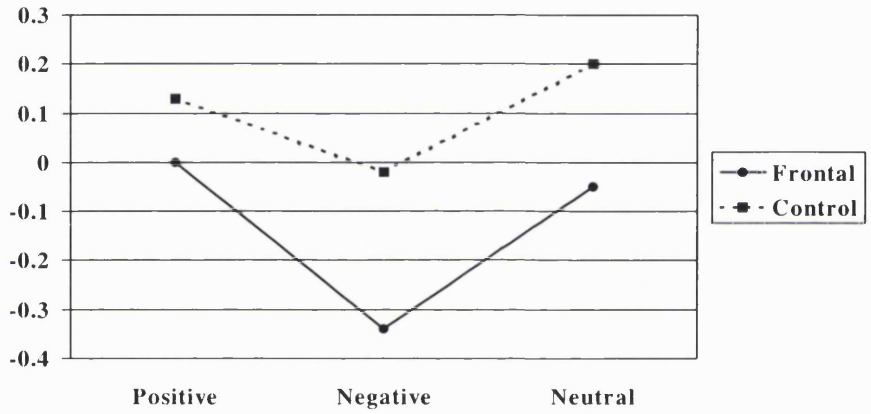
	POSITIVE	NEGATIVE	NEUTRAL
Frontal	2.34 (1.19)	2.62 (1.48)	2.48 (0.92)
Control	2.63 (1.03)	2.85 (1.25)	2.51 (0.95)

Mean bias index scores (C) for each group are shown in Table 14 and in Figure 5. A 2 X 3 repeated measures ANOVA was carried out to look at the effects of 'group' and 'emotion' upon C (measure of recognition criterion). There was a significant effect of emotion ($F_{(2,30)} = 3.73$, $p=0.04$), suggesting that the criterion for familiarity of a stimulus varies as a function of emotion. There was no interaction between emotion and group ($F_{(2,30)} = 0.38$, $p=0.69$) and no significant overall effect of group ($F_{(1,15)} = 0.86$, $p=0.37$). This suggests that emotion biases the hypothetical criterion line set by participants. Inspection of mean C indices (See Table 14 and Figure 5) seems to indicate that a different criterion point was used for negative, as opposed to positive and neutral, pictures, and this effect was seen in both groups.

Table 14 – Mean (s.d.) values of bias index (C) in each valence category for each group

	POSITIVE	NEGATIVE	NEUTRAL
Frontal	-0.0009 (0.66)	-0.34 (0.80)	-0.05 (0.41)
Control	0.13 (0.58)	-0.02 (0.54)	0.20 (0.32)

Figure 5 - Mean bias index (C) for each group, in each valence category



6.2 Source memory scores

Source memory scores were calculated for each participant, i.e. the number of times they correctly recalled the colour that a picture had previously been shown in. Mean percentage scores for correctly identified colours in each picture valence category were therefore calculated, and are shown in Table 15 and in Figure 6.

A 2 X 3 repeated measures ANOVA was carried out to look further at source memory scores with 'emotion' (positive, negative and neutral) being entered as the within

subjects factor and 'group' (frontal, control) being entered as the between subjects factor. There was no main effect of emotion on source memory ($F(2,30) = 2.19$, $p=0.13$) but there was a significant interaction between emotion and group ($F(2,30) = 3.56$, $p=0.04$). T test analyses confirmed that frontal participants were significantly poorer at recalling the colour associated with positively valenced pictures than controls ($t(15) = -2.31$, $p=0.04$). There was no significant difference between source memory scores in the two groups for negative ($t(15) = -0.92$, $p=0.37$) or neutral ($t(15) = -0.13$, $p=0.90$) pictures.

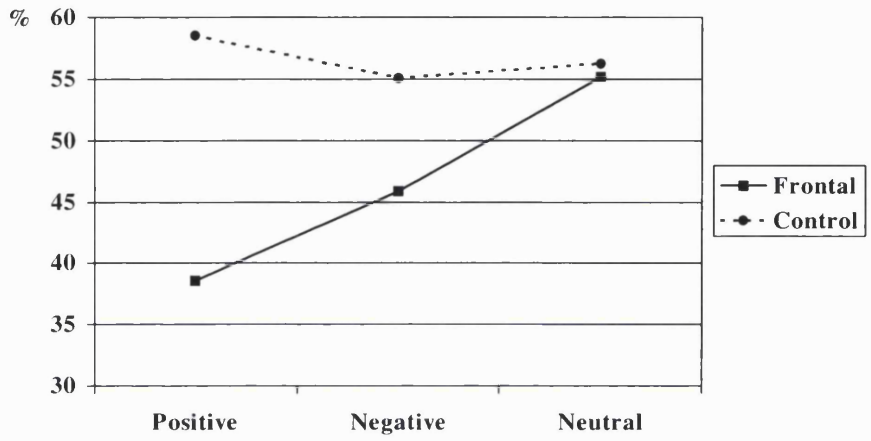
Positive and negative pictures were combined to investigate interactions between emotional and neutral material. A 2 X 2 ('group' X 'emotion') ANOVA showed a trend towards a main effect of emotion ($F(1,15) = 3.30$, $p=0.09$) and a trend towards an interaction between emotion and group ($F(1,15) = 3.93$, $p=0.07$). There was not a significant overall effect of group ($F(1,15) = 1.00$, $p=0.33$). Inspection of group means finds that the direction of this effect in the frontal participants was that of poorer source memory for emotional rather than neutral material. Control participants showed similar source memory performance for emotional and neutral pictures.

Table 15 – Source memory scores (% colour correct identified) (s.d.) in each group for each valence category

	POSITIVE	NEGATIVE	NEUTRAL
Frontal	38.54 (17.42)	45.83 (18.40)	55.21 (16.02)
Control	58.52 (16.83)	55.11 (20.50)	56.25 (16.30)
T	-2.31*	-0.92 n.s.	-0.13 n.s.

df = 15 in all cases. * = $p<0.05$

Figure 6 - Mean percentage of correct source identified for each valence category



6.3 Summary of the results of the emotional picture task

- Emotional valence did not have a significant effect on discrimination of old from new items (d'), and a similar profile was shown across both groups.

- There was a significant main effect of emotion upon bias (C). This suggested that a different criterion point was used for the discrimination of negative, as opposed to positive and neutral, pictures in both groups.

- There was a significant interaction between group and emotion for the source memory task. The frontal group performed significantly worse on source identifications for positive pictures than controls.

- There was a trend towards an interaction between group and emotion overall (positive and negative combined). This was a trend for the frontal group to have poorer source recall for emotional rather than neutral pictures whilst controls performed similarly for both.

CHAPTER 4 - DISCUSSION

Overview

The rationale and aims of the study will first be reviewed, and the findings of both the background and emotional memory tasks will then be presented. These will be explored in terms of both the three main research questions and in the context of the research literature. Methodological issues will then be considered, and both research and clinical implications outlined.

1. Aims of the study

This study aimed to explore emotional memory in people with frontal lobe lesions. Contemporary accounts of emotional memory to date have described a significant role for the amygdaloid complex, but evidence has suggested that other brain regions might also be important in mediating these effects. Since frontal regions of the brain have been broadly implicated in both emotional responsiveness and aspects of emotional learning (e.g. Rolls, 2000), it was postulated that the frontal cortex might also play a role in underpinning emotional memory. This study, therefore, compared the performance of six people with frontal lobe lesions, with that of twelve healthy controls, on five experimental tests designed to measure different aspects of emotional memory.

2. Background tests

In terms of the background tests, both groups were matched for age, educational background, current cognitive ability, and memory functioning. Clinical, scan and

neuropsychological test findings provided strong evidence of frontal lobe lesions in the experimental group, and clinical description confirmed significant social and emotional changes post lesion. Both frontal and control participants reported some anxiety and depressive symptoms, but there were no significant differences in the reports of these across the two groups. In comparison to control participants, the frontal group described significant subjective emotional change since their frontal injury, which was not found to be associated with depressed mood. Hornak et al (1996), who developed this subjective emotional change measure, found it was correlated with behavioural and personality changes (as indicated by relative/carer report), and hence this further substantiates the argument that this is a 'frontal' group, in terms of clinical presentation.

