SEX DIFFERENCES IN BRAIN LATERALIZATION FOR CLINICALLY
DEPRESSED PATIENTS

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APPENDIX 3. TRANSFORMED MEANS AND SDS FROM THE STATISTICS CONDUCTED ON TRANSFORMED RTS IN EXPERIMENT TWO................................................................. 293
Research in neuropsychology has found depression to be related to impaired right hemisphere (RH) functioning. How clinical depression affects brain lateralized functioning for each sex, however, is not clear. The main aim of this thesis was to investigate how clinical depression impacts brain lateralized functioning for each sex. Additionally, this thesis investigates brain lateralization for emotional processing in a non-depressed group, as well as sex differences in brain lateralization for spatial, verbal, and emotional processing in a non-depressed group. In order to examine each of these research areas, sixty non-depressed participants, and thirty-nine clinically depressed patients were recruited to complete a set of neuropsychological tasks that measure brain lateralized spatial, verbal, and emotional functioning. The neuropsychological tasks that were selected also measure the brain regions known to be involved with depression (frontal lobe and right parietal lobe). The tasks were: the mental rotation task (MRT) to measure RH spatial functioning; the verbal fluency task (phonemic and semantic) to measure left hemisphere (LH) verbal functioning; and the chimeric faces task to measure frontal lobe emotional functioning. The data from these tasks were reported as two separate experiments.

Experiment One examined sex differences in brain lateralization for spatial and verbal processing in a non-depressed group. Experiment One also investigates brain lateralization for emotional processing in a non-depressed group, in particular to determine whether there is a sex difference in brain lateralization for emotional processing. The aim of Experiment One was to replicate the male advantage in spatial processing and the female advantage in verbal processing, which have previously been interpreted as reflecting sex differences in brain lateralization for these functions. It was also the aim to differentiate between the competing RH and valence hypotheses of brain lateralization for emotional processing and further investigate sex differences in brain lateralization for emotional processing. Sex differences in brain lateralization for spatial, verbal, and emotional processing were examined by comparing the performance of thirty non-depressed males and thirty non-depressed females on the MRT, verbal fluency task, and chimeric faces task respectively. The hypothesis that males would mentally rotate the stimuli of the MRT faster than the females was not supported, as no significant sex differences in performance were
observed on the MRT. Failure to replicate the male advantage in spatial functioning was attributed to a possible sex difference in level of spatial ability, which has been found to mediate hemispheric functioning. The hypothesis that the females would generate significantly more words than the males on the verbal fluency task was supported, thus replicating the female advantage in verbal processing. For the chimeric faces task, the group findings supported the RH hypothesis for brain lateralization for emotional processing, with responses being significantly faster and more accurate to happy and sad expressions shown in the LVF than in the RVF. No consistent sex differences in performance were observed between the RT and accuracy rate analyses of the chimeric faces task. Reaction times to the chimeric faces showed a LVF advantage in emotional processing for the males, and no hemispheric bias for emotional processing for the females. In contrast, recognition accuracy of the chimeric faces showed a LVF advantage for emotional processing for both the males and the females. The inconsistent sex differences on the chimeric faces task suggests that there is not a strong sex difference in brain lateralization for emotional processing.

Experiment Two investigated brain lateralization for spatial, verbal, and emotional functioning in a clinically depressed group. It was the aim of Experiment Two to determine whether clinical depression is associated with impaired RH functioning, as suggested by the literature. It was also the aim of Experiment Two to examine more specifically, how clinical depression affects brain lateralized functioning for each sex separately. To examine the effect of clinical depression on brain lateralized functioning, the performance of thirty-six (fifteen males, twenty-one females) clinically depressed patients (three excluded from the recruited thirty-nine) and thirty-six (eighteen males, eighteen females) non-depressed control participants was compared on the MRT, verbal fluency task, and chimeric faces task. The hypothesis that clinical depression would be associated with impaired RH functioning was partially supported by the results of Experiment Two. The depressed group performed significantly poorer than the control group on both the RH task (the MRT intercept and overall RT) and the LH task (semantic verbal fluency). Therefore, impaired RH and LH functioning on the spatial and verbal task was evidenced for the clinically depressed group in Experiment Two. A RH impairment in emotional functioning with clinical depression could not be clearly ascertained from the results of the chimeric faces task. The RT analyses of the chimeric faces task
showed a LVF advantage for emotional processing for both the control and depressed groups. In contrast to the RT analyses, the accuracy rate analyses of the chimeric faces task showed a LVF advantage in emotional processing for the control group, and no hemispheric bias for emotional processing for the depressed group. As the depressed group were significantly impaired for both RH and LH functioning in Experiment Two, it is possible that the findings of Experiment Two are reflective of a generalised performance deficit associated with clinical depression, rather than to a disturbance in brain lateralized functioning. The depressed group was also found to respond significantly slower than the control group in overall RT on the MRT and chimeric faces task. The significant group difference on the intercept of the MRT implicates impaired information encoding for the clinically depressed group. The slowed RTs of the depressed group may also reflect impaired pre-motor organization with clinical depression, thus resulting in delayed motor responses.

In relation to the affect of clinical depression on brain lateralization for each sex, it was hypothesised that the depressed males would perform significantly poorer than the depressed females on tasks measuring functions lateralized to the cerebral hemisphere impaired due to clinical depression. The premise for this hypothesis lies in the evidence from past unilateral brain lesion research, which suggests that the stronger brain lateralization of males restricts assistance from the unimpaired hemisphere to perform the task of the impaired hemisphere. The bilateralization of females however, allows greater assistance of the unimpaired hemisphere to perform the task at hand. In contrast to the hypothesis however, there was no evidence from the results of Experiment Two that clinical depression had a greater impact on the brain lateralized functioning of males than females. No significant sex differences in performance on the MRT were observed for either the non-depressed control group or clinical depressed group. For the verbal fluency task, a female advantage in word generation was observed for both phonemic and semantic fluency, regardless of group. Also regardless of group, the RT analyses of the chimeric faces task showed that the males responded significantly faster to emotional expressions shown in the LVF than in the RVF. For the females however, there was no hemispheric bias in RT for emotional processing. The accuracy rate analyses from the chimeric faces task also showed no sex differences for either group. The similar findings of sex differences between the control and depressed groups across each task suggests that
clinical depression had a similar impact on both the males and the females, regardless of brain lateralization.

The results of Experiment Two could be indicative of impaired LH and RH functioning with clinical depression, or of a generalised performance deficit with clinical depression. A generalised performance deficit for the clinically depressed group in Experiment Two may explain why a sex difference in the effects of clinical depression on brain lateralized functioning was not observed. Future research observing a RH impairment with clinical depression is encouraged to further examine the affect of clinical depression on brain lateralization for each sex separately. Further understanding of the affect of clinical depression on brain lateralization for each sex could provide additional information on sex difference in the prevalence of clinical depression.
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To all of these people, and others who have helped along the way, I am sincerely grateful. Thank you.
DECLARATION

This thesis contains no material which has been accepted for the award to the candidate of any other degree or diploma, except where due reference is made in the text of the thesis. To the best of my knowledge, this thesis contains no material previously published or written by another person except where due reference is made in the text of the thesis.

Jo Spong
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<tr>
<td>2D</td>
<td>Two-dimensional</td>
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<tr>
<td>3D</td>
<td>Three-dimensional</td>
</tr>
<tr>
<td>ANCOVA</td>
<td>Analysis of covariance</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
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<tr>
<td>A.P.A.</td>
<td>American Psychiatric Association</td>
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<tr>
<td>BDI</td>
<td>The Beck Depression Inventory</td>
</tr>
<tr>
<td>CBF</td>
<td>Cerebral blood flow</td>
</tr>
<tr>
<td>COWA</td>
<td>Controlled Oral Word Association test</td>
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<tr>
<td>DSM</td>
<td>Diagnostic and Statistical Manual of Mental Disorders</td>
</tr>
<tr>
<td>ECT</td>
<td>Electro-Convulsive Therapy</td>
</tr>
<tr>
<td>EEG</td>
<td>Electroencephalography</td>
</tr>
<tr>
<td>fMRI</td>
<td>Functional Magnetic resonance imaging</td>
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<tr>
<td>HAMD</td>
<td>The Hamilton Rating Scale for Depression</td>
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<tr>
<td>LH</td>
<td>Left hemisphere</td>
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<td>LQ</td>
<td>Laterality Quotient</td>
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<td>LVF</td>
<td>Left visual field</td>
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<tr>
<td>MADRS</td>
<td>The Montgomery-Asberg Depression Rating Scale</td>
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<tr>
<td>MDD</td>
<td>Major Depressive Disorder</td>
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<tr>
<td>MRI</td>
<td>Magnetic resonance imaging</td>
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<tr>
<td>MRT</td>
<td>Mental Rotation Task</td>
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<tr>
<td>PET</td>
<td>Positron-emission tomography</td>
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<tr>
<td>PMA</td>
<td>Primary Mental Abilities</td>
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<tr>
<td>PTSD</td>
<td>Post traumatic stress disorder</td>
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<tr>
<td>rCBF</td>
<td>Regional Cerebral Blood Flow</td>
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<tr>
<td>REA</td>
<td>Right-ear advantage</td>
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<tr>
<td>RH</td>
<td>Right hemisphere</td>
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<tr>
<td>RVF</td>
<td>Right visual field</td>
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<tr>
<td>SD</td>
<td>Standard deviation</td>
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<tr>
<td>SEM</td>
<td>Standard errors of the mean</td>
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<tr>
<td>WAIS-R</td>
<td>Wechsler Adult Intelligence Scale - Revised</td>
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<tr>
<td>WAIS</td>
<td>Wechsler Adult Intelligence Scale</td>
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<tr>
<td>WASI</td>
<td>Wechsler Abbreviated Scale of Intelligence</td>
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CHAPTER ONE

OVERVIEW

The primary aims of this dissertation were: to examine brain lateralization for cognitive and emotional functioning in a clinically depressed group; and to examine brain lateralized cognitive and emotional functioning for each sex within a clinically depressed group. Chapter One presents a brief overview of the research topics investigated in this dissertation, along with a summary of the content of each chapter.

Since early observations that unilateral brain lesions result in relatively consistent cognitive and behavioural deficits (Benton, 1968; Kimura, 1973; Milner, 1964; Nebes, 1973; Ratcliff, 1979), research on the functional specializations of the cerebral hemispheres has been extensive. With corroboration from neuropsychological and neuroimaging research on neurologically normal participants (Cohen, 1972; Ditunno & Mann, 1990; Elfgren & Risberg, 1998; Jäncke & Steinmetz, 1994; Jordan, Heinze, Lutz, Kanowski, & Jäncke, 2001; Kimura, 1966, 1973; Pihlajamäki, et al., 2000; Tagaris, et al., 1997), it is now generally accepted that the left hemisphere (LH) is lateralized for verbal processing, and the right hemisphere (RH) is lateralized for spatial processing. It is also generally accepted that there are sex differences in brain lateralization for these functions, in which males are more brain lateralized for verbal and spatial processing than females (Flor-Henry, 1978; Harshman, Hampson, & Berenbaum, 1983; Kimura, 1969; Lansdell, 1961; Maccoby & Jacklin, 1974; McGlone, 1977, 1980; Springer & Deutsch, 1993).

As with cognitive functions, the conception that emotional processing might be a brain lateralized function began with early observations of disturbed emotional processing in patients with unilateral brain lesions (Gainotti, 1972; Heilman, Scholes, & Watson, 1975; Tucker, Watson, & Heilman, 1977). Since such observations, neuropsychological research on both clinical and non-clinical populations has become divided between two hypotheses of the brain lateralization for emotional functioning, these being the RH hypothesis and the valence hypothesis. The RH hypothesis predicts that the RH is specialized for emotional processing, regardless of emotional valence (Borod, et al., 1996; Carmon & Nachshon, 1973;
Heilman, et al., 1975; Safer & Leventhal, 1977; Safer, 1981; Schwartz, Davidson, & Maer, 1975; Silberman & Weingartner, 1986). In contrast, the valence hypothesis proposes that brain lateralization for emotional processing is dependent on emotional valence. Specifically, that the LH is superior for processing positive emotions, and the RH is superior for processing negative emotions (Canli, Desmond, Zhao, Glover, & Gabrieli, 1998; Davidson, Schwartz, Saron, Bennett, & Goleman, 1979; Jones & Fox, 1992; Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, Givis, & Moscovitch, 1983). The literature has also been inconsistent in showing whether there is a sex difference in brain lateralization for emotional processing. As a result, the roles of the cerebral hemispheres in emotional functioning, and whether there is a sex difference in brain lateralization for emotional processing are not clearly known, and are therefore research areas that require further examination. An additional aim of this dissertation was to examine brain lateralization for emotional processing, and to also examine whether there is a sex difference in brain lateralization for emotional processing.

A disruption to the normal pattern of brain lateralization has become a frequent correlate of clinical depression. Converging evidence from neuropsychological research suggests that depression is characterized by a functional insufficiency of the RH (Bruder, et al., 1989; Cassens, Wolfe, & Zola, 1998; Henriques & Davidson, 1997; Jaeger, Borod, & Peselow, 1987; Kucharska-Pietura & David, 2003; Lior & Nachson, 1999; Liotti, Sava, Rizzolatti, & Caffarra, 1991; Miller, Fujioka, Chapman, & Chapman, 1995; Moretti, Charlton, & Taylor, 1996; Rogers, et al., 2002). There is an extensive amount of research that has been conducted to investigate how disturbed hemispheric functioning from unilateral brain lesions has affected brain lateralized functioning for each sex. In contrast, research investigating how disturbed hemispheric functioning from mental illness, such as clinical depression, affects brain lateralization for each sex separately, is lacking. The majority of research that has investigated brain lateralization in clinically depressed groups, failed to discuss the findings for each sex (Bruder, et al.; Cassens, et al.; Davidson, Schaffer, & Saron, 1985; Henriques & Davidson; Jaeger, et al., 1987; Kucharska-Pietura & David; Rogers, et al.). Further, due to the 2:1 ratio of females to males diagnosed with clinical depression, most of the research conducted on depressed groups has recruited only females (Crews & Harrison, 1994a, 1994b; Silberman, Weingartner, Stillman, Chen, & Post, 1983). Research that has examined
brain lateralization with depression, and included sex as a factor, has either recruited self-rated
“depressed” participants who were not professionally diagnosed with clinical depression (Moretti, et al.,
1996) according to the criteria of the Diagnostic and Statistical Manual for Mental Disorders (DSM) (Liotti,
et al., 1991), or recruited very small sample sizes for each sex (Lior & Nachson). As such, this dissertation
investigated brain lateralization for spatial, verbal and emotional processing in a clinically depressed
group, in attempt to investigate how clinical depression affects brain lateralized functioning for each sex.

To appreciate the consequences of disturbed brain lateralization for spatial, verbal, and emotional
processing with clinical depression, it is important to have an understanding of brain lateralization for these
functions in non-depressed individuals. Chapter Two begins the literature review of this dissertation by
presenting evidence from previous clinical and non-clinical studies that for non-depressed, neurologically
normal individuals, the LH is typically lateralized for verbal processing, and the RH typically lateralized for
spatial functioning. Two of the more popular models of brain lateralization that have been conceptualised
to explain the perceptual asymmetries that arise from functional lateralization of the hemispheres are also
presented: the structural models (Allen, 1983; Kimura, 1966, 1973), and the attentional model of
Kinsbourne (1970). Chapter Two also presents evidence from past research that there are sex
differences in brain lateralization for verbal and spatial functioning in non-depressed individuals, which
was the basis of its examination in a clinically depressed group. Variation in brain lateralization due to
handedness is also discussed.