3. Emotional memory tasks

On the emotional memory tasks employed in this study, results were mixed, but with some evidence of a reduced emotional memory effect on aspects of two out of the five tasks. These were the good guy/bad guy test and the emotional picture test. The autobiographical memory test showed some differences in the pattern of responding between the two groups. On the remaining two tasks, the Cahill and the emotional priming test, results did not differ significantly from controls providing some evidence of preserved emotional memory effects in the frontal group.

3.1 Good Guy/Bad Guy test

Findings on this test indicated that both groups performed similarly on explicit tests of recognition and recall of the good and bad characters. This suggests that altering the

exposure times for the frontal group successfully ensured that both groups performed at a similar level in terms of target memory, such that additional effects of emotion on memory can be differentiated. The trend for frontal participants to show poorer performance than controls on the forced choice (i.e. yes/no) test, in the context of matched performance on other recall tasks, may suggest that other factors associated with such a test contributed to poorer performance in the frontal group. For example in forced choice items, factors such as suggestibility and confabulation might contribute to a greater degree in determining response pattern since new, and potentially misleading, information is introduced. The task then may be one of suppressing currently irrelevant information and some studies have suggested that the frontal cortex is important to this type of memory/executive task (Schnider, Treyer & Buck, 2000).

Despite matched explicit memory for character information, results of the rating task provided some tentative evidence that the frontal group did not retain the emotional quality of character information over time to the same extent as controls. Whilst discrimination of good from bad characters at each time point did not differ significantly between the two groups per se, there was notably substantial variation within the performance of the frontal group. Five out of the six frontal participants showed significantly poorer discrimination of good from bad characters, suggesting emotional material was retained less well over time in this sub-group, in comparison to control participants. These findings could not be explained in terms of group differences on the rating task itself, since ratings at time 1 (prior to hearing character information) did not differ significantly, and hence judgement factors associated with making a 'blind' rating

were not significant confounding variables. Similarly at time 2, both groups responded to character information by changing ratings in the expected direction, i.e. increased for 'good' characters, decreased for 'bad' characters and showed no significant change for neutral characters.

This difference between the two groups in retention of emotional material seemed to reflect poorer retention of positive character information ('good guys') in the frontal group as opposed to differences for the 'bad guys'. This impairment in the frontal group, for positively, but not for negatively, valenced information is interesting in the context of performance on explicit recall where recall of positive information was greater than negative. This suggests that whilst frontal participants showed explicit memory for valent information, this information did not seem to be accessed, or utilised, in making implicit character ratings.

It is not clear, however, why this might be the case for positive character information but not for negative characters, for which better retention of emotional material was shown in the rating task. One possible explanation is that positively and negatively valent stimuli recruit different mechanisms to enhance memory and only in the case of positive valence is the frontal region implicated. An alternative explanation might relate to a distinction between the type of character information used in these descriptors. It is noted that the negative characters have all caused significant harm to others (i.e. murder or defraud of older people) which would be considered serious transgressions of moral codes. The 'good guys' are characters who are well-liked and help others but such

descriptors are less likely to elicit a strong emotional response, especially in the case of the frontal group where emotional blunting is likely to be evident. This is consistent with the idea that a certain threshold of arousal response must be reached for enhanced memory to be modulated (Canli et al, 2000).

The finding that a bias towards recall of positive information, as opposed to negative, was shown in the frontal group (as well as controls) might however suggest that the valence of character information was implicitly influencing recall in the frontal group. That is they showed a similar pattern of emotional memory enhancement to that seen in controls and which has been shown in a previous study employing this test (Shah, 1999). A possible explanation for this bias towards recall of positive information is that of mood congruency (Bower, 1981). This postulates that information that is congruent with mood at the time of learning is more likely to be retained. Since neither group were believed to be depressed, research would suggest that this might explain why positive characters were more easily recalled. Cognitive avoidance of negative character information may also play a part. In terms of the individual characters themselves it is noted anecdotally that details of one particular 'good guy' seemed to be better remembered. The character information in this case described the story of a man going for a walk and saving a boy from drowning; there may therefore be features of this particular story, or its imageability or narrative style, which contribute to better recall. It was not possible on this part of the test to compare recall of valent, to recall of neutral, information since neutral character descriptors were not included.

There was no effect of valence on recognition scores of either group and hence it did not seem that faces accompanied by emotionally valent information were any more likely to be remembered than those which had not been accompanied by any information. However this finding is somewhat misleading given that there were very few false negative responses (i.e. non-recognition of previously seen faces) for any of the positive, negative or neutral target characters. This indicates that there were very few errors for any of the faces previously seen (positive, negative or neutral) and the differential effect of emotion cannot meaningfully be interpreted. This ceiling performance in both groups may reflect the level of exposure to faces, since even in the control group target faces were seen on two occasions during test session 1. The lack of an effect of valence on recognition is similar to that found by Shah (1999) in a study comparing healthy controls with a Korsakoff's group.

It is not clear why participant A, who has also been clearly shown to have a frontal injury, might perform so differently to the remainder of the group on this task. This may be indicative of the importance of a range of factors, such as the severity of injury or functional impairment, predicting a greater or lesser degree of emotional memory impairment. In terms of factors specific to this test it is possible that his good performance on these tasks is related in part to A's premorbid occupation as a policeman. It is possible that strategies for ensuring recall of character information and associated facial recognition were well-rehearsed tasks in someone working for the police, such that these abilities were better preserved in his case than in others with frontal injuries.

3.2 Cahill test

On this test, comparing recall memory for emotional and neutral phases of a story, both groups were performing at a similar level overall (i.e. groups were matched in terms of level of memory functioning on this test), and both groups showed enhanced memory for the middle emotional section. Likewise enhanced memory for the most emotionally arousing picture in the emotional phase was shown in the frontal group, for all but one of the frontal participants. This suggests that the majority of the frontal group showed a preserved emotional memory effect on this test.

It is however noted that the frontal participant (E) who was an exception to this, showed surprisingly poor performance, scoring 0 despite average recall for the other slides. It is noted that such a score is lower than those obtained by all the Korsakoff's group in Shah's study (although a shorter delay time was utilised). Hamann et al (1997) also found superior memory for the emotionally arousing phase of the Cahill test in amnesic participants. This would suggest that the pattern shown by this one frontal participant would be unexpected even in the context of poor memory functioning.

3.3 Emotional priming task

On the wordstem completion task frontal and control participants performed similarly in terms of the ratio of emotional to neutral words produced, with both groups producing more neutral than emotional words. This does not seem to suggest that there was any impairment in the frontal group in their priming responses and that priming effects for

emotional stimuli were not dissimilar to those seen in controls. Whilst on this task priming effects for emotional stimuli did not exceed those shown for neutral stimuli in either group, there is no evidence to suggest that the frontal group were implicitly responding any differently to controls to the affective content of the threat words.

3.4 Autobiographical memory test

In this test, examining memory for autobiographical events, participants were asked to recall memories for specific events in response to positive, negative and neutral cue words. The specificity of the memory given and the latency time to recall a specific memory were taken to be indicative of the ease with which the memory was recalled. Frontal and control participants did not differ significantly in the number of specific and generic memory responses they produced, but both groups showed a tendency towards a higher proportion of generic memories in response to negative cuewords. This would suggest a greater difficulty in retrieving negative memories than positive for both groups. This pattern of response specificity was most evident in the frontal group where positive memories were more easily recalled than negative. Positive memories seemed to be recalled more easily in the frontal group than the control group but the reverse pattern was shown across the groups for neutral words.