Chapter Three continues the literature review of brain lateralization in non-depressed individuals, focusing
on brain lateralization for emotional processing. The chapter illustrates how brain lateralization for
emotional processing is not yet fully understood, by presenting evidence from past research that has
supported both the RH and valence hypotheses. Chapter Three also demonstrates that in comparison to
sex differences in brain lateralization for spatial and verbal functioning, sex differences in brain
lateralization for emotional functioning is far from established, and requires further study. This is
demonstrated by presenting some of the inconsistent empirical findings from past research of sex
differences in brain lateralization for emotional processing.
With an understanding of brain lateralization for spatial, verbal, and emotional functioning in non-depressed individuals, the thesis turns its focus to clinical depression in Chapter Four. Chapter Four begins with a review of the classification and prevalence of clinical depression, and also describes two popular depression rating scales, the Hamilton Rating Scale for Depression (HAMD) and the Montgomery and Åsberg Depression Rating Scale (MADRS), which were administered in the research of this thesis. The cortical areas that have been implicated by past electrophysiological and brain lesion studies as being involved in the clinically depressed state are highlighted, before evidence from past neuropsychological research of disturbed brain laterality in depression is presented. The findings from past neuropsychological research are consistent with the hypothesis of a RH impairment in depression, although there is some evidence to the contrary which is also presented. The final section of Chapter Four outlines sex differences in the prevalence of clinical depression, and also highlights that there is a lack of research investigating sex differences in brain lateralization within a clinically depressed group.

The research aims and hypotheses for this dissertation are presented in Chapter Five, which is followed by an outline in Chapter Six of each of the neuropsychological tasks that were selected to measure brain lateralized spatial, verbal, and emotional functioning. These tasks were: the Mental Rotation Task (MRT), verbal fluency task, and chimeric faces task respectively. Chapter Six also presents evidence that these tasks are suitable measures of brain lateralized performance, and provides evidence that they have generated sex differences in performance, which have been attributed to sex differences in brain lateralization.

Two experiments are reported in this dissertation, investigating the research aims outlined in Chapter Five. Experiment One, reported in Chapter Seven, examines sex differences in brain lateralization for spatial and verbal processing in a non-depressed group. Experiment One also investigates brain lateralization for emotional processing in a non-depressed group, in particular to determine whether there is a sex difference in brain lateralization for emotional processing. It was the aim of Experiment One to replicate the male advantage for spatial functioning and the female advantage for verbal functioning that have been
observed in the literature. It was also the aim of Experiment One to distinguish between the competing right hemisphere (RH) and valence hypotheses of brain lateralization for emotional processing and determine whether this was dependent on sex. Experiment Two, reported in Chapter Eight, investigates brain lateralization for spatial, verbal, and emotional functioning in a clinically depressed group in order to determine whether clinical depression is associated with a disturbance in RH functioning. The second aim of Experiment Two was to investigate brain lateralized functioning for each sex within a clinically depressed group. The results of each experiment are discussed in their respective chapters.

The final chapter of this dissertation, Chapter Nine, outlines the key findings from each of the experiments reported in this dissertation, along with the implications of such findings. The limitations of the research conducted in this dissertation, ideas for future research, and thesis conclusions are also presented in Chapter Nine.
CHAPTER TWO

BRAIN LATERALIZATION

2.1 Chapter Two overview

A considerable amount of research has been devoted to the study of brain lateralization of the cerebral hemispheres. Although both hemispheres typically participate in any complex task, hemispheric superiorities for processing different kinds of stimuli have been reliably shown. Two of the most frequently claimed instances of hemispheric specialization are the left hemisphere (LH) for processing verbal stimuli, and the right hemisphere (RH) for processing spatial or holistic relationships. While other functional differences in cognition have been identified between the hemispheres, it is the verbal and spatial functions that will be the focus of this thesis.

Evidence supporting the functional dichotomy of cerebral organization has been derived from clinical studies of patients with unilateral lesions (Kimura, 1973; Nebes, 1973; Rainville, Giroire, Periot, Cuny, & Mazaux, 2003; Ratcliff, 1979), split-brain studies (Bogen, 1969; Gazzaniga & Sperry, 1967; Levy-Agresti & Sperry, 1968; Milner, Taylor, & Sperry, 1968; Nebes, 1973; Sperry, 1964; Zaidel & Sperry, 1973), research with normal, healthy participants (Cohen, 1972; Jäncke & Steinmetz, 1994; Kimura, 1966, 1973), and neuroimaging techniques (Chee, O’Craven, Bergida, Rosen, & Savoy, 1999; Cuenod, et al., 1995; Faillenot, Decety, & Jeannerod, 1999; Foxe, McCourt, & Javitt, 2003; Fujii, et al., 2002; Harris, et al., 2000). Brain lateralization for verbal and spatial functioning is not constant, being found to vary between individuals for factors such as handedness and sex (Bryden, 1965; Crucian & Berenbaum, 1998). It is generally proposed that right-handed individuals and males are more brain lateralized for verbal and spatial functioning than left-handed individuals and females, who are less brain lateralized (Kimura, 1969, 1983; Lansdell, 1961; Lauber, et al., 1994; McGlone, 1977; Shaywitz, et al., 1995).

Chapter Two provides a general background of the results of previous research on brain lateralization for verbal and spatial functioning. Evidence of brain lateralization from clinical and non-clinical studies will be
presented, beginning with the evidence of LH lateralization for verbal processing in Section 2.2.1, followed by the evidence of RH lateralization for spatial processing in Section 2.2.2. Section 2.3 identifies two popular models that have been used to account for the perceptual asymmetries that arise from functional lateralization of the hemispheres, these being the structural models and the attentional model of Kinsbourne (1970). Section 2.4 presents evidence that a person’s handedness and sex contribute to individual variation in brain lateralization for verbal and spatial functioning.

2.2 Functional lateralization of the cerebral hemispheres

2.2.1 Evidence of left hemisphere (LH) lateralization for verbal processing

The earliest evidence of the functional asymmetry of the LH was derived from behavioural observations from individuals with brain damage. The observation of patients with unilateral cerebral lesions offered the unique opportunity to investigate the relationship between the site of the lesion and the subsequent cognitive or behavioural deficit(s) that arose.

The general acceptance that the LH is specialized for verbal functioning has rested mainly upon two observations: small LH lesions caused severe disturbance to verbal processing, whether it be with the comprehension or production of language, and large RH lesions caused minimal language deficits (Bogen, 1997). The early observations of Dax and Broca postulated the importance of specific areas of the LH for verbal functioning after the observation that a loss of speech was associated with damage to the posterior region of the left frontal lobe (Pinango & Zurif, 2001). This finding, that damage to the LH severely interrupts verbal function, was soon supported by Wernicke who observed that cortical lesions to the posterior region of the left temporal lobe impaired comprehension of language but not of speech production (Pinango & Zurif).

In addition to these behavioural observations, an important development in brain laterality research was the discovery of significant and consistent differences in the way patients with LH lesions and participants
with intact brains performed on verbal cognitive tasks. Two of the most common paradigms that have been used to investigate brain laterality in both clinical and normal populations are the dichotic listening technique (for the auditory modality) and the divided visual field technique (for the visual modality). Apart from offering a method of examining brain laterality, the main advantage of these techniques is that they provide a non-invasive method of investigating brain laterality in the intact brain.

The dichotic listening technique has been extensively administered to both clinical and neurologically normal controls for the purpose of investigating brain laterality differences in verbal processing. The verbal dichotic listening technique generally involves the simultaneous presentation of word pairs to the participant’s two ears, and the participant is asked to recall as many words as possible (free recall) (Welsh & Elliott, 2001). Research conducted using the verbal dichotic listening technique has generally reported a right-ear advantage (REA) for recalling verbal material, that is, participants recalled more words that were presented to the right ear than to the left ear (Jäncke & Steinmetz, 1994; Kimura, 1973). The explanation for this finding is related to the ipsilateral and contralateral pathways that connect the ears to the verbal processing areas of the brain. During performance on the dichotic listening task, the minor ipsilateral pathways are inhibited thus allowing the dominant contralateral pathways preferred access to the areas specialized for verbal processing (Welsh & Elliott). As the right ear has direct access to the verbal processing LH, participants are more likely to perform better with their right ear than their left ear (Welsh & Elliott). This was the observation of Kimura (1973) who found that neurologically normal participants reported words that they had heard with their right ear more accurately than those they had heard with their left. A REA was also reported by Jäncke and Steinmetz who found that participants responded significantly faster to a target syllable when it was presented to the right ear than to the left ear. The REA has generally been interpreted as reflecting the superior verbal performance of the LH (Jäncke & Steinmetz; Kimura, 1973; Milner, et al., 1968; Voyer & Rodgers, 2002).

Studies that have administered a verbal dichotic listening task to patients with unilateral lesions have generally found that patients with LH lesions recall fewer words correctly than patients with RH lesions (Kimura, 1961, 1973, Jäncke & Steinmetz, 1994). This was observed by Kimura (1961) who investigated
the performance of twenty-nine patients (nineteen with left-temporal lobectomies, ten with right-temporal lobectomies) both pre- and post-operatively on a task involving the recall of dichotic presented words. Pre-operatively, an overall REA was observed for both groups. Post-operatively, the REA had reduced significantly for the patients with left temporal lobectomy, whereas the REA was stronger for patients with right temporal lobectomy as more words were recalled. These results suggest that damage to the LH is more likely to impair verbal processing than damage to the RH.

Similar REA findings have been observed from research on patients who have undergone surgical separation of the two cerebral hemispheres, so called “split-brain” patients. The “split-brain” procedure, otherwise known as commissurotomy, involved the surgical section of the corpus callosum typically for the relief of intractable epilepsy, hence disconnecting the cerebral hemispheres (Corballis, Funnell, & Gazzaniga, 2002). Subcortical connections remained intact however, and patients retained mental function in each of the disconnected hemispheres (Levy, Trevarthen, & Sperry, 1972).

When examining the effects of commissurotomy on a patient’s recall of dichotically presented digits, Milner, et al., (1968) found that the difference between ears for the correct recall of digits was larger for the split-brain group than for the control group and temporal lobe lesion patients. A REA was observed for the control, right temporal lobe lesion, and split-brain groups, however, the advantage was considerably stronger for the split-brain patients. No ear advantage for the recall of digits was observed for the patients with left temporal lobe lesions. Apart from illustrating the dominance of the contralateral over the ipsilateral auditory pathways, the findings of Milner, et al. also illustrate the dominance of the LH for verbal processing, as near zero digits were recalled by the split-brain group for digits presented dichotically to the left-ear, thus the RH.

Rather than utilizing the auditory system, the divided visual field technique relies upon the structure of the afferent pathways within the visual system, which serve to ensure that material presented to either the left visual field (LVF) or right visual field (RVF) is delivered to the contralateral cerebral hemisphere (Nicholls & Clode, 1996). As shown in Figure 2.1, vision in the LVF is subsumed by the RH, and vision in the RVF is
subsumed by the LH (Kimura, 1969). To ensure that the stimuli are delivered unilaterally to either the LVF or the RVF, participants are usually required to fixate on a central point. Stimuli are then presented to either side of the central point (thus either the LVF or RVF) at a duration which is faster than that required to make a reflexive horizontal saccade movement, which could otherwise expose both hemispheres to the stimuli. Latencies of reflexive saccades are usually measured between the offset of a central fixation target and the onset of a peripheral saccadic target, and are typically reported to be about 150 msec (Currie, et al., 1993). Therefore stimuli are usually displayed for a duration of 150 msec or less (Nicholls, 1994).

The research of Kimura (1966) was among the earliest to apply the divided visual field technique to neurologically normal participants. Kimura presented verbal (large and small letters) and non-verbal (non-sense figures and dots) stimuli in random succession to the LVF or RVF, and found that the verbal stimuli were more accurately identified when they were presented to the RVF whereas the non-verbal stimuli were more accurately identified when presented to the LVF. Based on this observation, Kimura concluded that there is a LH advantage for the identification of verbal material, and a RH advantage for the registration of non-verbal material.

A similar finding was observed by Cohen (1972), who examined hemispheric differences in the same-different judgements of unilaterally presented letter pairs. Participants were asked to classify stimuli as “same” on the basis of name identity (such as “Aa”) or physical identity (such as “AA”). Cohen found that the task requiring verbal labelling of the stimuli (name identity) was performed faster when the letters were projected directly to the LH, whereas when requiring physical labelling, responses were faster to stimuli projected to the RH. Accuracy was approximately equal between the hemispheres. The findings of Cohen provide further evidence of the LH dominance for verbal processing.
Figure 2.1: Visual pathway of an image from the left and right visual fields to the occipital lobe in the brain (Gazzaniga, 1967).
The RVF advantage observed from neurologically normal samples for verbal processing support the earlier findings of Gazzaniga and Sperry (1967) who observed LH dominance for verbal processing in split-brain patients through the use of the divided visual field technique. The divided visual field task began by presenting pictures of different objects simultaneously to each visual field of split-brain patients. After presenting the pictures, the patients were asked to select with each hand, a picture that was closely related to the original pictures. When asked to explain their choices, the patients could easily and accurately explain the picture selected by the right hand. However the patient denied knowledge of the picture selected by the left hand, and incorporated the reason for its selection into the explanation provided for the right hand selection. Apart from demonstrating that the corpus callosum is a major communication channel between the two cerebral hemispheres, the study indicated that patients could only make an accurate verbal response to stimuli that was presented to the LH (Gazzaniga & Sperry; Sperry, 1964).

Neuroimaging techniques have provided further opportunity to validate some of the deductions drawn from brain lesion observations and findings from neuropsychological research on clinical and neurologically normal participants. Fujii, et al. (2002) administered positron emission tomography (PET) on neurologically normal participants to examine the encoding-related brain activity involved during the deep processing of verbal material. The researchers found that the brain areas associated with deep semantic or shallow phonological processing of new or repeated words were located in the LH. The finding of predominant activation in the LH for verbal processing supported the earlier findings of Weiller, et al. (1995) who examined regional cerebral blood flow (rCBF) during the repetition of pseudowords and during verb generation in neurologically normal participants and patients recovering from Wernicke’s aphasia. During the performance on the verbal tasks, Weiller, et al. observed strong rCBF increases in the LH of the healthy participants with some weak rCBF increases of the RH. For the patients, rCBF was preserved in the frontal areas, however RH activation was evident, homotopic to the LH language related areas. Apart from illustrating that the LH is dominant for processing verbal stimuli, the study of Weiller, et al. demonstrated that functional reorganization in the language system occurs following stroke and damage to the language related areas of the LH.
Using functional magnetic resonance imaging (fMRI), Cuenod, et al. (1995) found that the generation of words beginning with a given letter (verbal fluency) generated left inferior-frontal activity in and around Wernicke’s area and the left superior temporal gyrus. Also using fMRI, Chee, et al., (1999) found that auditory language processing activated mainly left temporal regions, and that visual word processing involved the posterior left superior-temporal gyrus, and the left supramarginal gyrus. The findings from these studies illustrate that the LH is significantly more involved in verbal processing than the RH, regardless of auditory or visual modalities.

Given that a LH advantage on tasks of a verbal nature has been observed across modalities, differing experimental techniques and across differing sample bases, it can reliably be assumed that verbal processing is a strongly lateralized LH function. As with the LH, a consistent RH advantage for processing spatial information has been observed across experimental conditions and parameters. Evidence of the RH dominance for processing spatial stimuli is presented in the next section.

2.2.2 Evidence of right hemisphere (RH) lateralization for spatial processing

Right hemisphere specialization for spatial processing (particularly for visuospatial and manipulospatial functions) is usually regarded as the complement of the LH specialization for verbal processing. As observed for the LH, early evidence of the functional asymmetry of the RH was derived from observations of the subsequent behavioural deficits that arose from RH lesion. Ratcliff (1979) observed that patients with RH damage had difficulty with spatial perception, specifically mental rotation. When asked to decide which hand (left or right) of an upright or inverted human figure diagram was covered by a black disc, patients with RH lesions experienced extreme difficulty in performing the task when the figures were inverted. Subsequently, the patients with RH lesions performed significantly poorer than the patients with LH lesions. When the figures were upright however, the performance between the LH and RH lesion patients was comparable, suggesting a specific deficit in mental rotation with RH lesions.
More recently, Rainville, et al., (2003) examined executive and spatial functioning in a patient with lesions in the subcortical structures of the RH. In addition to memory deficits, neglect, and anosognosia, Rainville, et al. observed that the patient had impaired spatial functioning. The lesion patient obtained a score on the Wechsler Adult Intelligence Scale Revised (WAIS-R) verbal subtests that was within the lower average range, whereas their score on the performance subtests clearly indicated the presence of a deficit. Performance by the lesion patient on the spatial tasks suggested impairments in mental rotation, localization of topographical positions (landscape test), perspective rotations (three mountains task), and in left/right discrimination (moving 180° rotation) (Rainville, et al.).