The time taken to produce a specific memory (response latency) to each cueword gave a further indication of ease of retrieval in each cueword category. Findings suggested that the frontal group had greater difficulty overall in retrieving memories of autobiographical events (i.e. longer response latencies), showing a more significant

difficulty in response to negative cue words. Taking these findings together does therefore seem to suggest that the groups differ in ease of memory recall, with the frontal group showing greater difficulty than controls. There was also tentative evidence to suggest that the retrieval of specific memories or events in response to negative cues was a difficulty for the frontal group, whilst retrieval of positive memories is enhanced relative to controls.

Whilst this might suggest that frontal participants differed from control participants on this task of retrieving autobiographical memories for some reason, it is not evident at what point in the process of retrieval this difficulty occurs. For example this may be indicative of a difficulty in initiating the search in response to the cue, an ineffective retrieval strategy, a problem with the activation of the memory trace, or even disruptions at the point of encoding (or a combination of these). A tendency to produce more generic than specific memories has been found in other clinical populations, for example in people with depression (Williams & Scott, 1988) and alcoholics (Whiteley, 1998). Explanations cited in these two studies include overgeneral encoding strategies (Williams, 1992) and apathy resulting in the premature discontinuation of retrieval strategies (Zola-Morgan, Cohen & Squire, 1993). Whilst there was no obvious evidence of apathy in the frontal group on this task, and memories of some sort was produced in response to the majority of cue words, this is often noted as a clinical feature of this group and so cannot be completely excluded.

It has been suggested that the prefrontal cortex plays a specific role in the retrieval of episodic memories (Tomita et al, 1999 cited in Windmann & Kutas, 2001) and the findings on this test would be consistent with this possibility. Recent studies have corroborated this suggestion, using scanning techniques to show involvement of the right prefrontal cortex in episodic retrieval (Nyberg, Cabeza &Tulving, 1996; Fletcher et al, 1997). 'Autonoetic awareness', the capacity to mentally represent past, present and future subjective experience, has been proposed as one way of conceptualising the involvement of the frontal cortex in episodic retrieval (Wheeler, Stuss & Tulving, 1997). Wheeler et al (1997) postulate a crucial supervisory role for frontal regions in this 'autonoetic consciousness' and hence it might be expected that retrieval of personal experiences from memory would be impaired in a frontal group, in whom this capacity to consider oneself across time is thought to be disrupted. This would however be consistent with a higher proportion of generic memories in response to all cuewords, since an impairment in this 'autonoetic' capacity would imply difficulty in retrieving all memories with personal significance (i.e. all episodic memories) and a greater likelihood (for all cue words) of retrieving semantic memories without links to a particular context (i.e. generic). This was not shown in this frontal group and specific positive memories were in fact more easily recalled in the frontal group than in control participants.

The reasons why this difficulty might be shown primarily for negative memories, with enhanced recall of positive memories, are therefore less clear. Since the control group also showed a pattern of greater difficulty recalling negative, as opposed to positive, specific memories (although they did not show longer latencies) this may not indicate a

specific group difference per se. In this case mood congruency effects might be considered such that memories incongruent with the current mood of participants would be harder to intentionally recall (Bower, 1981). Negative personal experiences themselves may also be harder to verbalise and in an experimental setting, participants may resist giving a descriptive, personalised account of a difficult experience, which would contribute to slowness in producing a response and possibly to a vagueness in contextual and temporal details. The seemingly greater tendency for the frontal group to retrieve negative memories may therefore reflect a combination of these factors and greater difficulty with retrieval of episodic memories as suggested above.

If there were a particular difficulty for the frontal group in the retrieval of specific negative experiences (which could tentatively be concluded from the combination of a high number of generic memories and longer response latencies for negative cues), in addition to the greater ease of recall of positive memories, then the implications of this also need to be considered. The opposite pattern of longer response latencies to positive words has been shown in depression, where the difficulty in accessing memories of specific positive events is thought to be a maintaining factor in the illness (Williams, 1988). The converse pattern shown in the frontal group, with positive memories more easily recalled, might likewise contribute to understanding aspects of clinical presentation such as euphoria and even impulsivity, where past negative experiences are less easily recalled, or are declaratively recalled but do not seem to have personal relevance or familiarity.

Subjective valence of memories

Participants rated the subjective valence of each of their recalled memories on a scale from –10 (extremely negative) to +10 (extremely positive). In both groups the ratings given by participants varied appropriately according to the cue word valence, suggesting that, for both groups, positive and negative words did in fact cue positive and negative memories respectively. There was a trend for frontal participants to rate memories given in response to neutral cue words as subjectively more negative, than controls. It is not clear why this may be the case and indeed it may be indicative only of random variation rather than an overall group pattern. If this finding were significant it might however propose an interesting question about the ease of recall of negative memories in the frontal group. Response latency scores and specificity of the first memory response are assumed to be indicative of ease of recall. In the frontal group findings on these two components of the test would, based on the above assumption, indicate that negative memories are harder to recall. Yet, in the case of neutral words subjectively negative memories seem more likely to be activated. This might suggest that it is negative words themselves that cue different, and possibly less successful, retrieval strategies as opposed to particular impairments in negative memory traces.

3.5 Emotional pictures task

This task measured two types of memory for positive, negative and neutral pictures; firstly it gave a measure of recognition memory and secondly it assessed source memory for the colour in which a picture is presented. Signal detection analysis was used as a way of measuring participant's ability to discriminate old from new pictures, such that

the effect of valence could be looked at further. Emotion-induced recognition bias was shown in both groups, with negative pictures more likely to be considered 'previously seen', than neutral or positive pictures. There was a significant effect of emotion upon criterion, suggesting that a different criterion point for recognition was set, according to the valence of the stimuli. The finding that a different criterion level is adopted for negative items has been described in previous studies, which similarly found that negative items are more likely to be considered 'old', whether or not they have actually been previously seen, than neutral and positive items (Windman & Kutas, 2001; Brignell, 2002). This bias is postulated to serve an adaptive function in ensuring that negative items, which might signal threat, are less likely to be 'missed'.

These findings therefore seem to be consistent with the findings of previous studies and lend support to the hypothesis that emotion can bias recognition. The finding that this effect is shown in the frontal group is however more surprising, since it seems to indicate that frontal participants are showing a normal pattern of emotion-induced recognition bias. Given evidence that emotional responsiveness may be impaired in this group, it was expected that an effect, which is assumed to be mediated by the emotional response elicited, would not be shown to the same extent as that seen in healthy controls. Furthermore Windmann and Kutas (2001) suggested, in their electrophysiological study of healthy controls, that the frontal cortex region plays a crucial role in responding to emotional 'alarm' signals and adjusting the criterion for recognition accordingly. They cite findings of frontal activations during emotional memory recognition tasks as evidence of this. In a group of people with frontal lesions it might therefore be expected

that such mechanisms would be impaired. Windmann & Kutas (2001) further propose that in individuals with psychopathy, who are also purported to show altered emotional responsiveness, weaker (or absent) emotion-induced recognition bias would be expected. This therefore seems to be contradictory to the findings here in which recognition bias is evident in a group of participants in whom emotional responsiveness is reduced.

A measure of discrimination (d') was also calculated but discrimination did not vary between the groups as a function of valence. Both groups were performing similarly overall, with no significant difference in discrimination of old from new pictures in any of the valence categories. This finding indicates that although there was enhanced correct recognition ('hits') for negative pictures, as opposed to positive or neutral, there was no difference in discrimination ability for negative pictures. This suggests that retention is not affected by emotion whereas bias, as described above, does vary as a function of valence. A similar pattern has been shown on previous studies using this task with healthy controls, where a much clearer effect of picture valence on bias, as opposed to discrimination, was evident (Brignell, 2002).

Source memory

The findings on this part of the test produced strong evidence for impairments of emotional source memory in the frontal group. Whilst controls showed a similar pattern of source memory for each valence category, the frontal group showed poorer performance for source identifications of emotional as compared to neutral pictures. This was most evident for identifications of the source detail of positive pictures. This

effect was shown in the absence of any specific impairment on the source memory task itself since performance for neutral pictures was well matched to that of controls.

Source memory has been shown to be disrupted in healthy participants under conditions of high arousal, an effect which is postulated to represent a 'trade-off' between central and contextual details, such that for high arousal conditions, essential information is not 'missed' (Jurica & Shimamura, 1999). The opposite pattern is however shown here where source memory is less affected by negative (and significantly more arousing) picture content, than by positive pictures. Poorer source memory for negative pictures was not shown in the control group and a similar response pattern to that shown in these controls has also been found in other studies using this task (Brignell, 2001). Whilst it is not clear if this is indicative of a weakness in the theoretical account, or an artefact of the test itself, it does suggest that this explanation cannot account for the performance of the frontal group. Previous studies have suggested that the linking of contextual details to memory (i.e. source memory) is underpinned in some way by the frontal lobe (Janowsky, Shimamura & Squire, 1989). In this case, however, whilst source memory judgements for neutral stimuli are matched to controls, valent picture content seems to impair encoding of contextual details.

4. Integration of findings

What then, is the answer to the first question posed by this research (i.e. Do people with frontal lobe lesions show a similar degree of enhanced memory for emotional material, as seen in healthy controls?). The findings on these five tests are mixed but seem to

provide some preliminary evidence that memory is enhanced to a lesser extent in people with frontal lobe lesions. The finding of impairments in source identification for emotional material perhaps provides the strongest evidence of a differential response to affective content. Reduced retention of emotional material in the 'good guy' test, despite matched target memory, adds weight to this suggestion. Conversely on the Cahill test enhanced memory for emotional material was shown, and similarly a pattern of emotion-induced recognition bias was shown in the frontal group as in controls on the picture task. Hence a tentative response to this first question might be to suggest that the effects of emotion upon memory in a frontal group do differ from those seen in healthy controls, but only when measured on certain tasks.

This raises the question of what factors might contribute to the different performance shown across tasks. The tasks themselves vary both in the way in which retention itself is measured (e.g. implicitly or explicitly), as well as in the nature of the emotional material presented. Hence it is plausible to suggest that performance across the different tests indicates a pattern of emotional memory impairment in the frontal group, and that this pattern may relate to variation on either of these dimensions (i.e. way of measuring, nature of material), or reflect a combination of the two factors. These two factors will therefore be considered in turn.

In considering the way in which retention is assessed across these five tasks, some evidence was found to suggest a difference between findings on implicit and explicit tasks. The 'good guy' test found evidence for poorer retention of emotional material in

the implicit rating task, in the context of matched explicit memory for the emotional material. Explicitly assessed memory for the Cahill story showed evidence for superior memory for emotional, as opposed to neutral, material and similarly on the picture task, affective picture content biased recognition in the same way as in controls. These findings may suggest that on certain explicit memory tasks frontal participants show enhanced memory for emotional material in the same way as controls whereas the affective tone of stimuli is not implicitly retained.

This suggestion that affective information is less well retained in a frontal group, when retention is assessed implicitly, might be considered to be consistent with the 'somatic marker hypothesis' (Damasio, 1991). This suggests that events and knowledge are tagged with a specific somatic state and that this state can then be reactivated in response to a specific situation to guide decision making and behaviour. Wall and Meisser (2001) similarly postulate a role for the frontal cortex in integrating somatic information, or "viscero-emotional markers" in associative memory networks. In this way it might be suggested that whilst emotional content may be factually retained in people with frontal lesions, visceral markers which signal its importance are not linked to, or integrated with, the factual content. This would allow information to be intentionally retrieved but suggests that it is less likely to be implicitly activated. This might suggest an affirmative answer to the second research question (i.e. Does performance on emotional memory tasks in this population depend upon how emotional memory is measured?). However such an account does not explain why superior memory for emotional material is shown on explicit tasks; the theory would suggest that neutral and emotional information

should be equally well recalled since neither would be signalled to have a greater significance than the other. This suggests that a distinction between implicit and explicit assessment of memory can only in part account for differences in the performance of the group across these tasks.

This leads to the third question posed by this research (i.e. Is there a difference in performance on tasks in which stimuli are intended to elicit an emotional arousal response, and on tasks in which stimuli are emotionally valent but do not specifically elicit arousal?). It is firstly noted for clarity that no actual measures of physiological arousal were used in this study and therefore evidence relating to the emotional responsiveness of this group on these tasks is tentatively deduced from their observable and recorded responses to the experimental material. Clinical description of each frontal participant supports a case for presupposing altered emotional responsiveness in this group and the following experimental findings lend some support to this.

Emotional responsiveness

Firstly, subjective valence ratings of the Cahill story were found to be generally lower than those shown in controls, and lower than is usually seen in studies using this task (Cahill & McGaugh, 1996). Such a finding might tentatively support the theory that the capacity to show empathy is impaired in people with frontal lobe lesions (Eslinger, 1998). Ratings of 'bad guys' immediately after hearing negative character descriptors were found to be higher (although not significantly higher), indicating that characters were rated slightly less negatively by the frontal group than controls. Given the nature

of the information (i.e. descriptors of people committing murder or causing serious harm) it would be considered surprising to find variation in ratings within a group and certainly the control group show smaller variation.

Conversely, the overall response to hearing character information at time 2 was similar to the control group (i.e. changed in the correct direction) and this might be taken to be indicative of an 'appropriate' emotional response to the valent information. However such a finding is not inconsistent with a hypothesis of reduced emotional responsiveness in this group, since case studies suggest that many people with frontal injuries have, and are able to access, intact social and emotional knowledge despite deficits in emotional responsiveness (Damasio, 1991). Blair & Cippolotti (2000) found hyporesponsivity to emotional stimuli in a man with orbitofrontal damage, but they showed he was also clearly able to access knowledge about morals and social conventions. Interestingly they note that their patient was less clear about the degree of severity of transgressions of these different conventions and this might be a factor here in understanding why some of the frontal group do not respond as negatively as might be expected to the character information given. The responses of frontal participants to character ratings are inconsistent with the model proposed by Grafman (1995) to explain social and emotional change, which suggests that social schema knowledge is stored in the frontal lobes and cannot be accessed in the case of damage to frontal regions. It seems that impairment in emotional responsiveness can be present, despite a preserved knowledge base, which enables frontal participants to respond in a 'socially expected' way.

Comparison of arousal and valence

If altered emotional responsiveness is assumed, it does seem that aspects of the memory enhancing effects of emotion remain intact despite this. For example on the Cahill test, despite lowered subjective ratings, recall for emotional phase information is enhanced, as in controls. Similarly on the emotional picture task negative pictures seemed to elicit the same recognition biasing response as was evident in the control group. It is noted that the Cahill slide and the negative pictures were the most emotionally arousing elements of all the tasks described, other tasks using emotionally valent, but significantly less arousing, stimuli. Emotionally valenced words are not generally considered to elicit a significant autonomic response whilst negatively valenced pictures are known to evoke responses of much greater magnitude (Doerksen & Shimamura, 2001). It therefore seems there might be a case to suggest that where emotional arousal mediates enhanced memory the performance of frontal participants is unimpaired.

A possible explanation for this is that enhanced memory is being mediated by the amygdala, and that the frontal cortex is not essential, as such, to this mechanism. This would suggest that, despite some evidence of impaired emotional responsiveness, an arousal mediated amygdala system can be activated in people with frontal lesions under conditions of high (negative) arousal. This suggestion would be consistent with previous studies which have postulated the idea that a stimulus must exceed a certain threshold of emotional arousal before amygdala activation (as opposed to activations of other brain regions) modulates memory (Canli et al, 2000). It is not however clear how these findings might fit with the presupposition that emotional arousal responses are in

themselves impaired in a frontal group. As has already been described, the neurobiological components of arousal are proposed to play a key role both in amygdala activation, and in modulating memory-enhancing effects in conjunction with the amygdala (see Hamann, 2001 for review). This may suggest that sufficient emotional arousal was elicited in this group to instigate this modulation, perhaps indicating that where stimuli are highly aversive, or signal danger, the threshold for amygdala activation can be exceeded. It is possible that these findings relate to this frontal group and that a more impaired group (in terms of functioning and behaviour change) would show insufficient emotional responsiveness to activate amygdala mechanisms. This group, however, does have a presentation that is consistent with those described in other studies of people with frontal lesions, in which physiological measures have been used and have shown hyporesponsivity (Dimitrov et al, 1999; Tranel & Damasio, 1994).