Early research by Bogen (1969), and Levy-Agresti and Sperry (1968) examined the split-brain patient’s capacity to make intermodal spatial transformations from three-dimensional (3D) to unfolded two-dimensional (2D) forms. When required to select with their hand a 2D layout that was representative of a 3D stimulus, the patients were significantly more accurate with the stimuli felt by the left hand (thus RH) than by the right hand (thus LH). These results suggest that at the basic level of line orientation and spatial transformation, the RH dominates (Bogen; Levy-Agresti & Sperry). Similarly, when Zaidel and Sperry (1973) asked split-brain patients to select with their hand a tactile design that would complete a visual pattern, the left hand was more accurate than the right hand. Such findings from the split-brain patients strengthen the view that the RH generally surpasses the LH in perceiving and manipulating spatial relationships, and is more competent to perceive the overall configurational aspects of a stimulus resulting from the spatial arrangement of its parts.

The RH advantage for processing spatial material has also been demonstrated in neurologically normal participants. One of the most cited studies demonstrating a LVF advantage for processing spatial stimuli in a neurologically normal sample, is that of Kimura (1969). Kimura administered a spatial dot localization task to examine spatial processing in neurologically normal participants. The task presented dots at a hundredth of a second within a circle on a plain white card and participants were asked to indicate on a separate card, the point at which the dot was presented. Kimura found that the dots that were presented in the LVF were located more accurately by the participants than the dots that were presented in the RVF.
Based on these findings, Kimura concluded that the performance advantage of the RH on the spatial dot localization task was facilitated by its superiority in locating spatial material and its ability to mediate spatial information.

Neuroimaging techniques have supported the view that the RH is dominant for processing spatial information. Harris, et al. (2000) examined rCBF and PET as seven healthy participants performed a mental rotation task (MRT). The researchers observed significantly greater activation in the right posterior parietal lobe than in the left parietal region, which was interpreted as evidence that the RH was dominant for processing the task.

An earlier study by Faillenot, et al., (1999) also used PET to investigate the role of the parietal cortex in the perception of visuospatial properties of objects. PET was recorded as participants completed a matching task that required the discrimination of simultaneously presented objects based on one of their spatial properties. Three spatial attributes were selected: principal axis orientation (2D), surface orientation (3D), and size of flat objects. Faillenot et al. found that compared to performance on a sensorimotor control task, there was a similar pattern of cerebral activation for the three property matching tasks. Specifically, the whole occipital lobe, the right intraparietal sulcus, and the right occipitotemporal junction were the areas of activation during the spatial tasks. Based on their results, Faillenot et al. concluded that in an object presentation task involving spatial features, there is a significant contribution in performance of both the temporal and parietal cortices of the RH, thus supporting the general finding of a RH dominance in spatial functioning.

In summary, there is a vast amount of literature suggesting that certain psychological functions or modes of processing are lateralized in one hemisphere. Evidence from both clinical and non-clinical domains, and from varying methodological techniques, infer that the LH is more strongly lateralized for verbal functioning, and the RH is more strongly lateralized for spatial functioning. Various accounts of the functional lateralization of the hemispheres have been presented. Two of the most commonly reviewed models of brain lateralization are outlined in the next section.
2.3 Models of the relation between functional and perceptual asymmetries

Various models have been conceptualised in an attempt to explain the relationship between the visual field / ear advantages for the recognition of verbal and spatial stimuli and the hemispheric superiority for the processing of such stimuli. Two of the more popular models that account for the perceptual asymmetries that arise from functional asymmetry will be outlined in this section, beginning with the structural models (Allen, 1983; Kimura, 1966, 1973) in Section 2.3.1, and the attentional model of Kinsbourne (1970) in Section 2.3.2.

2.3.1 The structural models: absolute and relative structural models

The absolute structural model (Kimura, 1966) of cerebral asymmetry has been the traditional interpretation for the findings from dichotic listening and divided visual field research. The model assumes that there is absolute specialization within each hemisphere in which the LH processes verbal material independently, and the RH processes spatial material independently. Thus, in the case of the divided visual field technique, the model assumes that verbal stimuli presented to the LVF are transferred to language processing centres in the LH via the corpus callosum, and spatial stimuli presented to the RVF are transferred to spatial processing centres in the RH via the corpus callosum. It has also been suggested (Kimura, 1966) that this transcallosal transfer of information prolongs the processing of the information, and may also degrade the quality of the information, resulting in slower overall RT and lower levels of accuracy. Conversely, when information is directed to the hemisphere which is specialized for processing the given information, no interhemispheric transfer is required, and speed and accuracy are preserved.

Since the proposal of the absolute structural model by Kimura (1966), the RH has been found to have a certain degree of linguistic capability (Butler & Norrseil, 1968; Waldie & Mosley, 2000), thus questioning the adequacy of the absolute structural model which proposes that the RH has no role in verbal processing. A variant of the absolute structural model, which attempts to account for the contribution of
the “less dominant” hemisphere in stimulus processing, is the relative structural model. The relative structural model assumes that both hemispheres are capable of performing a task, but one hemisphere is better at doing so (Allen, 1983). The model proposes that the cerebral hemispheres differ in their relative ability to process information thus having differing levels of efficiency in performing a task. For example, verbal stimuli presented to the RVF would be processed faster and more accurately than verbal stimuli presented to the LVF as the verbal processing centres located in the LH are believed to be more efficient. Verbal stimuli presented to the LVF would be processed more slowly and less accurately because the verbal processing centres in the RH are inferior to those of the LH.

In contrast to the absolute and relative structural models of brain lateralization, it has been proposed (Kinsbourne, 1970) that the visual asymmetries are in fact the result of an attentional bias, which is outlined next.

### 2.3.2 The attentional model

Among the many models of brain lateralization, the attentional model of Kinsbourne (1970) has been one of the most influential. The attentional model assumes that behavioural asymmetries are the result of an attentional bias, where the expectancy of a certain stimulus activates the hemisphere which is better suited for processing such material, and that this activation results in an increased deployment of attentional resources to the contralateral visual field. The model proposes that the functional asymmetries of the hemispheres are the result of an imbalance between the hemispheres in their state of activation. During a resting state, the attentional model assumes that the hemispheres are in a state of reciprocal-inhibitory balance; that is, the LH is inhibiting the RH, and the RH is inhibiting the LH simultaneously, thus resulting in an even allocation of attention between the hemispheres. According to the model, the visual presentation of verbal material would result in an activation of the LH, which in turn, would cause a bias of attentional resources to the RVF. Similarly, the expectancy of spatial material would lead to the activation of the RH, which would cause a bias of attentional resources to the LVF.
Support for the attentional model has been provided by some researchers (Cohen, 1975a; Kinsbourne, 1970; Nicholls & Wood, 1998; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990), while others have failed to offer support (Geffen, Bradshaw, & Wallace, 1971; Hardyck, Chiarello, Dronkers, & Simpson, 1985; Kallman & Corballis, 1975; Nicholls, 1994; Nicholls & Clode, 1996). Kinsbourne demonstrated support for the attentional model by using an indirect approach to manipulate attention and prime the LH. The study of Kinsbourne involved presenting a square to either the LVF or RVF and asking participants to identify whether it contained a gap in one of its sides. The results indicated that there was no significant difference in hemispheric performance. When participants were asked to remember a list of words whilst performing the task however, a RVF advantage was produced, which Kinsbourne attributed to an attentional imbalance caused by the priming of the LH.

Further corroboratory evidence for the attentional model was provided by Cohen (1975a), who examined the brain lateral asymmetries produced from tasks that involved pre-cueing and tasks that did not involve cueing. Without cueing, no hemispheric asymmetry was observed for the recognition of letters presented in the LVF and RVF. When cued however, by verbally stating the letters prior to visual presentation, a RVF advantage in the recognition of the letters was observed. Similarly, when a mixed series of words, digits, and dots were presented to the visual fields, no hemispheric asymmetry in performance was observed. Yet when a precue indicated the type of stimulus that would appear, a LH advantage in recognition was found for words and digits, and a RH advantage in recognition found for dots. Cohen related the results to the attentional model of brain lateralization.

Conversely, Hardyck, et al., (1985) observed a strong RVF advantage on a lexical decision task, after participants were pre-cued for the reception of spatial information, which according to the attentional model, should have activated the RH and primed the LVF. Lack of support for the attentional model was also reported by Nicholls and Clode (1996) who examined the effect of different experimental techniques and stimuli on the RVF priming effect observed in the study of Kinsbourne (1970). Like Kinsbourne, the study of Nicholls and Clode began by presenting a neutral task to participants, which involved identifying the colour of a square presented laterally to the visual fields (black, white, dark or light grey). Consistent
with the study of Kinsbourne, no differences in visual field performance was evident when there was no priming of the stimuli. Nicholls and Clode then sought to induce a RVF advantage for the detection of neutral stimuli by overlaying each neutral trial with a verbal recognition task. Contrary to the findings of Kinsbourne and the predictions of the attentional model, which would predict the activation of the LH and thus a bias of attention to the RVF, no asymmetry was observed. Thus the verbal precueing did not effect the distribution of attention. Even after changing the priming technique so that the neutral trials were intermixed with trials associated with a word recognition task, no asymmetry was found for the neutral detection task. The researchers argued that if an attentional bias did exist, a RVF advantage should have been produced for the neutral detection task when cued with verbal stimuli (Nicholls & Clode).

Although the findings of Kinsbourne (1970) have not always been successfully replicated, the theoretical claims of the attentional model have been influential in the study of hemispheric interactions. Whilst the model predicts that hemispheric asymmetries arise as a result of the differential allocation of attention to the hemispheres, it still assumes that the LH is superior for processing verbal information and that the RH is superior for processing spatial information. This is implied by the prediction that a verbal cue will result in a RVF advantage in task performance, and that a spatial cue will result in a LVF advantage in task performance.

In summary, the models of brain lateralization have offered important insights into cerebral asymmetry. The structural models assume that hemispheric asymmetries for verbal and spatial stimuli are the result of fixed structural differences in the neural pathways connecting the hemispheres to the visual and auditory afferent pathways. Whereas the attentional model predicts that cerebral asymmetries are the result of a differential allocation of attention to the LH and RH. Although these models of brain lateralization differ in their assumed hypothetical mechanisms, they are similar in assuming that the LH is dominant for processing verbal material and the RH is dominant for processing spatial material.
2.4 Variations in brain lateralization

Past research on brain lateralization has found that there are individual variations in brain lateralization with handedness and sex of the participant. In general, participant groups that are right-hand dominant are considered to be more strongly lateralized in the RH for spatial tasks and more strongly lateralized in the LH for verbal tasks. Whereas participant groups that are left-hand dominant have been found to be less hemispherically differentiated and some have shown reversed brain laterality patterns in which the LH is lateralized for spatial processing (Bryden, 1965; Gur, et al., 1982; Harshman, et al., 1983) and the RH is lateralized for verbal processing (Knecht, et. al., 2000). Similarly, males are considered to be more strongly brain lateralized for verbal and spatial processing than females, who are considered to be less brain lateralized for these functions, that is, spatial and verbal functioning overlaps across both hemispheres. The impact of handedness on brain lateralization is outlined in Section 2.4.1, and the impact of a person's sex on brain lateralization outlined in Section 2.4.2.

2.4.1 Handedness and brain lateralization

One of the best known examples of brain lateralization is related to handedness. It is generally accepted that a relationship exists between handedness and brain lateralization. Studies on neurologically normal participants have reported that right- and left-hand dominant groups have different patterns of perceptual asymmetries, and these asymmetries have been led to infer brain lateralization. Right-hand dominant groups tend to respond faster and more accurately when verbal stimuli are presented to the LH than RH, and when spatial stimuli are presented to the RH than the LH, which is taken to indicate the superiority of the LH for verbal material and the RH for spatial material (Keane, 1999). In contrast, left-hand dominant groups are more likely to exhibit bilateral organization or reversed brain lateralization patterns (Bryden, 1965; Gur, et al., 1982; Hellige, Bloch, & Cowin, 1994; Keane).

The relationship between brain lateralization and handedness was observed by Bryden (1965) who compared the performance of twenty left-handed and twenty right-handed participants in the recognition of
single letters during a dichotic listening and tachistoscopic divided visual field presentation task. The results from the dichotic listening task indicated that the right-hand dominant group was significantly better at recalling numbers that were presented to the right ear than to the left ear. In contrast, a left-ear advantage for the recall of numbers was found for the left-hand dominant group. For the tachistoscopic divided visual field task, the right-handed participants were significantly more accurate at identifying letters that were presented to their RVF. In contrast, no visual field advantage in accuracy for the identification of letters was evident for the left-hand dominant group. The results of this study illustrate that there is a difference in brain laterality between right- and left-hand dominant groups.

The results of Bryden (1965) were later supported by a neuroimaging study conducted by Gur, et al. (1982) who compared handedness and cognitive performance while measuring rCBF in thirty right-handed and thirty-two left-handed participants. Measurements of rCBF were taken from each participant during periods of rest, and when solving verbal analogies and a spatial line orientation task. Relative to the baseline resting condition, metabolic patterns in the right-hand dominant group indicated significant LH involvement during performance on the verbal task and significant RH involvement during performance on the spatial task. The brain laterality effect was weaker for the left-hand dominant group, as both hemispheres appeared active for the verbal task, while the RH was more involved for the spatial task. The rCBF results indicated that brain lateralization was not as strong in the left-hand dominant group in comparison to the right-hand dominant group.

Similarly, Knecht, et al. (2000) observed a near linear relationship between the degree of handedness and brain lateralization for verbal processing. Examining functional transcranial Doppler sonography as participants completed a word generation task, Knecht, et al. found that a RH dominance for language was more likely to be observed among the left-handed participants. The researchers concluded that the degree of handedness is associated with differences in the cerebral organization of language.

Witelson (1985) proposed that the greater bilateralization of cognitive functions in left-hand dominant groups might be associated with greater anatomical connection between the hemispheres. To test this
proposal, Witelson conducted a post-mortem examination on twenty-seven right-handed patients and fifteen mixed-handed patients (patients showing right and left-hand preference). Witelson found that the mid-sagittal area of the corpus callosum was 11% larger in the mixed-handed patient group compared to the right-hand dominant patient group. Magnetic resonance imaging (MRI) scans were also taken of the midsagittal section of two left-handed men. For both men, the total callosal area was greater than three standard deviations (SD) above the mean, and greater than each individual score of the male right-handed group. Witelson suggested that since left-handed people generally show greater bilateralization of cognitive functions, the difference in callosal anatomy between right-, left-, and mixed-handed groups may be associated with their different patterns of functional lateralization.

In summary, past research investigating handedness and brain lateralization has found that left-hand dominant groups are more likely than right-hand dominant groups to display bilateral or reversed lateralization. For this reason, the majority of research investigating brain laterality has recruited right-handed participants only, so that if a brain laterality effect is observed, then the results can be more reliably attributed to the lateralized processes commonly observed for each hemisphere.

2.4.1.1 Measuring handedness

Two approaches have been adopted in the past to assess the handedness of an individual. The first approach involves asking the participant to perform unimanual tasks with their left and right hands. Performance on these tasks is scored for speed and accuracy and an index of handedness is calculated. The problems associated with this approach is that it is time consuming, it may be affected by the participants' differing experience on similar tasks, and it may be influenced by the sex, age, and culture of the participant (Oldfield, 1971). In the second approach to measuring handedness, participants answer questions about their practice in performing a number of everyday tasks, in which the roles of the left and right hands are distinguished (Oldfield). The Edinburgh Handedness Inventory is an example of this second approach, and is the most widely applied handedness inventory in psychological research. The Edinburgh Handedness Inventory determines the participant's preferred hand by examining which hand
the participant uses dominantly across a range of twelve activities (e.g. writing, using a toothbrush, using a broom). Based on responses to each activity, a Laterality Quotient for hand preference is then calculated, indicating the participants’ preferred hand.