The performance of the frontal group on tasks which include emotionally valent stimuli, that are less likely to elicit a significant arousal response, does however seem to differ from the performance of healthy controls. In particular the results of the 'good guy' test and the source memory component of the emotional picture test seem to indicate greater impairment in the frontal group for positively, as opposed to negatively, valenced stimuli. Whilst the positive character information given in the 'good guy' test has an affective tone it is unlikely to elicit any physiological emotional response. In the picture task the greatest impairment was seen for source identifications for positive pictures and again whilst these pictures were affectively valenced they did not have such high arousal ratings as the negative stimuli (Lang et al, 1988). The control group continued to show

enhanced memory for these stimuli and significantly better retention than the frontal group.

It has previously been suggested that valent information, which is not specifically arousing, enhances memory largely because of its semantic cohesiveness (Phelps et al, 1997). In this account emotion engages organisational strategies to facilitate encoding and hence subsequently serves as a memory retrieval cue. Other accounts suggest that valent stimuli elicit autobiographical clustering effects in which stimuli with an affective quality activate personal schemas or memories at the point of encoding which enhance subsequent retrieval (Doerksen & Shimamura, 2001). Hamann (2001) similarly suggests that one of the ways in which emotion has an enhancing effect upon memory is via the recruitment of cognitive mechanisms at encoding (e.g. attention and elaboration) and during consolidation. One possibility is therefore that in people with frontal lesions these cognitive (semantic or schema-driven) mechanisms are impaired in some way and hence are not recruited to enhance memory for such stimuli. This might suggest that there is either impairment in the cognitive mechanisms themselves or a failure of the valence 'signal' to activate such mechanisms (or both). This would be consistent with accounts which suggest the frontal lobe works as a "viscero-emotional" processor, i.e. playing a role in the attentional monitoring of emotional signals and in integrating information in an associative emotional memory network (Wall & Meisser, 2001). This would imply that in the case of frontal damage valence 'signals' are not processed or integrated in this way, and hence organisational strategies do not facilitate encoding and/or do not provide a semantic cue for retrieval.

An alternative, although not inconsistent, possibility to explain these findings is that the frontal lobe is specialised in some way for processing of positively valenced information. Hence damage to this area of the brain may result in a specific impairment in encoding positive responses. This is consistent with the findings of Hamann (2002) who found, in a neuroimaging study, that the frontal lobe was a part of a network of brain regions consistently activated during responses to positive emotional stimuli. For negative emotional responses frontal activations were not shown and the amygdala region was primarily implicated. This therefore seems to be a possibility worthy of further investigation.

5. Research limitations

One of the limitations of this study is the small sample size, and this means that it is difficult to generalise from these findings to the wider population. Efforts were however made to ensure that both groups were matched where possible, in order to minimise confounding variables, and studies of people with brain injury do tend to involve small samples, because of the difficulties of obtaining a suitable sample. Other studies involving small samples of people with organic brain damage have been able to make a valuable contribution to the understanding of brain functioning, and where carefully matched to a control group (as here) it would still be considered valid to draw conclusions from the differences between the groups. The majority of the measures included in this study have been widely used and hence the performance of healthy controls can be considered a robust finding. This study was modelled upon a previous

study, which employed the same number of participants, but the lack of strong statistical findings on some of the tests in this study may represent a problem with statistical power. This in itself might, however, suggest that the effect size is smaller than anticipated. Clearly the generalisability of the findings remains a concern and replication of these effects will be important to explore further these conclusions.

Variation within the frontal group is also an important factor to consider. Analysis of individual performance on the Good Guy task found one of the frontal participants (A) performed significantly better than the remaining five. Similarly, results of the Cahill test indicated that participant E, in contrast to the rest of the frontal group, did not show superior memory for the emotional material. It is evident that the group varied in the nature, and aetiology, of lesion and in the time since injury, and this is an important factor to consider in interpreting group findings. The term 'frontal lobe' encompasses a large area of the brain, and within this, disparate roles have been identified for specific areas. Damage to different areas of the frontal cortex have been postulated to contribute to different clinical presentations (Kaplan-Solms & Solms, 1996). Exploration of within group differences on each task were undertaken to try to counteract this limitation but the impact of differences within the group is acknowledged as a limitation of research of this nature.

In interpreting the results of this study a further issue is that of the wider impact of frontal injury, both considering what is already known from previous studies but also in taking account of the complexities of this brain region that are yet to be well-understood.

For example executive functioning and volition are known to be impaired in people with frontal injuries and hence these factors might have had an impact upon test performance. In order to minimise the impact of differences between the groups in executive functioning, the tests themselves largely measured memory specifically, and could not be considered to be complex reasoning tasks. Exposure times were varied between the groups to minimise the impact of general memory or attentional impairments in the frontal group and results would suggest that this was largely successful in allowing both groups to perform at a similar level in terms of target memory.

A further issue to consider in interpreting results is the effect of possible confabulation, which has been found in a small minority of people with frontal lesions (e.g. Joseph, 1999). This would have the most significant impact upon the autobiographical memory test and it was not possible within the scope of this study to confirm the validity of responses with relatives. There was no observable evidence of confabulatory responses, in that responses from the frontal group did not seem bizarre or implausible, and participants seemed able to indicate they were unable to think of a memory as opposed to always producing a response. The possibility of confabulation cannot be completely ruled out, but as noted this is known to effect only a small minority of the population.

6. Implications of the study

6.1 Research implications

The finding that source memory judgements were impaired for valent items, whilst item recognition remained in tact, is an interesting finding which is worthy of further

investigation. Replication of this in another frontal group would lend support to these findings. Manipulations of the methodology (e.g. of the nature of the source information, using emotional words instead of pictures, manipulation of the instructions given to intentionally learn the colour etc.) would assist in building a clearer picture of how emotion may impair source memory in people with frontal lesions. In this study, the source memory effect was specifically shown for positively valent stimuli, and since several of the other findings of impairment in this group related to positive as opposed to negative stimuli (e.g. 'good guy' test), this specificity of impairment on positively valent items deserves further study.

It is surprising that, to an extent, preserved emotional memory effects were shown on some of these tests, in the context of presumed reduced emotional responsiveness. For example the findings on the recognition task of the picture test seem to contradict the suggestions of a previous ERP study (Windmann & Kutas, 2001). This raises questions about emotional responsiveness in this particular group and it may be that a more impaired frontal group, in terms of functioning and behaviour, would show a different pattern of performance. Given that there were findings to suggest that the memory enhancing effects of emotion were impaired to a degree in this group, and noting the variation within the group on their performance on some of these tasks, it is suggested that studying a more impaired group might produce interesting results. Issues of matching to a control group would however require substantial consideration in such a study.

6.2 Clinical implications

The task of developing an account of emotional memory has significant implications for clinical practice. Understanding how memory and emotion interact and influence each other is a crucial component both of developing models of psychological symptoms, such as those of depression and post-traumatic stress disorder, and of considering how psychological treatments might act upon those symptoms. The findings of this study contribute to gaining a greater understanding of the mechanisms by which emotion enhances memory and provide some support to existing evidence for involvement of the frontal cortex. The finding that memory for source, or contextual, information may be impaired by affective content, in the case of frontal damage, could provide crucial insights into the role of the frontal region in episodic memory. Source memory could be described as the essence of episodic memory, in that it gives the recollection of events a sense of personal familiarity. Contextual details (e.g. where, when, who) are essential to the process of remembering or reliving a past experience. Given studies which have begun to explore the impact of traumatic life events upon the development of the brain (Glaser, 2000), and which have shown evidence of impairments in frontal regions, a greater understanding of how frontal damage affects the integration of memory and emotion is essential.