2.4.2 Sex differences and brain lateralization

Sex differences in cognitive abilities are well documented. Males are typically reported to perform better at tasks of visual-spatial ability, such as the detection of shapes, mental rotation, geometry, maze learning, and block design, whereas females are reported to perform better on tasks involving both receptive and productive language, verbal fluency, and verbal memory (Flor-Henry, 1978; Harshman, et al., 1983; Maccoby & Jacklin, 1974). One of the most popular theories invoked to explain such sex differences in cognitive functioning relates to sex differences in brain lateralization. More specifically, males are more lateralized for spatial abilities in the RH and for verbal abilities in the LH, whereas females are less lateralized, or “bilateralized”, for these abilities in which spatial and verbal abilities overlap in both cerebral hemispheres (Kimura, 1969; Lansdell, 1961; McGlone, 1977, 1980; Springer & Deutsch, 1993).

The strongest evidence suggesting that brain lateralization differs for each sex has been derived from studies testing unilateral brain damaged patients. Males with unilateral lesions are generally more likely than females to show selective defects in spatial skills with RH damage, and in language skills with LH damage. The stroke study of McGlone (1977) and brain lesion study of Kimura (1983) reported that aphasia, a disorder of language, occurred more frequently in males with LH damage, than in females with LH damage.

Similarly, Inglis and Lawson (1981, 1982) and McGlone (1977) reported sex-related differences in performance on the Wechsler Adult Intelligence Scale (WAIS) for patients with LH and RH lesions from stroke. Specifically, the males with LH lesions were impaired on the verbal subtests, and the males with RH lesions were impaired on the performance subtests. Females however, were impaired on both verbal and performance subtests regardless of whether their lesion was to the LH or RH. Based on the results,
McGloon speculated that both verbal and spatial abilities were less lateralized in females than in males. Similarly, Lewis and Kamptner (1987) found that within their non-brain-damaged group, there was a male advantage in performance on the Block Design subtest of the WAIS. For the brain-damaged group however, the males with RH lesions scored lower on the Block Design subtest than the females with RH lesions, and the males and females with LH lesions. Performance on the Block Design subtest between the females with RH and LH lesions was similar with their scores falling between those of the RH and LH lesion males. Lewis and Kamptner suggested that the findings suggested greater bilateral representation of visuo-spatial functioning in females, and greater RH lateralization of visuo-spatial functions for the males.

Further evidence that similar cerebral lesions affect males and females differently is provided by research on split-brain patients. Lansdell (1961) examined the spatial skills of a sample of epileptic patients who, in addition to commissurotomies, had surgical removal of part of the RH. The male patients performed poorly on the spatial measure, whereas the spatial performance of female patients was minimally affected. Lansdell suggested that for females, spatial tasks may be processed in both hemispheres of the brain, but in males such skills are more specifically lateralized to the RH. Lansdell tested this conjecture by presenting a spatial problem exclusively to the LVF of split-brain patients without RH damage. Spatial performance was better for the males than for the females. Conversely, when a test of artistic judgement was presented solely to the LVF, females performed better than did males, again implicating the involvement of both hemispheres for females in performing the tasks.

Research reporting differences in brain lateralization between the sexes has not been limited to patient samples. A tachistoscopic divided visual field study by Kimura (1969) on a neurologically normal sample reported a strong LVF advantage for males on a spatial dot localization task, which was absent for the females. Kimura concluded that differentiation of the hemispheres with respect to visuospatial ability is greater in males than in females. Similarly, a dichotic listening study by McGloon (1980) found a REA for the recall of words for both males and females, however, the REA was weaker for the females. McGloon concluded that speech is less dependent on the LH in females than in males.
Differences between the sexes in brain lateralization have also been reported in neuroimaging studies. In a PET study, Lauber, et al. (1994) presented a series of letters via computer and asked participants whether the current letter on screen was the same as the letter presented three trials prior. The case of the letter was randomly varied to force matching by letter identity rather than by shape. Greater activity was observed in the LH when the males performed the task, however, both hemispheres were active when the females performed the task (Lauber, et al.). An additional spatial component of the study presented three dots in random locations around a central fixation cross on a computer screen. Once the dots disappeared, a probe circle was presented and participants were asked to indicate where in the circle the dot had appeared. During task performance, greater involvement of the right parietal lobe was observed for the male participants, whereas both hemispheres were active for the females (Lauber, et al.). The findings from both the verbal and spatial components of this study are consistent with the suggestion that males are more brain lateralized for processing verbal and spatial stimuli than females.

Using fMRI, Shaywitz, et al. (1995) found that during performance on phonological tasks, brain activation in males was lateralized to the left inferior frontal gyrus region, whereas for females the pattern of activation included both the left and right inferior frontal gyrus. These results were replicated by the fMRI study of Jaeger, et al. (1998), who also reported left unilateral activation in males and bilateral activation in females during performance on a task in which participants generated the past tense of visually presented verbs. A more recent study by Rossell, Bullmore, Williams, and David (2002) employed fMRI to investigate sex differences in brain activation during a paradigm similar to a lexical-decision task (deciding which visual field a word compared to a pseudoword was presented). The results indicated a strong left lateralized pattern of activation in males while a more symmetrical pattern in language related area was found for females.

It is not known why the brain is organised differently for each sex for the optimal functioning of different abilities. Based on the differing neuropsychological and neuroimaging findings of sex differences in brain lateralization, it is evident that bilateral representation has different consequences for verbal and spatial
functioning, as does unilateral representation. Clearly bilateral representation of spatial ability in females is less efficient than the unilateral representation of spatial ability in males (Crucian & Berenbaum, 1998). In contrast, bilateral representation of verbal ability in females appears more efficient than the unilateral representation of verbal ability in males. Springer and Deutsch (1993) postulate that spatial capabilities may have preceded the evolution of verbal capabilities, and Levy (1969, 1976) and Levy and Reid (1978) suggest that the bilateralization of verbal functions interferes ontogenetically with the development of the neural circuits necessary for spatial ability. In this case, it might be argued that only the LH became involved in verbal abilities for males, thus leaving spatial functions intact in the RH, whereas for females, verbal abilities were established in both hemispheres, thus interfering and “crowding” the spatial capabilities. Springer and Deutsch state that being “more lateralized” would therefore be better for spatial functioning, whereas being “less lateralized” would be better for verbal functioning. This theory, may explain sex differences in verbal and spatial functioning (McGlone, 1980).

Some investigators have questioned whether there are sex differences in brain lateralization. Hardyk (1977) argued that many complex psychological functions depend on active cooperation between the cerebral hemispheres, and noted that models of cerebral organization should assume that the functional interaction between hemispheres is cooperative rather than competitive as has been predicted for males with separate hemispheric lateralization. Buffery and Gray (1972) proposed paradoxically that it was females who have greater RH specialization for spatial abilities, while males are more bilateral. In support of their view, Buffery and Gray reported that when attempting to draw with both hands simultaneously, females showed a greater left hand and therefore RH superiority compared to males. Buffery and Gray also proposed that LH dominance for verbal functions is attained earlier in females than males, which in turn does not allow spatial processing to be as bilateral in females.

Further, there has also been research that has failed to find reliable sex differences in spatial and verbal functioning (Demarkis & Harrison, 1997; Desrocher, Smith, & Taylor, 1995; Harrison, Buxton, Husain, & Wise, 2000; Jones & Anuza, 1982; Roberts & Bell, 2002; Uecker & Obrzet, 1993), which has led some researchers to question the reality of sex differences in brain laterality. Hyde (1981) suggested that
research on cognitive sex differences may often produce reliable but small differences. This was observed by Hiscock, Inch, Jacek, Hiscock-Kalil, and Kalil (1994) following an exhaustive review of auditory laterality studies published in six mainstream neuropsychology journals. Hiscock, et al., (1994) found that 40% of the 352 studies on dichotic and monaural listening experiments provided information on sex differences. Of these, forty-nine experiments yielded a significant effect or interaction involving sex of the participant and of these, only twenty-one outcomes (14.9% of the informative studies) met less stringent criteria to support the hypothesis of differential brain lateralization between the sexes. This finding was suggestive of a weak population-level sex difference in brain lateralization. Similar findings were observed in a further review of visual laterality studies in the same six mainstream neuropsychology journals (Hiscock, Israeli, Inch, Jacek, & Hiscock-Kalil, 1995). Of 516 experiments, only sixty-eight yielded a significant sex main effect or interaction. When applying less stringent criteria, Hiscock, et al. (1995) found twenty-seven outcomes (12.3% of informative studies) which were consistent with a differential brain lateralization hypothesis, in which six were found to be contrary to the hypothesis of males being more strongly brain lateralized than females.

Despite the research that has been presented, brain laterality findings for spatial and verbal functioning have not always been clear and consistent. This has been evident with brain lateralization for verbal functioning in females not always being found to be bilateral. The results of the presented functional brain activation studies, and neuropsychological research on neurologically normal participants and brain lesion patients, suggests that spatial functions are more lateralized in the RH and verbal functions more lateralized in the LH in males than in females. These findings, however, have not always been replicated with differing brain laterality findings being observed for each sex.

2.5 Summary of Chapter Two

Numerous studies that have employed a variety of experimental techniques have demonstrated brain lateralization of verbal and spatial functioning. In the typical right-handed adult, verbal functioning is generally assumed to be the province of the LH, and spatial functioning to be the province of the RH. This
general observation of brain lateralization has been found to be less reliable in left-hand dominant groups, who have shown less or reversed brain lateralization patterns. Evidence has also accumulated suggesting that males and females differ in brain lateralization for verbal and spatial functioning. More specifically, males are more lateralized for spatial functioning in the RH and for verbal functioning in the LH. In contrast, females are less lateralized for spatial and verbal functioning with these abilities being shared between hemispheres.

Results from past neuropsychological research that has investigated brain lateralization for emotional processing have not been as consistent as the findings from research investigating brain lateralization for verbal and spatial functioning. The next chapter outlines findings from past research that has investigated brain lateralization for the processing of emotional stimuli.
CHAPTER THREE

BRAIN LATERALIZATION AND EMOTION

3.1 Chapter Three overview

Findings from research examining brain lateralization for emotional functioning are less clear and consistent than findings from research examining brain lateralization for spatial and verbal functioning. There are two competing speculations regarding brain lateralization for emotional processing; the right hemisphere (RH) hypothesis, which proposes that the RH is superior to the left hemisphere (LH) for all forms of emotional processing (Borod, et al., 1996; Carmon & Nachshon, 1973; Heilman, et al., 1975; Safer, 1981; Safer & Leventhal, 1977; Schwartz, et al., 1975; Silberman & Weingartner, 1986); and the valence hypothesis, which proposes that brain lateralization for emotional processing depends on emotional valence, with the RH being dominant for processing negative emotions and the LH being dominant for processing positive emotions (Canli, et al., 1998; Davidson, et al., 1979; Jones & Fox, 1992; Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, et al., 1983). Qualified support for the RH and valence hypotheses has been derived from behavioural observation, brain laterality paradigms, and neuroimaging techniques, on brain damaged patients, and on neurologically normal participants. As support for both hypotheses has been obtained over a range of experimental techniques and populations, the role of the LH and RH in emotional processing has not yet been fully determined.

Sex differences in brain lateralization for emotional processing have not been clearly defined. Although females have generally been found to be more emotionally expressive and arguably more emotionally perceptive than males (Barr & Kleck, 1995; Buck, Miller, & Caul, 1974; Hall, 1978; Kring & Gordon, 1998; Mcifiable, 2000; Moscovitch & Olds, 1982; Rahman, Wilson, & Abrahams, 2004; Thayer & Johnsen, 2000), this sex difference in emotional processing has not indicated whether there is a sex difference in brain lateralization for emotional processing.
Chapter Three provides a general background of the results found from previous research on brain lateralization for emotional processing. Empirical evidence from clinical and non-clinical research on brain lateralization for emotional processing will be presented within Section 3.2, outlining evidence supportive of the RH hypothesis of brain lateralization, and also of the valence hypothesis of brain lateralization. Section 3.3 of this chapter outlines the inconsistent findings of sex differences in the brain lateralization for emotional processing.

3.2 Brain lateralization for emotional processing

3.2.1 The right hemisphere (RH) hypothesis

One of the oldest hypotheses of emotion in the brain is the RH hypothesis, which proposes that the RH is dominant over the LH for emotional processing, irrespective of valence (Borod, et al., 1996; Carmon & Nachshon, 1973; Heilman, et al., 1975; Safer, 1981; Safer & Leventhal, 1977; Schwartz, et al., 1975; Silberman & Weingartner, 1986). Support for the RH hypothesis has been the strongest from studies involving the perception of emotion.

Past research that has examined the ability of individuals with unilateral lesions to comprehend emotional material has implicated RH involvement for the interpretation of emotional stimuli. Heilman, et al. (1975) found that patients with RH lesions had greater difficulty detecting emotional messages conveyed by speech intonations than patients with LH lesions. Similarly, Tucker, et al., (1977), found that patients with RH lesions had difficulty discriminating whether pairs of sentences that had the same words, were spoken with the same or different intonations. When asked to identify the emotion conveyed by the content of the story however, the RH lesion patients performed as effectively as the controls. This finding indicates that the patients with RH lesions had not lost the concept of different emotions, but had difficulty with the perceptual cues of emotion.
Borod, Andelman, Obler, Tweedy and Welkowitz (1992) further observed impaired emotional perception with RH damage when patients with RH lesions were asked to perform a task involving lexical emotional perception. After being presented with positive and negative emotion, and non-emotional lexical perception tasks, the patients were asked to identify and discriminate between the emotional and non-emotional words and sentences. In comparison to the patients with LH lesion and the control group, the patients with RH lesion were significantly impaired at emotional identification and discrimination, regardless of emotional valence. Borod, et al. (1992) subsequently argued that emotional processing involves strategies and functions for which the RH is dominant.

The effect of RH damage is not limited to impaired emotional perception but has also been found to impair emotional expression. Impaired verbal emotional expression was observed by Borod, et al. (1996), who examined discourse reports of emotional and non-emotional experiences of unilateral lesion patients and matched controls. Borod, et al. found that the patients with RH lesions revealed less appropriate word choice, and produced words with lower emotional intensity than did patients with LH lesions, and the controls.

Reduced emotional facial expressions have also been reported in patients with RH lesion. Buck and Duffy (1980) and Borod, Koff, Lorch, and Nicholas (1985) found that the facial expressions made by patients with RH lesion as they viewed emotionally evocative slides were significantly less expressive than those made by patients with LH lesion, and normal controls. Blonder, Burns, Bowers, Moore, and Heilman (1993) replicated these findings after videotaping semi-structural interviews between unilateral lesion patients and their spouse, and rating the facial expressivity of the patients. In comparison to the patients with LH lesion, and to the normal controls, the patients with RH lesion displayed significantly less facial expressivity. Blonder, et al. (1993) concluded that the RH mediates expressivity of emotion during spontaneous social interaction.

Support for the RH hypothesis of brain lateralization for emotional processing has also been obtained from neuropsychological research on neurologically normal participants. One such neuropsychological study is
that of Nagae and Moscovitch (2002) who used the divided visual field technique to investigate hemispheric differences in the memory of emotional and non-emotional words. The researchers successively presented emotional and non-emotional words to both visual fields at 180 msec, and at the end of each stimulus set, asked participants to recall as many words as possible. Regardless of the visual field of presentation, the recall of positive and negative emotional words was significantly better than the recall of non-emotional words. The difference in recall between the emotional and non-emotional words however, was greater for the words presented to the left visual field (LVF) than to the right visual field (RVF). The better recall of positive and negative emotional words presented to the RH than to the LH suggests that the RH is dominant for emotional explicit memory and recall (Nagae & Moscovitch), regardless of valence.

In an earlier dichotic listening study, Camon and Nachshon (1973) asked participants to listen to dichotic pairs of emotion eliciting sounds (laughing, crying, and shrieking from a man, woman and child) and indicate the sound they heard by pointing to an illustration depicting the characteristics of the sound. Nineteen of the twenty-five participants were more accurate at identifying the stimulus that was presented to the left ear, thus the RH. Similarly, in two separate studies examining emotional prosody and brain lateralization, Bryden and MacRae (1989), and Erhan, Borod, Tenke, and Bruder (1998) presented nonsense syllables stated with emotional tones dichotically to participants, who were asked to respond to a target emotion. The results indicated that the target prosodic emotion was recognised with more accuracy when presented to the left ear than the right ear. The findings were interpreted as providing further support for the RH hypothesis.