These findings could also be important in understanding aspects of the clinical presentation of people with frontal lobe lesions. For example, in everyday life, source memory could include memory for contextual details such as the location in which information is encountered or the person who presented the information. Impairments in

encoding these details could impact significantly upon an individual's capacity to make sense of, and function within, their environment. This raises the question of how the findings of this study might translate into the clinical context, and of their relevance to the field of cognitive neurorehabilitation. In answer to this there are several aspects of this research that should be considered. Firstly, the finding that people with frontal lesions show a preserved emotional memory effect for arousing material suggests that they may benefit from learning strategies which employ techniques such as embedding information in an emotional and personally relevant context. The degree of preserved emotional memory also indicates that people with frontal lesions are able to retain affective reactions to an extent, and hence whilst they may show a degree of emotional blunting, and diminished emotional responsiveness, they are clearly able to experience some affective reactions. Therefore, as in all clinical work, their feelings should be taken into account, and valued and respected.

Secondly findings of impaired emotional memory for valent, but not specifically arousing, material would indicate that people with frontal lesions might find it hard to make sense of and attribute meaning to a complex social environment, where emotional cues are likely to be subtle. They might benefit from strategies which draw their attention to, and make explicit, the emotional meaning of a situation/experience. These strategies might initially entail manipulating the saliency of external cues and simplifying the social environment, but could then move to focus upon ways of internalising these strategies. In particular cognitive-behavioural techniques for tuning into and becoming more aware of the signals of mood states could be employed. The

finding that implicit priming is intact in this group might indicate a third area in which rehabilitation strategies might be usefully employed, using cueing techniques to make use of this preserved ability. It may also be helpful, in terms of developing individualised rehabilitation programmes, to consider assessing memory for emotional material as well as using standard memory tests. Current research in neuro-rehabilitation highlights the importance of knowing what strategies people use in completing tasks, in order to develop ways of making best use of those abilities which are preserved (Mateer, 1999). A wider assessment of learning ability, of a range of different material, might assist in gaining this understanding of the individual strategies employed.

Finally, the findings of this study also contribute to being able to better explain and conceptualise social and emotional change in people with frontal lesions, which is important in the task of supporting and enabling patients and their families. In particular educating the family and significant others, as well as the person themselves, about brain injury, and how to respond to, and manage, the consequent difficulties is an invaluable part of the rehabilitation process. Providing a way of understanding and reframing what may seem like incomprehensible changes could have a significant impact in reducing the distress associated with these.

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APPENDIX 1

CONSENT FORM

St Thomas' Hospital Research Ethics Committee

CONSENT FORM FOR PARTICIPATION IN RESEARCH PROJECTS & CLINICAL TRIALS

Title of Project:
An investigation of the effects of mood on concentration and memory in people with frontal lobe lesions

Principal Investigator: Prof. M. Kopelman	**Ethics Committee**
Other Investigator/s Ms. Lucy Laing	**Code No:** ECO1/043
Enrolling patients: Prof. V. Curran	**Version No:** 2 **Date:** June 2001

Outline explanation:
You are invited to participate in a study looking at different aspects of people's concentration, memory and mood. The aim of the study is to find out how different kinds of material affect people's concentration and therefore the results will help to develop ways of helping people with concentration problems. In these experiments you will be shown a range of pictures, including one or two some people might find mildly distressing.

It will require you to attend two sessions a few days apart and your travelling expenses will be reimbursed. Each session will last approximately two hours. In the sessions you will be asked to fill in some questionnaires and do a number of straightforward tasks involving both words and pictures.

Please note that these experiments do not involve either drugs or any other invasive procedure.

All information gained from the study will be totally confidential. Only the person you see at the session will know your name and at no time will your name appear in any records. Please feel free to ask any questions or voice any concerns you may have to Ms. Lucy Laing.

You do not have to take part in this study if you do not want to. By taking part you will be helping us in our research, and therefore developing better ways of helping people with concentration problems. If you do decide to take part you may withdraw at any time without having to give a reason. This will in no way affect your future medical care.

All proposals for research using human subjects are reviewed by the ethics committee before they can proceed. This proposal was reviewed by the St. Thomas' Ethics Committee.

I (name) _____

of (address) _____

_____

hereby consent to take part in the above investigation, the nature and purpose of which have been explained to me. Any questions I wished to ask have been answered to my satisfaction. I understand that I may withdraw from the investigation at any stage without necessarily giving a reason for doing so and that this will in no way affect the care I receive as a patient

SIGNED (Volunteer) _____ **Date** _____

(Researcher) _____ **Date** _____

(Witness, where appropriate) _____ **Date** _____

3 copies required:- one for researcher, one for patient/volunteer, one for patient's notes

APPENDIX 2

NOTIFICATION OF ETHICS APPROVAL

Guy's and St Thomas' Hospital NHS
NHS Trust

ST THOMAS' HOSPITAL RESEARCH ETHICS COMMITTEE
Medical Committee Office
Block 5, South Wing

Chairman - Dr G du Mont
Administrator - Ms S Hirsch

St Thomas' Hospital
Lambeth Palace Road
London SE1 7EH

Tel: 020 7928 9292

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11 May 2001

R2315

Professor M Kopelman
Division of Psychiatry & Psychology
Block 8, South Wing
St Thomas' Hospital

Dear Professor Kopelman

EC01/043 **An investigation of the effects of mood on concentration and memory in people with frontal lobe lesions** *Professor M Kopelman Ms L Laing, Prof V Curran*

Thank you for addressing the queries raised by the Research Ethics Committee at its meeting on 27 March 2001. This is satisfactory and I am happy for the study to commence.

Please note that this project carries a reference number, noted above, which must be quoted in any future correspondence.

The project number and the principal investigator must be clearly stated on the consent form. If approval is given to named investigators only, these names must also be stated on the form.

In the case of research on patients, a copy of the consent form (if applicable) must be placed in the patient's medical records, together with a note of the date of commencement of his/her participation in the research. A label must appear on the outside cover of the records when the patient is participating in the research.

The investigators must adhere to the published Guidelines of the Committee and provide the Chairman with annual progress reports and an end of study report. The research should start within 12 months of the date of approval.

The St Thomas' Hospital LREC is compliant with the ICH GCP requirements.

Yours sincerely

Dr G du Mont
Chairman
Research Ethics Committee

Encl.

APPENDIX 3

GOOD GUY/BAD GUY RATING SHEETS

PLEASE PUT A TICK IN EACH BOX OF EVERY ROW TO INDICATE HOW EACH OF THE ADJECTIVES BELOW BEST DESCRIBES THE PERSON IN FRONT OF YOU.

More kind than most people	More kind than many people	Average	Less kind than many people	Less kind than most people
More honest than most people	More honest than many people	Average	Less honest than many people	Less honest than most people
More likeable than most people	More likeable than many people	Average	Less likeable than many people	Less likeable than most people

APPENDIX 4

Descriptors accompanying the Good and Bad Guys in the Good guy/Bad guy test and free, cued and forced choice questions

Good Guy 1

This man is a pensioner. All his life he has worked locally, first as a milkman and then more lately as a lollipop man in front of the local primary school. He is liked and respected by all the locals. He has done voluntary work, helping the aged with their shopping and gardening, and frequently driving them to hospital appointments or on outings to the coast. On Fridays he goes to the local post office to collect his pension, as well as the pensions of three elderly people who cannot get out of their houses. A day centre is being opened locally by the Queen and all the locals want him to be the person who presents her with flowers, he has accepted.

1. What can you tell me about this man?
2. What is his job now?
3. Who will this man meet?
4. What happens on Fridays?
5. Was he a policeman?
6. Did he used to work a long way away?
7. Does he drive elderly people to hospital?