Neuroimaging studies have provided further insight into the brain lateralization of emotional processing, providing additional support for the RH hypothesis. A study by Gandour, et al. (2003) used fMRI to examine how the brain processes linguistic and affective prosody. The researchers asked Chinese and English participants to make discrimination judgements of intonation and emotion (happy, angry and sad) from semantically neutral Chinese sentences. The Chinese language was selected because it is a tone language in which both intonation and emotion is signalled prosodically. When comparing emotion to
intonation, the fMRI showed that the anterior and posterior prefrontal regions were activated in the RH only, for both Chinese and English participant groups. This finding supported the earlier findings of Buchanan, et al. (2000) who also used fMRI to investigate the neural areas involved in the recognition of emotional prosody and verbal components of spoken language. For the study of Buchanan, et al., participants were asked to discriminate between words based on either expressed emotional tone or phonemic characteristics. The fMRI contrasts comparing language detection with emotion detection showed significantly lateralized activity in the frontal lobes. Increased right frontal activity was observed during emotional detection and increased left frontal activity was observed during verbal detection.

Despite the support that has been offered to the RH hypothesis from differing participant groups and methodologies, there has been some evidence of a valence effect in brain lateralization for emotional processing. The valence hypothesis of brain lateralization for emotional processing is outlined next.

### 3.2.2 The valence hypothesis

A more recent conceptualisation of emotion in the brain is the valence hypothesis which proposes that brain lateralization for emotional processing depends on emotional valence. More specifically, that the RH is dominant for processing negative emotional stimuli and conversely, that the LH is dominant for processing positive emotional stimuli (Canli, et al., 1998; Davidson, et al., 1979; Jones & Fox, 1992; Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, et al., 1983; Silberman & Weingartner, 1986). Early insights indicating that the processing of positive and negative emotions might be separately lateralized in the brain, derived from observations of the emotional expressions displayed by patients with unilateral brain lesion.

General observation of the emotions expressed by patients with unilateral lesions showed that patients with a LH lesion were more likely to report, or display, feelings of despair and sadness. In contrast, patients with a RH lesion were more likely to report, or display, indifference-euphoric reactions (Canli, et al., 1998; Gainotti, 1972; Sackheim, et al., 1982). Sackheim, et al. examined cases of pathological
laughing and crying, in which patients showed spontaneous uncontrollable displays of emotion that were uncorrelated with objective events. The researchers found that patients with pathological laughter were three times more likely to have a RH lesion than a LH lesion, whereas pathological crying was twice as frequent in patients with a LH lesion. Sackheim, et al. concluded that the two sides of the brain differ in subserving positive and negative emotion states, supporting the prediction of the valence hypothesis. Sackheim, et al. also examined patients with uncontrollable emotional outbursts accompanying epileptic seizures. Of ninety-one patients showing outbursts of laughing, LH hyperexcitability was twice as likely as RH hyperexcitability. Of six cases of crying, four patients were found to have RH hyperexcitability than LH hyperexcitability. The model of brain lateralization for emotional processing that emerges from these findings, is one in which the LH subserves positive emotions, and the RH subserves negative emotions.

Extreme emotional reactions have also been reported after unilateral injection of sodium amobarbital into the carotid artery (the Wada test). To determine speech lateralization prior to surgery, sodium amytal was often injected into the left or right carotid artery where the sedating effects were confined to one hemisphere, and a simple speech performance task indicated speech lateralization (Tucker, 1981). Terzian (1964) found that the most obvious change with the Wada test involved affect, with a depressive response following LH sedation, and inappropriate euphoria following RH sedation. Similarly, when unilateral seizures were induced with Electro-Convulsive Therapy (ECT) in psychiatric patients, Deglin and Nikolaenko (1975) observed depression and dysphoria following LH seizures, and euphoria following RH seizures. These differing emotional responses, whether produced as a result of unilateral lesion, the Wada test, or induced seizure, have not always been consistently reported however. There have been some reports of a similar emotional characteristic with one hemisphere but not the other, reversed emotional hemispheric responses, or no production of emotional characteristics from either hemisphere (Gainotti, 1972; Sackeim, et al., 1982).

The most cited neuropsychological studies that support the valence hypothesis using neurologically normal samples are those by Reuter-Lorenz and Davidson (1981) and Reuter-Lorenz, et al. (1983). The researchers employed a bilateral visual field paradigm in which an emotional facial expression was
presented to one visual field, and a neutral expression of the same person was presented to the other visual field for a brief duration. Participants were asked to identify the visual field containing the affective face. The results indicated that responses to the positive (happy) expressions were faster and more accurate when they were presented to the RVF than to the LVF. Responses to the negative (sad) stimuli however, were faster and more accurate when presented to the LVF than to the RVF. Reuter-Lorenz et al. (1981, 1983) concluded that their results support the valence hypothesis of differential hemispheric specialization for positive and negative emotion.

Jones and Fox (1992) used electroencephalography (EEG) to investigate differences in brain lateralization during the experience of emotions, and whether differences were related to personality style. Participants who were rated with high positive and negative affectivity on Tellegen’s Multidimensional Personality Questionnaire, were asked to view emotionally evocative film clips and rate the intensity of the emotions they experienced. Analyses of the EEG data indicated differences in regional activation during the emotional film clips, especially for happy and disgust emotions. In support of the valence hypothesis, the RH was more active when processing the negative components of the film, and the LH more active when processing the positive components.

The findings of Jones and Fox (1992) support those obtained in the earlier study of Davidson, et al., (1979) who examined frontal and parietal EEG asymmetries as participants viewed portions of a television show that varied in emotional content. The participants were asked to indicate when they liked and disliked the material shown in the television show. The results indicated that there were differential activation asymmetries in response to positive versus negative emotional events, which were observed predominantly over the frontal region. In the frontal lobes, the LH was more active during the segment perceived by the participants as positive, and the RH was more active during the segment perceived as negative. The EEG over the parietal regions displayed consistent RH activation during all periods of emotion. Therefore, brain lateralized activation patterns depended on mood valence in the frontal areas, but favoured the RH regardless of valence in the posterior regions.
Direct support for the valence hypothesis from functional neuroimaging studies has remained elusive. Canli, et al., (1998) claim that the failure of imaging studies to replicate the neuropsychological observations supporting the valence hypothesis, may be due to differences in study design or methodology. For example, many imaging studies have not been explicitly designed to test the valence hypothesis as they have only assessed brain activation in response to negative versus neutral stimuli, which eliminates the chance to compare brain laterality patterns across valence types. It is also impossible to determine whether the brain laterality patterns associated with the emotive stimuli in these studies, is only associated with negative emotions or with emotion in general. Therefore, Canli, et al. conducted an fMRI study designed explicitly to test the valence hypothesis, where both positive and negative valenced pictures, controlled for arousal, were presented in alternating blocks to fourteen female participants. When the experience of valence was equated for arousal, brain activity was lateralized to the LH for the viewing of positive pictures and towards the RH for the viewing of negative pictures. As with the EEG study of Davidson, et al., (1979), the activation in response to the affective stimuli was most consistently observed in the frontal lobe. Apart from directly supporting the valence hypothesis and the earlier EEG study of Davidson et al., the findings of Canli, et al. also suggest that the frontal lobe is primarily involved in processing emotion by valence.

3.2.3 Partial support for the RH and valence hypotheses

Research on brain lateralization for emotional processing has not always produced results supporting either the RH hypothesis or valence hypothesis. Findings from past research have also shown bilateral involvement for processing positive affect, with RH involvement for processing negative affect. This finding was observed by Dimond, Farrington, and Johnson (1976) who asked participants to view three films (a cartoon, a surgical operation, and a travel film) while wearing specially designed contact lens, which the researchers argued would restrict the viewing of the films to either the LH or RH. The participants then rated each film on a scale of one to nine, on four dimensions of humorous, pleasant, horrific and unpleasant. The films that were presented to the RH were rated as more unpleasant and
horrific than the films presented to the LH. No significant differences between the hemispheres for the categories humorous or pleasant were observed.

Bilateral involvement for processing positive affect with RH involvement for the processing of negative affect was also observed by Asthana (2001). Asthana presented pairs of photographs simultaneously to the visual fields for 150 ms, so that one photograph was displayed to one visual field, and the other photograph displayed to the opposite visual field. The pairs of photographs comprised facial composite (right, right and left, left, that is, one half of the face was matched with its mirror-image) and hemifacial (right, left and left, right) faces depicting happy or sad expressions. Participants were asked to select the photograph that looked more emotionally expressive. Asthana found that sad photos presented to the LVF were more likely to be judged as more expressive, however there was no hemispheric advantage for happy photographs. Based on the results, Asthana argued that negative emotions are relatively strongly lateralized to the RH, whereas positive emotions are less lateralized and processed bilaterally.

The findings of Dimond, et al. (1976) and Asthana (2001) partially support both the valence and RH hypotheses. The processing of positive valence by the LH did not reach statistical significance to support the valence hypothesis, and the RH did not process both the positive and negative emotions as predicted by the RH hypothesis.

3.2.4 Two hypotheses or one?

It is clear from the literature that findings from research examining brain lateralization for emotional processing have generally favoured either the RH hypothesis or the valence hypothesis, whilst sometimes not favouring either. Rather than treating the two main hypotheses as separate, Hellige (1993) considered reconciling the two, suggesting that they may somehow coexist. As such it was proposed that the RH is dominant for emotional processing, however, the level of activation of the RH determines whether the emotion expressed or perceived is positive or negative. More specifically, over-activation of the RH would
be associated with negative emotion, and under-activation of the RH would be associated with positive emotions (Hellige).

In an alternative explanation, Davidson (1992) proposed that the anterior regions of the hemispheres are differentially specialized with regard to experiencing emotion, with the left frontal region being active during the experience of positive emotion, and the right frontal region being active during the experience of negative emotion. Yet, the RH may be dominant for the perception of emotion, irrespective of valence. Although the proposal of Davidson (1992), and the results from the EEG study of Davidson, et al. (1979) suggest a possible relationship between the valence and RH hypotheses, with the valence hypothesis being related more to the experience of emotions, the findings from Reuter-Lorenz and Davidson (1981) and Reuter-Lorenz, et al. (1983) have shown that the valence hypothesis can also relate to the perception of emotion, more specifically for the perception of emotional faces.

Rather than attempting to merge the RH and valence hypotheses into one, other researchers (Silberman & Weingartner, 1986; Tucker, 1981) have suggested that the contradictory nature of the literature in regards to the brain lateralization for emotional processing may be due to the components of emotion that are studied, and how they are elicited. For example, depression and fear could be rated equally negative but could be expected to have different implications for neuropsychological activation patterns and information processing (Tucker). Furthermore, Silberman and Weingartner argue that uncontrolled participant and behavioural variables have contributed to the lack of consistent results. For example, brain lateralization is known to differ for each sex, however many studies of brain lateralization for emotional processing have not controlled for sex by failing to recruit both males and females (Asthana, 2001; Canli, et al., 1998), or by not treating sex of the participant as a factor in their analyses. Lee et al. (2002) support this argument, claiming that brain lateralization of emotional processing is sex and emotion specific.

Although relatively consistent findings have been observed from research examining sex differences in the brain lateralization of spatial and verbal functioning, findings from research examining sex differences in
brain lateralization for emotional processing has failed to provide the same consistency. Sex differences in brain lateralization for emotional processing are discussed in the next section.

3.3 Sex, emotion, and brain lateralization

Although sex differences in verbal and spatial processing are well documented, sex differences in emotional processing are less established. The general opinion is that females are better at expressing emotions than males, which has been observed mainly from non-verbal behaviours, such as smiling and gesturing while viewing emotion-eliciting stimuli (Barr & Kleck, 1995; Buck, et al., 1974; Kring & Gordon, 1998; Moscovitch & Olds, 1982), and from research examining sex differences in facial expressions (Ladavas, Umiltà, & Ricci-Bitti, 1980; Rahman, et al., 2004; Thayer & Johnsen, 2000). The developmental perspective suggests that males and females learn different rules for the expression and perception of emotion (Brody, 1985). Females believe that their emotional expressiveness is a true indicator of what they are feeling, whereas males learn to distance their feelings from their expressive reactions (Griffitt, May, & Veitch, 1974).

Led by the findings from research examining sex differences in emotional identification and perception (Hall, 1978; McClure, 2000; Rahman, et al., 2004; Thayer & Johnsen, 2000), it has also been argued that females possess the complementary ability to make fine discriminations when judging emotional stimuli. Males, however, are believed to lack the emotion discriminating ability of females (Cupchik & Poulos, 1984). The findings from research examining sex differences in emotional perception are mixed, with some studies reporting a female advantage for identifying and distinguishing emotional stimuli (Ladavas, et al., 1980; Rahman, et al., 2004; Thayer & Johnsen, 2000) and other studies reporting no significant sex differences (Grimshaw, Bulman-Fleming, & Ngo, 2004; Herrero & Hillix, 1990).

Despite the research that has failed to observe a sex difference in emotional processing, the general perception is that females are better at decoding emotional information than males. Whether this means that there is a sex difference in the brain lateralization for emotional processing remains unclear. As
outlined Chapter Two, sex differences for spatial and verbal functioning have often been attributed to sex differences in brain lateralization for those functions. It could therefore be argued that sex differences in emotional processing are reflecting a sex difference in brain lateralization for emotional processing. The question of whether there is a sex difference in brain lateralization for emotional processing however, remains unanswered due to inconsistent findings in the literature.

The earliest evidence suggesting that the sexes may differ in brain lateralization for emotional processing came from the observation that unilateral brain lesions resulted in differing emotional expressions between the sexes. Sackeim, et al. (1982) observed that the associations between predominant side of brain damage and type of emotional outburst differed between the two sexes. Male patients were equally likely to present laughing outbursts as crying outbursts following LH damage, whereas the female patients were three times more likely to present crying than laughing following LH damage. Both males and females were more likely to manifest laughing rather than crying subsequent to RH damage, however this effect appeared to be stronger for the male patients. Generally, pathological laughing was more frequent among male than female patients, whereas pathological crying was more common for female than male patients. Based on the results, Sackeim, et al. suggested that the degree of brain lateralization in mechanisms subserving positive and negative emotional experience differs for the two sexes. In terms of the competing hypotheses of brain lateralization for emotional processing, the female patients in the study of Sackeim, et al. presented emotional behaviour that was more in line with the proposal of the valence hypothesis. The male patients however, presented a pattern of emotional expression that implicated bilateralization for processing positive emotion and RH dominance for processing negative emotion, thus partially supporting both the RH and valence hypotheses.

Research examining sex differences in brain lateralization for emotional perception on neurologically normal participants has failed to replicate the findings of Sackeim, et al. (1982), or provide consistent results. Lee et al. (2002) also obtained results in support of the valence hypothesis by one of the sexes, however unlike Sackeim et al., it was observed for males not for females. Lee, et al. used fMRI to examine brain activation as neurologically normal participants viewed happy and sad facial expressions.
Lee, et al. presented pairs of photographs (either a happy or sad facial emotion matched with a neutral facial emotion) for three seconds to participants and asked them to manually respond to the pair that contained a target emotion (happy or sad). Brain laterality indexes indicated that greater LH activation was associated with the viewing of happy faces for both the male and female participants. When viewing faces depicting sad emotions however, greater LH activation for females and more RH activation for males were observed.

Also using facial stimuli, Killgore (2000) failed to find a sex difference in the accuracy of identifying the emotion of facial expressions (pleasure, neutral, disgust) that were presented to participants via videotape for 5 seconds. Interestingly, Killgore found that when the orientation of the face was laterally reversed, the perceptual accuracy of males enhanced significantly. It has been argued that emotional facial expressions are often asymmetrical, where the left half of the face displays the stronger affective intensity cues, which has been attributed to the RH being dominant for emotional expression (Christman & Hackworth, 1993; Moreno, Borod, Welkowitz, & Alpert, 1990; Sackeim & Grega, 1987; Sackeim & Gur, 1978). Killgore argued that reversing the expression of the faces placed the cues for affect from the poser's left face into the LVF of the participant, therefore permitting greater processing of the affective cues by the hypothesised emotionally dominant RH.