Good guy 2

This man decided to go for a walk with his dog, Barnie, on a cold but sunny January morning. It was Sunday and very few people were about in the park. As he approached the pond he saw that it was frozen. He looked to the other end of the pond and he saw a small boy aged eight or nine skating on the pond. This brought back memories of when he himself used to ice skate as a child in Holland. As he was watching the boy slipped and landed on his bottom. The ice must have been very thin because it broke and the boy fell in. This man realised that he could not get out and there was no time to call others. He did not think of his own safety, but ran over and jumped in. To his surprise he found that his feet touched the bottom of the pond and he managed to lift the boy out of the water, slide him over the ice and then get out himself.

1. What can you tell me about this man?
2. What fond memories were brought back to this man by seeing a small boy on a frozen pond?
3. What happened to the small boy?
4. What did this man do?
5. Was the pond twenty feet deep?
6. Is this man's dog called Barnie?
7. Did his daughter come on the walk?

Good guy 3

This woman moved down from Scarborough and opened a hostel in Kings Cross, London. This area is full of drug dealers and unfortunately many young people end up there because of the railway station. Unless they can find cheap shelter and some kind of job quickly, they fall prey to the crooks. She looks after these young people. After they arrive, she asks others to let their parents know they are safe, but without revealing where they are. She has organised a scheme with social services whereby they quickly get work as care assistants working in day centres for the disabled, mentally ill and elderly. The youngsters enjoy this and are grateful to her as it gives them a sense of self-worth, often for the first time.

1. What can you tell me about this woman?
2. Where did this woman move from?
3. Where is she now?
4. What has she opened?
5. Does she look after young people?
6. Does she ask them to work in the local fish shops?
7. Do the young people work with the elderly?

Bad guy 1

This woman ran two nursing homes in South West London. Although she had once been sacked by Merton Social Services, because of alleged cruelty to residents when she was a care assistant, nobody discovered this when she made applications for Fairhaven and Marigold to be registered. Both Tooting social work department and doctors at St. Crispin's Hospital thought her homes were rather good as she took on severely demented people, especially women who had no living relatives. However she stole all she could especially jewellery from these old people and on three occasions went on collecting pensions of people who had been dead for months.

1. What can you tell me about this woman?
2. What was her job at Merton?
3. Why was she sacked?
4. What did she do with some pensions?
5. Did doctors at St. Crispin's know of her?
6. Did she steal from young people?
7. Did she steal jewellery?

Bad guy 2

This man was expelled from the army for starting pub brawls. Once discharged, he worked as a plumber and drank eight pints of strong lager every evening in the Stag where fights are frequent. On one occasion his friend Bill was knifed and died. When questioned this man had showed little sorrow. Apparently he was sleeping with Bill's wife Gina, and thought that stabbing him during a brawl would be the perfect crime. He carried the knife with him in his back pocket, behind his comb, and while he thought no one was looking, he stabbed his friend and threw the knife away by running outside and hurling it over the garden fence. But he forgot to clean it and his fingerprints were found on it.

1. What can you tell me about this man?

2. Why was this man expelled from the army
3. Why did he kill his friend?
4. How was it discovered that he was the killer?
5. Was he sleeping with his friend's wife?
6. Did he shoot his friend?
7. Did he throw the weapon over the fence?

Bad guy 3

This woman has always felt that people who are ill are weaklings, who need to be killed. Her parents, who live in Canterbury recall how when she used to play doctors and nurses she would often get great pleasure in hurting other children or pretending to kill the dolls. They thought it a passing phase. However, she grew into a studious adolescent. Her parents were told that because of her 12 grade A O levels she should try to get into medical school. Her ideas of murdering people came back when she was at medical school. She has been qualified for five years and recently was arrested on suspicion of having killed at least ten people in Derby, Bournemouth, Norwich and Folkestone. She worked as an anaesthetist so that she would have access to the greatest number of patients in a vulnerable situation.

1. What can you tell me about this woman?
2. Why does this woman want to kill people?
3. How did she do at school?
4. How many people did she kill?
5. Did she work as a surgeon?
6. Did her parents live in Canterbury?
7. Had she worked in Canterbury?

APPENDIX 5

Narrative accompanying slides in the Cahill test

Slide 1: A mother and her son are leaving home in the morning

Slide 2: She is taking him to visit his father's workplace

Slide 3: The father is the chief laboratory technician at a nearby hospital

Slide 4: They check before crossing a busy road

Slide 5: While crossing the road, the car is struck by a runaway car, which critically injures him.

Slide 6: At the hospital, staff prepare the emergency room, to which the boy is rushed

Slide 7: All morning long, surgeons struggle to save the boy's life

Slide 8: Specialised surgeons were able to successfully reattach the boy's severed feet

Slide 9: After surgery, while the father stayed with the boy, the mother left to phone her other child's pre-school

Slide 10: Feeling distraught she phones the pre-school to tell them she will soon pick up her child

Slide 11: Heading to pick up her child, she hails a taxi at the number nine bus stop

Slides 1, 2, 3, 4 = Phase 1 (neutral)
Slides 5, 6, 7, 8 = Phase 2 (emotional)
Slides 9, 10, 11 = Phase 3 (neutral)

APPENDIX 6

Examples of questions in the Cahill test

Slide 1

1.1 Who is pictured in slide 1?
- a. a mother and her son
- b. a father and his son
- c. a mother and father
- d. no one is pictured

1.2 What are the mother and son doing?
- a. eating at a table
- b. leaving home
- c. walking
- d. riding in a car

1.3 Where are the mother and son standing?
- a. in front of a school
- b. in front of their home
- c. at a bus stop
- d. next to their house

1.4 What is the mother doing?
- a. locking the house door
- b. tying her son's shoe
- c. getting into her car
- d. standing in a doorway

1.5 What is the colour of the house door?
- a. green
- b. black
- c. red
- d. blue

1.6 What is visible in the foreground of the picture?
- a. lawn
- b. trees
- c. steps
- d. a driveway

1.7 What is the boy carrying?
- a. a soccer ball
- b. his lunch
- c. a backpack
- d. a teddy bear

1.8 What time of day is it?
- a. morning
- b. afternoon
- c. evening
- d. it was not mentioned

Slide 8

8.1 What is pictured next?
- a. doctors talking to nurses
- b. father and mother
- c. the boy after surgery
- d. the father and the boy

8.2 What has been done to the boy?
- a. skin grafts were put on his legs
- b. his feet were reattached
- c. his broken legs were in a cast
- d. it was not mentioned

8.3 What part of the boy is shown?
- a. head only
- b. whole body
- c. legs only
- d. torso only

8.4 Where were the scars visible on his body?
- a. on the feet
- b. near the ankles
- c. on the knees
- d. torso only

8.5 What else is pictured besides the boy?
- a. a surgical tool
- b. an IV drug line
- c. pillow
- d. nothing

8.6 What is the position of the boy?
- a. lying on his stomach
- b. lying on his back
- c. lying on his side
- d. sitting

Slide 10

10.1 Where is the mother?
- a. on a curb
- b. in a telephone booth
- c. getting into a taxi

10.2 Who does the mother call?
- a. her parents
- b. her boss
- c. her child's school
- d. the taxi company

10.3 What is she leaning on?
- a. a soccer ball
- b. her purse
- c. a telephone book
- d. the door

10.4 The phone is where relative to the mother?
   a. on the right
   b. on the left
   c. behind the mother
   d. is not visible at all

10.5 The mother was described as
   a. feeling tired
   b. feeling distraught
   c. running late
   d. feeling anxious

APPENDIX 7

AUTOBIOGRAPHICAL TEST – LIST OF CUE WORDS

PRACTICE: enjoy
friendly
bold

Cue:

HAPPY

GUILTY

POTTERY

RELIEVED

HOPELESS

GIGANTIC

PROUD

FAILURE

ABSENCE

EAGER

GRAVE

WILDLIFE

GLORIOUS

UGLY

BREAD

SUNNY

WORSE

SEARCH

APPENDIX 8

EMOTIONAL PRIMING – LIST OF WORDS

Emotional	**Neutral**
VIOLENT	VIOLINS
CASUALTY	CASSETTE
SUICIDAL	SUITCASE
IGNORANT	IGNITION
CRITICISM	CRITERION
TUMOUR	TUMBLE
SPITE	SPICE
TRAPPED	TRAWLER
DESPISED	DESCRIBE
INQUEST	INQUIRE
BLAME	BLAST
ATTACK	ATTEND
ASHAMED	ASHTRAY
CORONARY	CORDUROY
SCORN	SCOOP
CLUMSY	CLUTCH

APPENDIX 9

EMOTIONAL PRIMING – WORD STEM LIST

1. **SAN.**
2. **OCT….**
3. **SPI…**
4. **VIO….**
5. **ASH….**
6. **RIN.**
7. **COR…..**
8. **CLU…**
9. **TAL.**
10. **BLA…**
11. **SUI….**
12. **SCO..**
13. **CAR.**
14. **ATT…**
15. **CAS…..**
16. **WIL.**
17. **IGN…..**
18. **TUM…**
19. **INQ….**
20. **TIL.**
21. **TRA….**
22. **DES…..**
23. **CHA..**
24. **CRIT…..**

APPENDIX 10

EMOTIONAL PICTURE TEST – COLOUR EXAMPLE SHEET

Purple

Green

APPENDIX 11

SUBJECTIVE EMOTION QUESTIONNAIRE

1. **Over the past year, have you experienced any general change in your ability to experience emotion?**

None	Slight	Definite	Extreme (or absence of emotion)
☐	☐	☐	☐

2. **Over the past year, have you experienced any change in the intensity or frequency of the following emotions?**

Sadness

None	Slight	Definite	Extreme (or absence of emotion)
☐	☐	☐	☐

Anger

None	Slight	Definite	Extreme (or absence of emotion)
☐	☐	☐	☐

Fear/anxiety

None	Slight	Definite	Extreme (or absence of emotion)
☐	☐	☐	☐

Disgust

None	Slight	Definite	Extreme (or absence of emotion)
☐	☐	☐	☐

Excitement/enjoyment

None	Slight	Definite	Extreme (or absence of emotion)
☐	☐	☐	☐

Happiness

None	Slight	Definite	Extreme (or absence of emotion)
☐	☐	☐	☐

3. **Over the past year, are you aware of any difficulty in expressing the following emotions, either facially or vocally?**

Sadness

None ☐ Slight ☐ Definite ☐ Extreme ☐

Anger

None ☐ Slight ☐ Definite ☐ Extreme ☐

Fear/anxiety

None ☐ Slight ☐ Definite ☐ Extreme ☐

Disgust

None ☐ Slight ☐ Definite ☐ Extreme ☐

Excitement/enjoyment

None ☐ Slight ☐ Definite ☐ Extreme ☐

Happiness

None ☐ Slight ☐ Definite ☐ Extreme ☐

4. **Over the past year, have you found that other people have had greater difficulty interpreting your mood and feelings?**

None ☐ Slight ☐ Definite ☐ Extreme ☐

5. **Over the past year, have you found that you have had greater difficulty interpreting the moods and feelings of others?**

None ☐ Slight ☐ Definite ☐ Extreme ☐

APPENDIX 12

Further information about participants in the frontal group

Participant A

Past history

A is the youngest of 3 siblings and he remained living at home with his mother for much of his life, moving out after she died 10 years ago. He met his wife soon after that, subsequent to his neurosurgery and his resulting frontal pathology. In terms of educational history he left school at the age of 18 and then worked as a clerk before training in the police. He continued to work for the Metropolitan Police until 1986 when he retired on medical grounds. This was following a transfrontal operation to remove a pituitary tumour, subsequent to which he was deemed unfit to return to work. Clinical reports following injury describe A as showing "explosions of anger" and becoming markedly more irritable, disinhibited and impatient.

Current circumstances

A is at present 60 years old and living at home with his wife. He is not in paid employment but has an active role in organising music and dance events in aid of charity. Recent clinical reports indicate some decrease in the frequency of 'anger outbursts' but continued irritability, disinhibition, impulsiveness and impatience. A continues to show poor insight into his difficulties.

Participant B

Past history

B described leaving school at the age of 15 and training as a glazier. He subsequently worked in the building trade before taking early retirement in 1989 due to poor physical health. He met his wife at the age of 17 and they have 4 children. Reports indicate that 2 years ago he began to express bizarre ideas, and seemed somewhat disinhibited and socially inappropriate. He was also found to show some signs of forgetfulness day to day. This clinical presentation was thought to be best explained by the early stages of a frontal dementia (a frontal variant of fronto-temporal dementia). A CT scan showed marked cortical atrophy in the frontal region of the brain.

Current circumstances

At present B is 58 years of age, and lives at home with his wife and one of their sons. Clinical reports indicate he continues to show signs of apathy, and can be disinhibited and inappropriate at times. Cognitive testing reveals that he is functioning in the average range but performance on executive tests was found to be disproportionally impaired relative to memory and other cognitive tasks.

Participant C

Past history

C left school at 17 years of age and subsequently trained in accountancy. He worked as an accountant, within financial institutions, for much of his life. After completing his MBA he moved abroad working in several places in Europe. He stopped working 5

years ago and returned to England. At that time he took up some part time consultancy work. He was admitted to hospital after being found unconscious following a fall at home. A CT scan at that time revealed large bilateral frontal haematomas, with intra-cranial haemorrhaging in the right frontal lobe, and the haematoma was consequently evacuated. Assessment post-surgery indicated strong evidence of impairment on frontal/executive tasks and some deterioration in cognitive functioning.

Current circumstances
Whilst C has shown some improvement in terms of his cognitive functioning, one year post-surgery he continues to show strong evidence of impairment on frontal/executive tasks. A subsequent MRI scan has shown bilateral frontal atrophy secondary to the earlier lesions. Reports indicate he continues to find it difficult to recognise the scope of his problems and it was not thought he would cope with living alone. He has recently moved to live in supported accommodation and is not working at present.

Participant D
Past history
D described leaving school at 16 after taking his O levels but subsequently attended university at the age of 21. He worked throughout his life in the shipping industry and more recently worked for the government in the field of IT training. He developed a frontal lobe syndrome following a right-sided fronto-parietal abscess. This followed a massive teeth infection 2 years ago. Post-injury he developed seizures and clinical reports describe frequent impulsive and aggressive episodes. He has been admitted to a psychiatric unit on one occasion since this time.

Current circumstances
D was seen whilst inpatient in a neuropsychiatric rehabilitation unit, although was increasingly spending time at home with his wife. Current clinical reports describe continued impulsivity, mood swings, irritability, and somewhat slow and pedantic speech. He is also reported to show some obsessive symptoms, such as a preoccupation with collecting magazines. D has not worked since his injury.

Participant E
Past history
E described leaving school at the age of 18 and has worked as a Registered General Nurse (RGN) throughout her working life. She was married, although her husband is no longer alive, and has 4 daughters. Following a frontal infarct 6 years ago she was described as disinhibited, labile and emotionally inappropriate.

Current
E currently lives alone, with the support of her daughters. Recent clinical reports indicate C to be less disinhibited, and there has been a reduction in the lability of her mood. However she remains somewhat apathetic and non-responsive. A recent MRI scan shows a similar picture to that shown previously (on a scan undertaken 4 years ago) and indicates a mature large left frontal infarct. On standard tests of frontal functioning she continues to show impairments.

Participant F

Past history

F grew up in Hong Kong with his parents and younger brother. He came to England to study accountancy and subsequently worked in credit control. He describes a number of physical health problems, including severe eczema. F underwent surgery to remove a frontal meningioma in 1998, and following this he showed significant emotional lability and was described as increasingly irritable. He also showed difficulty in sequencing complex tasks.

Current circumstances

F currently lives alone and is somewhat socially isolated. He has not been in paid employment since his injury but until recently was employed on a voluntary basis by a council finance department. A recent MRI scan shows a similar picture to that post-injury and it is noted that his mood remains variable, with some evidence of lability and irritable outbursts.