Similarly, a RH advantage for males was observed by Graves, Landis, and Goodglass (1981) when investigating sex differences in the visual recognition of emotional and non-emotional words. The researchers presented a set of emotional, non-emotional, and nonsense words to each visual field separately for a duration of 150 msec, and asked participants to respond when they identified a “real” word. The male participants showed an overall RVF superiority due to the verbal nature of the stimuli, however emotional words were identified with significantly greater accuracy than non-emotional words that were presented in the LVF. For the females, no overall visual field advantage was observed for the processing of the stimuli, however a larger effect of a RVF superiority for the recognition accuracy of emotional than non-emotional words was evident. Thus, the results from the study of Graves, et al. (1981) were not consistent between the sexes.
In addition to inconsistent findings of a sex difference, some research has failed to find any sex differences in brain lateralization for emotional processing. Bulman-Fleming and Bryden (1994), and Herrero and Hilliz (1990) reported a RH advantage for both males and females when asked to identify a target emotional tone (either positive or negative) on a dichotic listening task. This finding suggests that there are no sex differences for the brain lateralization of emotional perceptual processing, and that the RH is dominant for processing emotional information, regardless of sex.

In summary, the results from differing neuropsychological techniques, neuroimaging, and both clinical and non-clinical groups of sex differences in brain lateralization for emotional processing have largely been inconsistent. As suggested by Grimshaw, et al. (2004), it may be that procedural variables influence the type of sex difference observed, and perhaps such inconsistency in the findings is a reflection of the fact that there may simply be no sex differences in the brain lateralization for emotional processing.

3.4 Summary of Chapter Three

The literature on brain lateralization for emotional processing is clearly divided between two hypotheses. The RH hypothesis proposes that the RH is dominant for all forms of emotional processing (Borod, et al., 1996; Carmon & Nachshon, 1973; Heilman, et al., 1975; Safer & Leventhal, 1977; Safer, 1981; Schwartz, et al., 1975; Silberman & Weingartner, 1986). Whereas, the valence hypothesis proposes that brain lateralization for emotional processing depends on emotional valence, where the RH is dominant for processing negative emotions, and the LH is dominant for processing positive emotions (Canli, et al., 1998; Davidson, et al., 1979; Jones & Fox, 1992; Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, et al., 1983). Both the RH and valence hypotheses have received empirical support from research on unilateral lesion patients and neurologically normal participants, using neuropsychological, electrophysiological, and neuroimaging techniques. Furthermore both hypotheses have received support from research investigating both emotional expression and perception. Attempts have been made to consider the RH and valence hypotheses as one coexisting process (Davidson, 1992; Hellige, 1993), however research
has generally approached brain lateralization for emotional processing as involving two competing hypotheses. Whereas sex differences in brain lateralization for spatial and verbal functioning have been a relatively consistent finding, reports of sex differences in brain lateralization for emotional processing have been inconsistent and thus definitive conclusions remain unclear. Further research is required to examine brain lateralization for emotional processing in general, and also for each sex.

It is interesting to note that depression, which is one of the most common affective disorders, is associated with altered brain lateralization. Furthermore there is a clear sex difference in the incidence of clinical depression in which females are twice as likely to be diagnosed as males (Kessler, 2003; Kuehner, 2003). The next chapter outlines depression as a clinical affective disorder and presents empirical evidence of altered brain lateralization in depressed patients. Sex differences in both the incidence of clinical depression and in brain lateralization of depressed patients is also discussed.
CHAPTER FOUR
CLINICAL DEPRESSION

4.1 Chapter Four overview

Feelings of depression are universal and heterogeneous, and most people experience feelings of sadness, lethargy and inadequacy that last for a short period of time. For patients diagnosed with clinical depression, these feelings differ in their intensity and duration, and they may emerge without clear precipitant. Although the prominent feature of depression is a disturbance of mood, there has been a growing interest in the cognitive impairment often associated with depression.

There are various aspects of cognitive functioning that distinguish depressed from non-depressed adults. Abnormalities in brain lateralized cognitive functions represents one of the more frequent correlates of clinical depression. There is considerable converging evidence suggesting that brain lateralized functions are impaired during the depressed state. More specifically, the majority of neuropsychological studies (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Lior & Nachson, 1999; Liotti, et al., 1991; Miller, et al., 1995; Rogers, et al., 2002) have reported evidence that there is impaired performance of the RH in depressed patients. Electrophysiological studies (Kano, Nakamura, Matsuoka, Iida, & Nakojima, 1992; Robinson & Szetela, 1981; Schaffer, Davidson, & Saron, 1983; Sinyor, et al., 1986) have also implicated the involvement of the frontal lobe and posterior RH in depression.

Another consistent finding in research on depression is that females constitute the majority of patients diagnosed with clinical depression, approximately doubling that of males (Kessler, 2003; Kuehner, 2003). Although a vast amount of research has been devoted to examining sex differences in brain laterality, research examining brain lateralization for each sex in a clinically depressed group is lacking.

Chapter Four begins with Section 4.2 providing an outline of the prevalence and classification of adult clinical depression as outlined by the Diagnostic and Statistical Manual for Mental Disorders (DSM)
(American Psychiatric Association [A.P.A.], 2000), the most commonly used classification system for the depressive disorders. A review of the popular rating scales used to measure the severity of depression are then presented, with particular focus on the Hamilton Rating Scale for Depression (HAMD) and the Montgomery-Åsberg Depression Rating Scale (MÅDRS), the rating scales that were selected for use in this research. The proceeding Section 4.3 presents evidence from electrophysiological and brain lesion research of the cortical areas involved with depression, and the neuropsychological evidence of disturbed brain laterality associated with depression. Section 4.4 of this chapter reviews the sex differences observed in the prevalence of clinical depression, followed by discussion of the lack of research examining the effect of clinical depression on brain lateralized functions for each sex.

4.2 Classification and prevalence of clinical depression

The clinical depressive disorders listed in the DSM-IV include: Major Depressive Disorder (MDD), Dysthymic Disorder, and Bipolar Disorder.

According to the DSM-IV (A.P.A., 2000), MDD includes depressed or irritable mood and involves the presence of five or more of the following symptoms for two weeks or more: diurnal variation in mood; reduced appetite, sleep, or weight; fatigue; decreased libido; menstrual disturbances for women; difficulty concentrating; feelings of worthlessness and guilt; lack of interest; and, in moderate to severe cases of MDD, recurrent thoughts of death.

The lifetime risk for MDD, also known as unipolar depression, is between 10% and 25% for women and 5% to 12% for men (A.P.A., 2000; Hauenstein, 2003). A family history of depression is believed to double an individual’s risk of MDD (Winokur & Tanna, 1969). Although MDD may develop at any age, the average age of onset is in the 20s (A.P.A.).

The mean length of a MDD episode is approximately seven to nine months, although for 15% to 20% of people it can last two years or more. Rates of remission indicate that approximately 90% of patients remit
within one to two years, while the remainder experience distinctly longer depressive episodes or develop severe depression. After recovering from MDD, adults often experience negative attributions, sub-clinical symptoms, or impairment of global functioning (Maj, Veltro, Pirozzi, Lobrace, & Magliano, 1992; Parker & Roy, 2001). The probability of recurrent depression by two years is 40%, and 70% by five years. Those with lower socioeconomic backgrounds and education levels are vulnerable to recurrent episodes, as are those who develop their first episode of depression at a younger age (Parker & Roy).

The DSM-IV (A.P.A., 2000) criteria for Dysthymic Disorder and MDD differ from one another in both severity and chronicity. Dysthymia requires the presence of a sad or irritable mood for at least one year and only two of the symptoms listed for MDD. Dysthymia lasts for a mean length of four years and distinctly increases the likelihood of an episode of Major Depression within two to three years of its onset (Parker & Roy, 2001). Adolescents who develop MDD subsequent to dysthymia are described as suffering from double depression, and tend to have longer, severe and more recurrent depressive episodes. The prevalence rate of dysthymic disorder is 8% in adults (Birmaher, et al., 1996).

Approximately 10% to 15% of adults with recurrent MDD subsequently develop Bipolar Disorder (A.P.A., 2000). In Bipolar Disorder, both mania and MDD are part of the illness spectrum (Hauenstein, 2003; Nolen-Hoeksema, 1987). Mania is characterized by an expansive or irritable mood accompanied by an inflated self-esteem, decreased need for sleep, extreme talkativeness, and flight of ideas. Furthermore, attention is distractible, thoughts and activities are expansive, and auditory and visual hallucinations are sometimes present (Hauenstein). Typically, a manic episode immediately precedes or follows the depressive phase of the illness. The number of manic episodes varies for each individual (Hauenstein).

The incidence of Bipolar Disorder is lower than that of MDD. It has generally been assumed that there are no sex differences in the incidence of bipolar depression, yet in a review by Clayton (1981), women predominated among people diagnosed with Bipolar Disorder as well as those with MDD. Bipolar Disorder has more of a genetic predisposition than MDD, with approximately 80 to 90% of individuals with Bipolar Disorder having a family history of a mood disorder (Winokur & Tanna, 1969).
4.2.1 Rating scales for depression

There are many rating scales purporting to assess the clinical construct of depression. Some researchers may assume that all depression scales assess the same construct, however, the selection of the instrument may influence the outcome of the study. These instruments are either completed by the participant (self-rating scales), administered by the interviewer (observer scales), or derived from the observations of others, such as nurses (Snaith, 1993). The first two are predominant in depression research.

Some of the popular self-rating scales include: Carroll's Rating Scale, the Zung Self-rating Depression Scale, and the Hospital Anxiety and Depression Scale (Snaith, 1993). Self-rating scales are easy to administer, however, the reliability of self-assessment is questionable (Snaith). They are subject to criticism for their construction of simple ‘yes / no’ responses to a long list of statements, and also for being too wide or too narrow in content validity (Snaith). Such scales are not useful for the seriously ill or semiliterate patients who are unable to deal with them. A number of scales have been devised to cover the whole range of symptoms in depression, however such all-inclusiveness has disadvantages. It is very difficult to differentiate some symptoms that look alike, yet are quite different and appear in different settings (Hamilton, 1960).

Some of the popular observer scales include: the Cronholm-Ottosson Rating Scale, the Melancholia Scale, and the Beck Depression Inventory (BDI) which can also be self-administered (Snaith). Two observer scales that have achieved prominent use in depression research are the 17-item HAMD and the MÅDRS (Leentjens, Verhey, Lousberg, Spitsbergen, & Wilmink, 2000). The HAMD and MÅDRS are described in more detail in the next two sub sections.
4.2.1.1 The 17-Item Hamilton Rating Scale for Depression (HAMD)

The HAMD was first published in 1960 in an attempt to improve on existing interview measures of depression. Over the years, modifications of the HAMD have resulted in several different versions. The original twenty-one item scale is the most widely used and is frequently cited for the severity assessment of depression (Veroff, Alexander, & Feiger, 2001). The first seventeen items of the scale are typically summed to yield a total score, therefore the scale is often referred to as the 17-item HAMD.

The HAMD has been found to have very good validity, high reliability, and is highly sensitive, that is, it can detect treatment-related symptom change (Veroff, Alexander, & Feiger, 2001). The scale was constructed on the basis of a study of the major symptoms observed in depressed patients admitted to hospital (Hamilton & White, 1959). Although most of the development work was conducted using an inpatient population, Hamilton anticipated that it would also be used in outpatient research, used to detect change over time for treatment studies, and be administered by a diverse group of clinically trained interviewers (Veroff, et al., 2001).

The items on the HAMD assess: depressed mood, guilt, insight, appreciation for life, insomnia (initial, middle and delayed), working capacity and interest, psychomotor retardation, agitation, anxiety (“psychic” and somatic), somatic symptoms (gastro-intestinal, genital and general), hypochondriasis, and weight loss (Hamilton, 1960). The four items that were excluded from the original 21-item HAMD scale to make it the 17-item HAMD were: diurnal variation, derealization, paranoid symptoms and obsessional symptoms. Hamilton removed these items because he believed that they were not a measure of depression or of its intensity, but rather symptoms that define the type of depression (Hamilton).

The HAMD was devised to be administered on patients already diagnosed as suffering with depression. As the main emphasis of the HAMD is on psychomotor symptoms and somatization of mood, researchers may be limited if they plan to examine a wider range of depressive features. An observer scale that can
be applied along with the HAMD to broaden the assessment of the depression is the MÅDRS, which is concerned exclusively with the “psychic” symptoms of depressive illness (Kearns, et al., 1982).

4.2.1.2 The Montgomery-Åsberg Depression Rating Scale (MÅDRS)

The MÅDRS was constructed in 1979 and has a more simple structure than the HAMD. Montgomery and Åsberg (1979) sought to invent a scale for rating the severity of depression where sensitivity and accuracy of change estimates were the major criteria being assessed. It is a time-efficient scale, composed of only ten items that are rated on a seven-point (0-6) scale (Snaith, 1993). The ten items included on the MÅDRS are core symptoms of depressive illness. These are: apparent sadness, reported sadness, inability to feel, inner tension, suicidal thoughts, lassitude, concentration difficulties, reduced sleep, reduced appetite, and pessimistic thoughts (Montgomery & Åsberg).

Like the HAMD, the most widely used strategy at present is to apply the MÅDRS for severity assessment after a diagnosis of depression according to the DSM-IV has been attained (Muller, Szegedi, Wetzel, & Benkert, 2000).

4.2.1.3 Why use the HAMD with the MÅDRS?

The HAMD and the MÅDRS are popular rating scales with high inter-rater reliability (Muller, et al., 2000). They have both been compared against each other, and have been found to perform equally, and be consistent in their severity findings, thus showing high concurrent validity and reliability in their ratings. Leentjens, et al. (2000) administered both the HAMD and MÅDRS to patients with Parkinson’s disease and depressive symptoms, in order to assess the concurrent validity of the scales in relation to the DSM-IV criteria for depression. The results indicated that both scales had very high concurrent validity, and the researchers concluded that both the HAMD and the MÅDRS could be used as reliable screening instruments. It was further concluded that maximum discrimination between non-depressed and
depressed patients can be reached, as application of the scales allows the highest sum of sensitivity and specificity (Leentjens, et al.).

Both scales assess different information, therefore the administration of both the HAMD and the MÅDRS widens the number of symptoms assessed. As mentioned, the MÅDRS obtains information about the patient’s “psychic” symptoms, but does not cover psychomotor symptoms, which is the emphasis of the HAMD (Benazzi, 1999; Kearns, et al., 1982).

The HAMD and MÅDRS reportedly have satisfactory correspondence in cut-off values (gradations) to separate depression severity categories (mild, moderate and severe depression). In a study by Muller, et al. (2000), which compared the HAMD ratings to those of the MÅDRS, 80% of patients were grouped in the same severity category. The use of both rating scales therefore also increases the reliability of the data by ensuring that the severity category that the patient has been assigned to is accurate.

4.3 The brain and depression

Electrophysiological studies and research with brain lesion patients (Schaffer, et al., 1983; Kano, et al., 1992; Robinson & Szetela, 1981; Sinyor, et al., 1986) have highlighted areas of the brain that are associated with depression. The most robust finding is that depression is associated with relatively less activity in the left than the right frontal lobe (Henriques & Davidson, 1991; Lior & Nachson, 1999) and reduced activity in the posterior RH (Lior & Nachson). In regards to brain lateralized functions, there is considerable evidence from neuropsychological research that depression is associated with impaired functioning of the RH (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Lior & Nachson; Liotti, et al., 1991; Miller, et al., 1995; Rogers, et al., 2002). This section begins with a review of the evidence from electrophysiological and brain lesion studies of the cortical areas and resting brain asymmetries involved with depression in Section 4.3.1. Neuropsychological evidence of disturbed brain laterality with depression is then presented in Section 4.3.2.
4.3.1 Cortical areas and resting brain asymmetries involved with depression

Research examining patients with unilateral brain lesions have generally found that hemispheric disruption leads to a disturbance of mood (Canli, et al., 1998; Gainotti, 1972). It has also been found that brain lesions that are closer to the frontal pole are more likely to produce severe mood disturbances (Robinson & Szetela, 1981; Starkstein, Robinson, & Price, 1987). This was observed by Robinson and Szetela, who found a significant inverse correlation between severity of depression and distance of the anterior border of left hemisphere (LH) lesion from the frontal pole. When patients with left posterior lesions were added to the sample, the correlation decreased. Sinyor, et al. (1986) found a positive relationship between the severity of post-stroke depression and proximity to the frontal pole in the LH, although they found a curvilinear relation in the right hemisphere (RH) so that both anterior and posterior lesions were associated with increased depression.

Several electroencephalography (EEG) studies examining the resting asymmetries in non-psychotic depressed patients have also yielded evidence of heightened activation of the right frontal hemisphere in depressed patients relative to that of the LH, and to that of non-depressed controls (Kano, et al., 1992; Schaffer, et al., 1983). Schaffer et al. examined resting frontal and parietal EEG asymmetries in a sample of depressed and non-depressed students, and found a significant group difference during the eyes closed condition, in which depressed patients showed greater right frontal activation compared to the non-depressed group. It has been suggested that the over-activation of the right frontal lobe may merely be the result of a complementary process from the under-activation of the left frontal lobe in depression (Hellige, 1993) or vice versa.

As activation of the RH has been associated with feelings of avoidance and withdrawal, and the processing of negative emotions (Reuter-Lorenz, & Davidson, 1981; Reuter-Lorenz, et al., 1983), increased activation in this region has been predicted to exacerbate negative affect in an individual, thus leading to the depressed state (Shenal, Harrison, & Demaree, 2003). Davidson and Fox (1988) concluded that relative right-frontal activation predisposes an individual to experience negative affect. Similarly, if the
LH is responsible for processing positive affect, as predicted by the valence hypothesis, then the reduction in LH activity may be related to a reduction in positive affect experienced in depression.

In addition to the frontal lobe asymmetries, depression has also been associated with decreased activity in the posterior RH. An EEG study by Schaffer, et al., (1983) reported that depressed patients showed less relative right parietal activation in contrast to non-depressed controls. This difference, however, did not reach statistical significance. Reduced right parietal activation as shown by EEG was also observed by Davidson, et al. (1985) who found that among the depressed patients, larger decreases in left frontal activation were associated with greater decreases in right parietal activation.

The findings from EEG research have been supported by neuroimaging studies that have compared the brain activity of depressed patients to non-depressed participants. Matthew, et al. (1980) found a global reduction in rCBF in depressed patients, in which the reduction appeared to be most manifest in the frontal regions. Similarly, using PET to examine glucose metabolic rates in the cerebral regions of depressed patients, Baxter, et al. (1989) observed that in comparison to the control group, the rate of glucose metabolism was significantly lower in the anterior LH for the depressed patients.

In summary, depression has been associated with an under-activation of the left anterior hemisphere, coupled with over-activation of the right anterior hemisphere. Under-activation of the right posterior hemisphere has also been implicated (Figure 4.1).
4.3.2 Lateralized brain function with depression

The strongest form of evidence of disturbed lateral brain function in depressed patients is the finding that depression is associated with a poorer contribution of one hemisphere in the performance of neuropsychological tasks. The most common report is that depression is associated with poorer performance on neuropsychological tasks that depend on RH activation, particularly of the parietal lobe.

Impaired RH functioning in depression was implicated by the study of Miller, et al. (1995), who compared the performance of depressed patients and a control group on tasks measuring LH and RH functioning (a word-finding task and a spatial dot localization task respectively). The MDD patients performed
significantly poorer on the spatial dot localization task compared to the control group, however performance between the control and depressed groups on the word finding task did not differ significantly. As such, the results of Miller, et al. suggest a RH dysfunction specific to depression.

The results of Miller, et al. (1995) were later replicated by the study of Henriques and Davidson (1997) who, as well as administering the same tasks as Miller et al., recorded EEG to measure hemispheric activation while participants completed the tasks. Like the results of Miller et al., the depressed patients were found to have a specific deficit in the performance of the spatial task, whereas no group difference in performance was evident for the verbal task. In regards to the EEG findings, no activation in the posterior RH regions was evident while the depressed sample performed the spatial task. This finding suggests that dysfunctional right posterior functioning resulted in impaired spatial functioning for the depressed patients.

Depressed patients have also been reported to exhibit specific deficits on the mental rotation task (MRT), which is considered a measure of right parietal lobe functioning (Ditunno & Mann, 1990; Harris, et al., 2000; Jordan, et al., 2001; Papanicolaou, et al., 1987; Tagaris, et al., 1997). This was observed by Rogers, et al., (2002) who asked depressed and non-depressed control participants to decide whether rotated figures were the same or mirror-imaged, despite differing in orientation. Although there was evidence to suggest that the depressed patients were performing the task through mental rotation, the overall RTs from the depressed group were significantly slower than the control group, and mental rotation for the depressed group slowed progressively with increasing angle of rotation relative to the mental rotation of the controls. Based on these results, Rogers et al. argued that the slower RTs of the MDD patients were indicative of impaired RH functioning. Similarly, when examining simple RTs to laterally presented visual stimuli, Liotti, et al. (1991) observed significantly slower RTs to stimuli presented in the left visual field (LVF) of acutely depressed patients, which was not observed for patients with generalized anxiety disorder, or for a group of non-depressed, non-anxious patients.
Kronfol, Hamsher, Digire and Waziri (1978) also observed a RH impairment with depression when examining changes in brain laterality with the improved depressed state. The researchers found that where electro-convulsive therapy (ECT) alleviated depression, there was an improvement in performance on neuropsychological tasks of RH functioning but not on tasks of LH functioning. Similarly, Wexler, and Heninger (1979) observed a relationship between the severity of a patient’s depression and degree of laterality found on a dichotic listening task. When patients obtained ratings indicative of psychotic thought and behaviour, their performance on the dichotic listening task was suggestive of reduced brain laterality. When the patients were retested during a state of symptom remission however, their performance indicated greater brain lateralization.

A reduction in RH performance in depressed patients has also been observed on tasks involving the perception of emotional stimuli. Most commonly, a reduced performance in identifying emotional facial expressions shown in the LVF has been observed for depressed patients, especially on tasks involving chimeric faces. The chimeric faces task measures emotional perceptual bias towards the LVF or right visual field (RVF) by asking participants to judge the emotion expressed on a chimeric face. Jaeger, et al. (1987) reported a reduction in LVF bias in patients with MDD compared to non-depressed participants, when rating which of a set of happy / neutral and neutral / happy chimeric faces looked happier. This finding suggests a RH impairment in the clinically depressed group when performing the chimeric faces task. Similar results were obtained by Kucharska-Pietura and David (2003) who asked depressed patients, unilateral brain damaged patients, and normal control participants to judge which emotion was shown on happy / sad and sad / happy chimeras. The researchers found that both the depressed and the RH damaged patients performed significantly poorer than the control participants and the LH damaged patients when identifying the emotions shown in the LVF.

Lior and Nachson (1999) also examined the judgement of positive and negative chimeric facial expressions by schizophrenic, depressed, and healthy control participants, and found that both the control and depressed participants judged schematic chimeric expressions on the basis of the emotion presented in the LVF. The LVF bias however, was considerably weaker for the depressed patients than for the
controls. Moretti, et al. (1996) flashed positive and negative facial expressions to a depressed and non-depressed group through a bilateral visual field design, in which an emotional facial expression was presented to one visual field, and a neutral facial expression of the same model was presented to the opposite visual field. Participants were asked to identify which side (visual field) displayed the emotional facial expression. For the non-depressed group, a LVF advantage in RT and accuracy emerged for the identification of the sad expressions, however no visual field difference in RT and accuracy was observed for the identification of the happy expressions. An overall RH advantage in RT and accuracy was also found for the non-depressed group. The results of the depressed group were somewhat similar to those of the non-depressed group, however no overall RH advantage was found, and the RH advantage for the identification of the sad expressions was only observed for the open-mouth expressions. Moretti, et al. (1996) concluded that their results were consistent with the literature implicating a RH deficit in depression. The fact that a stronger RH deficit in the performance of the depressed group was not observed for the study of Moretti, et al., may be due to the fact that the depressed group consisted of students who were not clinically depressed, but had received a self-rated score on a depression rating scale that was indicative of having depressive symptoms.

Lior and Nachson (1999) suggested that the judgement of emotional stimuli might be affected by the participant’s emotional state given that cognitive and emotional processes interact. This was observed by David (1989), who found that induced elation and induced depression increased the number of happy and sad choices respectively. Similarly, Mandal and Bhattacharya (1985) found that a depressed group recognized a sad face with more errors than a non-depressed group, and labeled other expressions as sadness when affective content was not recognized.

Although depressed patients have been found to perform better at identifying sad emotions (David, 1989; Mandal & Bhattacharya, 1985), David found that the magnitude of the “sad” bias observed in depressed patients did not appear to influence the magnitude of their visual field bias. The magnitude of the visual field bias, however, does appear to be influenced by the severity of the depression. This was the observation of Heller, Etienne, and Miller (1995) who asked students who were classified as either high or
low-depressed, to judge which of happy / neutral and neutral / happy chimeric pairs looked happier. The results showed that the high-depressed students had a significantly smaller LVF bias than the low-depressed students. Therefore the degree of RH impairment depended on the magnitude of the participant’s depression. Based on the study of Heller, et al. (1995), it appears that the greater the depression, the greater the decrement in RH functioning.

The finding of a RH dysfunction with depression is therefore a common and relatively consistent finding in neuropsychological research. It is not a conclusive finding however. A bilateral dysfunction in depression was proposed by Bearden, Hoffman, and Cannon (2001) following a meta-analysis on the results of research comparing the performance of brain lesion and affective disorder patients on the WAIS. The researchers reported that the Performance IQ / Verbal IQ ratio was almost identical for the affective disorder group and the bilateral brain damage group, but was significantly lower for the RH damage group. Bearden, et al. (2001) found that the test profile for affective disorder patients was significantly closer to that of the bilateral brain damage group than to the RH damage profile, and suggested that there may be bilateral diffuse cerebral involvement in affective disorders, rather than a predominant RH dysfunction.

Silberman, et al. (1983) also failed to observe a predominant RH impairment with depression. Silberman, et al. conducted a study that presented two tasks, one requiring verbal processing (name identity of two letters) and one amenable to either verbal or visuospatial processing (physical identity of two letters). As predicted, an overall RVF advantage for the task requiring verbal processing was found for the non-depressed control participants. In contrast no RVF bias was found for the depressed group, but rather a trend toward a LVF advantage. No significant visual field differences were observed for the physical identity task for either group, however, a trend toward a RVF advantage was observed for the depressed patients for physical matching the optional verbal-spatial task. Silberman, et al. suggested that the interpretation of their results be a matter of conjecture. The study consisted of a very small sample size (n = 10 depressed patients), and the reversed laterality pattern observed on the verbal task by the depressed patients failed to reach statistical significance. Furthermore, the study only recruited depressed females, thus not allowing for the possibility that brain laterality changes may be evident for both depressed males
and females. Despite suggesting that these results be considered as preliminary, Silberman, et al. did propose that the evident shift away from a RVF advantage on an obligatory verbal task by the depressed group, suggests qualitative shifts in function, rather than merely an altered balance in levels of activation between the hemispheres. The researchers proposed that like patients with LH lesions, the functional shift to the RH might be analogous to the recovery of language, obviously depending on a degree of RH plasticity. In addition, Silberman et al. proposed that people at risk of depression might be relatively less lateralized than non-depressed people to begin with, thus allowing them to still perform functions if one hemisphere becomes impaired. Interestingly, Silberman et al. linked their proposal of less brain lateralization in depression to the well-documented preponderance of females among depressed patients, and the fact that females have less consistent task lateralization than males. The researchers acknowledged however, that further research was required in examining brain laterality in depression, with larger sample sizes and the recruitment of both depressed males and depressed females.

The sex difference in the prevalence of depression is discussed in section 4.4 along with how research examining brain lateralization for each sex within a depressed group is lacking.

4.4 Sex differences and depression

The higher prevalence of depression among females than males is one of the most widely documented findings in psychiatric epidemiology. Despite interest in the large sex difference in the prevalence of depression and in sex differences in brain lateralization among non-depressed groups, research on these topics have rarely combined to investigate brain lateralization for each sex of a depressed group. Where research on brain lateralization in depression has considered sex as a factor, the depressed group has comprised of participants who were not clinically depressed but who received a score on a self-rating depression rating scale that was indicative of having depressive symptoms (Moretti, et al., 1996), or patients who did not meet the DSM criteria for clinical depression (Liotti, et al., 1991), or the depressed sample sizes have been small for each sex (Lior & Nachson). Section 4.4.1 will outline the higher ratio of
females diagnosed with depression, and Section 4.4.2 will highlight how there is a lack of research examining brain lateralization for each sex in a clinically depressed group.

### 4.4.1 Sex differences in the prevalence of depression

Although there is a higher prevalence of females with adult depression, pre-adolescent boys are more likely to become depressed than pre-adolescent girls (Hankin, et al., 1998). Around the ages of thirteen to fourteen however, there are higher rates of females than males with depression (Nolen-Hoeksema & Girdus, 1994), whereas the depressive affect and symptoms for males remain relatively constant (Hankin, et al.). Thus, sometime during adolescence a gender switch occurs where by females are more vulnerable to depression than males. The female dominance in the depressed population carries over from puberty into adulthood and peaks at perimenopause, the transition into menopause. Although females tend to predominate over all age groups following adolescence, the rates of depression increases dramatically for both sexes between the period from fifteen to eighteen years of age, and also the rate of depression for females rises to approximately double that of males (Amenson & Lewinsohn, 1981; Birmaher, et al., 1996; Hauenstein, 2003; Kessler, 2003; Kuehner, 2003; Niculescu & Akiskal, 2001; Parker & Roy, 2001).

Symptomatology has also been reported to differ between males and females, with females likely to report more symptoms than males (Angst & Dobler-Mikola, 1984; Hankin, et al., 1998). Females are more likely than males to exhibit appetite and weight changes associated with depression, experience sleep disturbances and feelings of worthlessness, indecisiveness and guilt. Females are also more likely than males to report feelings of somatic anxiety, expressed anger, hostility, and hypochondriasis (Frank, Carpenter, & Kupfer, 1988). Males are more likely to report somatic tension and cognitive disturbance, such as memory problems, poor concentration and sleep disturbance (Warren, 1983). It is unclear whether females are more depressed than males, whether males and females experience depression in differing ways that lead females to express more symptoms, or whether females receive labels of depression in ways different from males (Hammen & Padesky, 1977).
Several psychosocial and biological theories have been proposed to account for the sex difference in the prevalence of depression, however, not one of these explanations has been supported definitively by research. Psychosocial theories propose that it is the relatively restricted and unsatisfying roles available to females in society, and expectations from out-dated sex roles that increase a female’s risk of becoming depressed (Kessler, 2003; Weissman & Klerman, 1977). Psychological mechanisms of depression are also proposed to be congruent with female socialization experiences, such as learned helplessness or self-directed aggression (Hammen & Padesky, 1977; Weissman & Klerman). Biological approaches argue that the sex difference in the prevalence of depression is the result of differing hormones and hormone levels, and different genes between the sexes (Amenson & Lewinsohn, 1981; Kessler, 2003). It has also been argued that the sex difference in the prevalence of depression is an artifact of culturally sanctioned differences between females and males in the expression of symptoms, help seeking and coping behaviours (Hammen & Padesky; Hammen & Peters, 1977; Warren, 1983). It is unlikely that there is one explanation for the sex difference in the prevalence of depression.

In summary, females are twice as likely to be diagnosed with depression as males. Various factors are likely to be responsible for the sex difference in the prevalence of depression, factors that may vary across individuals. There is a sex difference in the expression of symptomatology, with females being more likely to report depressive symptoms than males. It is unknown, however, whether the experience of depression differs between depressed males and females. Although a considerable amount of research from neuropsychological and brain lesion studies has indicated that brain lateralization differs between the sexes, whether this extends to a sex difference in the hemispheric dysfunction observed in depression remains unknown and in need of further examination.

4.4.2 Sex differences, brain lateralization, and depression

As previously mentioned, there has been a lack of research investigating the differential impact of hemispheric dysfunction in depression on males and females. Most of the studies investigating brain
lateralization in depression have either recruited only women (Crews & Harrison, 1994a, 1994b; Silberman, et al., 1983) or have simply not reported the findings of each sex (Bruder, et al.; Cassens, et al.; Davidson, et al., 1985; Hennques & Davidson; Jaeger, et al., 1987; Kucharska-Pietura & David; Rogers, et al.), making it impossible to examine the effect that depression has on the brain lateralization of each sex separately. Research that has examined brain lateralization in depression, and included sex as a factor, have recruited self-rated “depressed” participants who were not clinically depressed (Moretti, et al., 1996), recruited patients who did not meet DSM criteria for clinical depression (Liotti, et al., 1991) or recruited very small sample sizes for each sex (Lior & Nachson).

As previously discussed, the majority of research on brain lateralization in depression suggests impaired RH functioning with depression. In non-depressed groups, research examining the effects of unilateral brain damage on cognitive functions has found that RH lesions result in a greater impairment in the performance of males than females (Inglis & Lawson, 1981, 1982; Lewis & Kampfner, 1987; McGlone, 1977). Yet, the weaker, or less lateralization of females than males is proposed to allow a greater degree of assistance from the unimpaired hemisphere to perform the task of the impaired hemisphere. Based on such observations, it could be predicted that a similar sex difference would be observed for the depressed group, where impairment in RH functioning would have a greater detriment to the RH performance of the depressed males than of the depressed females.

Alternatively, Heller (1993) proposed that it is just as likely that the distribution of asymmetric activation is identical in depressed males and females, which is consistent with the proposal of Silberman, et al. (1983) who suggested that people with depression may be less lateralized to begin with. If this is the case and patients with depression are less lateralized, then it could be predicted that the hemispheric dysfunction associated with depression would result in a similar brain lateralized performance between males and females. Despite these proposals, Heller and Silberman, et al. have not expanded their research to empirically examine whether hemispheric dysfunction associated with depression impacts brain lateralized functioning for each sex differently. Silberman, et al. (1983) only recruited female depressed patients and in contrast to the majority of the literature, proposed LH impairment with depression. The study found that
depressed females were still capable of performing the verbal task to some degree in the RH. Although this finding suggests that depressed females are bilateralized for verbal functioning as would also be expected for non-depressed females, it fails to establish whether a similar pattern would be observed for males with depression.

Similarly, Crews and Harrison (1994b) only recruited depressed females to examine functional asymmetry in depressed patients. Using a hand dynamometer as a measure of hemispheric motor functioning, the researchers hypothesized that poor performance may indicate anterior cerebral dysfunction contralateral to the hand tested. Substandard performance by both hands, however, would be interpreted as bilateral cerebral dysfunction. The depressed females displayed significantly less perseveration at the left hand than the non-depressed females, and a non-significant trend of less perseveration at the right hand. Crews and Harrison interpreted this finding as evidence of greater arousal within the RH for motor performance than the LH, however again, this interpretation could only be applied to depressed females. Whether depressed males would display similar brain laterality patterns is unknown. It is also noted that the depressed females in the study of Crews and Harrison were classified according to a self-reported depression rating scale (BDI), and had not been diagnosed as suffering from clinical depression. Therefore, the results observed by Crews and Harrison may not be an accurate representation of what would be observed by clinically depressed females.

The studies of Liotti, et al. (1991), Lior and Nachson, (1999), and Moretti, et al. (1996) also included sex as a factor in their analyses, and reported no sex differences in their findings. As previously detailed in section 4.3.2, Liotti, et al. found that depressed patients responded significantly slower to stimuli shown in the LVF than patients with generalized anxiety disorder and non-depressed, non-anxious patients. Lior and Nachson observed a weaker LVF advantage for the depressed group compared to a non-depressed control group in the identification of positive and negative emotions shown on chimeric faces. Reduced RH performance of a depressed group in comparison to a non-depressed control group was also observed by Moretti, et al. in the recognition of emotional expressions shown in the LVF. The results of these studies suggest that the deficit in RH functioning is evident for both male and female depressed patients.
The depressed samples used in these studies should be noted. Like the study of Crews and Harrison (1994b), the depressed sample used by Moretti, et al. comprised participants who were classified as “depressed” according to a self-reported depression rating scale (BDI), and had not been diagnosed as suffering from clinical depression. Similarly, the depressed sample of Liotti, et al. had received a classification of depression by a referring psychiatrist, but for each, the depressed symptoms were not of sufficient severity to satisfy the criteria of the DSM for MDD. Therefore, the results of these studies may not be an accurate reflection of what would be observed for clinically, DSM and psychiatrist diagnosed, depressed males and females. The depressed group of Lior and Nachson comprised small sample of ten bipolar patients (five males and five females) who were in a depressive state at the time of testing. Apart from being an extremely small sample size to detect any sex differences in performance, the depressed group was suffering from bipolar depression, therefore their findings are more specific to this diagnosis of depression.

Apart from the questionable “depressed” samples recruited in the studies that have included sex as a factor in their analyses, not one of these studies have discussed the findings in terms of brain lateralization for each sex. It is clear from the literature that further research needs to be conducted not only investigating brain lateralization in clinically depressed patients, but also investigating and discussing brain lateralization for each sex of a clinically depressed group.

4.5 Summary of Chapter Four

Depression is an affective disorder that essentially involves impaired mood with a loss of interest and pleasure (Shenal, et al., 2003). Females are twice as likely to be diagnosed with clinical depression as males (Amenson & Lewinsohn, 1981; Birmaher, et al., 1996; Hauenstein, 2003; Kessler, 2003; Kuehner, 2003; Niculescu & Akiskal, 2001; Parker & Roy, 2001). The DSM-IV is the most common classification system for depression which is often accompanied by rating scales for depression to determine if depressive symptoms are present in a person, and if so, the severity of such symptoms (Hamilton, 1960;
Montgomery & Åsberg, 1979; Snaith, 1993). Two of the more popular rating scales of depression are the HAMD and the MÅDRS.

An abnormal pattern of resting asymmetric activity in the frontal lobe due to relative hyperactivity over the right and / or relative hypoactivity over the left frontal lobe has been frequently observed in depressed patients. In addition, disturbed cognitive functioning has been observed for depressed patients, to which a RH dysfunction in performance is commonly reported (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Liotti, et al., 1991; Lior & Nachson, 1999; Miller, et al., 1995; Rogers, et al., 2002). Whether the disturbance in brain lateralized functioning is the same for male and female clinically depressed patients remains unclear, as research on brain lateralization in clinical depression has not focused specifically enough on the effect that clinical depression has on the brain lateralization of each sex separately. Therefore the most fundamental requirement for future research is the need to assess brain lateralization for cognitive and emotional functioning in both male and female clinically depressed patients.
CHAPTER FIVE
EXPERIMENTS, AIMS AND HYPOTHESES

The research conducted in this dissertation investigates areas of brain lateralization that are in need of further investigation and further clarity. Chapter Five presents the aims and hypotheses of the two experiments conducted in this dissertation, and indicates how they were examined. Each experiment is explained in greater detail in their respective chapters (Chapters Seven and Eight). A properly constituted research and human ethics committee at Swinburne University of Technology approved the research reported in this dissertation.

Experiment One

As outlined in Chapter Two, brain lateralization for spatial and verbal functioning can vary depending on a person’s sex. Males have been reported to be more lateralized for spatial abilities in the RH and for verbal abilities in the LH, whereas females have been reported to be less lateralized for these abilities, in which spatial and verbal abilities are shared between the hemispheres (Kimura, 1969; Lansdell, 1961; McGlone, 1977, 1980; Springer & Deutsch, 1993). Sex differences in cognitive performance have been attributed to sex differences in brain lateralization. The better performance of males than females on spatial tasks (Flor-Henry, 1978; Harshman, et al., 1983; Maccoby & Jacklin, 1974) has been attributed to their stronger lateralized spatial skills in the RH, which has been proposed to be more efficient than the bilateral spatial functioning observed for females (Levy, 1969, 1976; Levy & Reid 1978; McGlone, 1980; Springer & Deutsch, 1993). In contrast, the superior performance of females than males on verbal tasks (Acevado, et al., 2000; Herlitz, Airaksinen, & Nordström, 1999; Herlitz, Nilsson, & Bäckman, 1997; Monsch, et al., 1992) has been attributed to bilateralization of verbal functioning being more efficient than the unilateral specialization of the LH for verbal functioning in males (Springer & Deutsch). Unlike spatial and verbal functioning, sex differences in brain lateralization for emotional processing have not been established, with findings in the literature being inconsistent.
As evident from the literature review in Chapter Three, past empirical research has produced inconclusive findings in regards to brain lateralization for emotional processing. The findings of the reviewed literature have either supported the right hemisphere (RH) hypothesis or the valence hypothesis of brain lateralization for emotional processing, or have failed to offer full support to either. Further research investigating brain lateralization for emotional processing is evidently necessary. Apart from differentiating between the RH and valence hypotheses, the findings of brain lateralization for emotional processing in Experiment One may provide additional information pertaining to the areas of the brain concerned with affective disorders.

Experiment One investigates sex differences in brain lateralization for spatial and verbal processing. Experiment One also examines brain lateralization for emotional processing, in particular to determine whether there is also a sex difference in brain lateralization for emotional processing. In order to examine sex differences in brain lateralization for spatial and verbal processing, the performance of males and females was compared on neuropsychological tasks that assess spatial and verbal. These tasks were: the Mental Rotation Task (MRT) and the verbal fluency task respectively. Based on the findings of past neuropsychological research, it was hypothesized that:

H$_1$ : The male participants will mentally rotate the stimuli in the MRT significantly faster than the female participants.

H$_2$ : The female participants will generate significantly more words for phonemic and semantic verbal fluency than the male participants.

To examine brain lateralization for emotional processing and sex differences in brain lateralization for emotional processing, the performance of males and females was compared on the chimeric faces task. The chimeric faces task, administered in this dissertation, would account for some of the larger limitations of past research that has used chimeric faces to examine brain lateralization for emotional processing. Such limitations include: the duration that the chimeric face stimuli are presented, the use of both positive
and negative emotional expressions, and the task demand (question) asked of participants. As will be reviewed in Chapter Six, the majority of past research that has used a chimeric faces task to investigate brain lateralization for emotional processing has generally reported findings in support of the RH hypothesis (Campbell, 1978; Christman & Hackworth, 1993; David, 1989; Drebing, et al., 1997; Moreno, et al., 1990). Despite the changes in methodology to improve the chimeric faces task, it was expected that the RH hypothesis would be supported by the results of Experiment One. Therefore, it was hypothesized that:

H₃: Responses will be significantly faster and significantly more accurate to happy and sad emotional expressions shown in the LVF than in the RVF.

Due to the literature on sex differences in brain lateralization for emotional processing being inconsistent, a directional hypothesis predicting a sex difference in brain lateralization for emotional processing could not be justified. It became the research aim of Experiment Two to further investigate brain lateralization for emotional processing for each sex using the chimeric faces task, and to determine whether brain lateralization for emotional processing differs between males and females.

**Experiment Two**

As reviewed in Chapter Four, the majority of past neuropsychological research that has investigated disturbed lateral brain function in depressed patients, has found that depression is associated with poorer performance of functions lateralized to the RH (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Liotti, et al., 1991; Miller, et al., 1995; Rogers, et al., 2002). There is an extensive amount of research that has been conducted investigating sex differences in brain lateralization, and the effect of unilateral brain lesions on brain lateralized functioning for each sex. Research investigating how clinical depression affects brain lateralized functioning for each sex separately, however, is lacking.
Experiment Two investigates brain lateralization for spatial, verbal, and emotional functioning in a clinically depressed group, and also examines how clinical depression affects brain lateralization for spatial, verbal, and emotional processing for each sex. Apart from extending the literature on brain lateralization with clinical depression, research on the effect of clinical depression on brain lateralization for each sex could further our understanding of why there is a sex difference in the prevalence of clinical depression. To examine brain lateralization in clinical depression, task performance on the MRT, verbal fluency task, and chimeric faces task was compared between a clinically depressed group and a matched non-depressed control group, and also between each sex in each group.

Based on the findings of past research, it was predicted that clinical depression would be associated with poorer performance of functions lateralized to the RH. Therefore, for Experiment Two, it was hypothesized that:

Hₐ: The depressed group will perform significantly poorer than the non-depressed group on the task measuring RH functioning, the MRT, by mentally rotating the stimuli significantly slower than the control group.

Hₐ: Performance between the depressed and control groups on the task measuring LH functioning, the verbal fluency task, will not significantly differ, with the number of words generated for phonemic and semantic verbal fluency being non-significantly different between the depressed and control groups.

Hₐ: For the chimeric faces task, the depressed group will respond significantly slower and be significantly less accurate than the control group when identifying the sad and happy expressions presented in the LVF.
H₁: For the chimeric faces task, the depressed group will respond significantly slower and be significantly less accurate when identifying happy and sad emotional expressions presented in the LVF than in the RVF.

Evidence from previous research on unilateral brain damaged patients (Inglis & Lawson, 1981, 1982; Lewis & Kamptner, 1987; McGlone, 1977) suggests that hemispheric dysfunction is likely to result in a greater impairment of the functions lateralized to the impaired hemisphere for males, than for females. As females are less brain lateralized than males, with spatial and verbal abilities overlapping in both hemispheres (Kimura, 1969; Lansdell, 1961; McGlone, 1977, 1980; Springer & Deutsch, 1993), they are assumed capable of performing the task of the impaired hemisphere to some degree in the unimpaired hemisphere. Whereas because males are more brain lateralized for verbal and spatial abilities than females (Kimura, 1969; Lansdell; McGlone, 1977, 1980; Springer & Deutsch), assistance by the unimpaired hemisphere to support the impaired hemisphere is limited, and therefore their performance is relatively more impaired than females. It has been suggested that brain lateralization may be similar between depressed males and females (Heller, 1993), and that depressed patients may be less brain lateralized than non-depressed individuals (Silberman, et al., 1983). The proposals of similar, less brain lateralization between depressed males and females however, have not been empirically tested.

Silberman, et al. linked the higher prevalence of females diagnosed with clinical depression (Silberman, et al.) to the possibility that clinical depression is related to people who are less brain lateralized. Based on previous literature that has indicated greater impairment in brain lateralized cognitive functioning for males with unilateral brain lesion, than females with unilateral brain lesion, it was hypothesized that:

H₀: Depressed males will perform significantly poorer than the depressed females on the tasks measuring functions lateralized to the cerebral hemisphere that is impaired during clinical depression.

If clinical depression impairs functions that are lateralized to the RH, then the depressed males will be expected to perform poorer than the depressed females on tasks requiring RH functioning, such as the MRT, than on the task requiring LH functioning, such as the verbal fluency task. For the chimeric faces
task, the depressed males will be expected to respond slower and be less accurate than the depressed females when identifying emotional expressions shown in the LVF. Comparison of sex differences in task performance across the depressed and control groups would also indicate the effect of clinical depression on brain lateralized functioning for each sex.

As the experiments in this dissertation were concerned with measuring and comparing brain lateralized functioning, particular consideration had to be applied to the selection of the neuropsychological tasks administered, specifically whether they are adequate measures of brain lateralized spatial, verbal, and emotional functioning. The selection of each task, along with research evidence that each task is a measure of brain lateral performance is outlined in the next chapter. Findings of sex differences in the performance on each task are also presented.
CHAPTER SIX

NEUROPSYCHOLOGICAL ASSESSMENT

6.1 Chapter Six overview

Neuropsychological assessment has been the most commonly used method of assessing brain function, and is used to draw inferences about the functional characteristics of the brain based on a variety of standardized tests (Benton, 1994). Advances in technology have also seen the development of new methodologies for examining brain function, such as functional neuroimaging techniques like positron-emission tomography (PET) and functional magnetic resonance imaging (fMRI). These neuroimaging techniques measure brain activity by means of regional cerebral blood flow (rCBF) during cognitive tasks. Whilst these advances in technology have increased the capability for visualising the brain and uncovering brain regions associated with cognitive tasks, there are a number of disadvantages in using neuroimaging techniques. Chapter Six begins with Sections 6.2 and 6.3 outlining neuroimaging and neuropsychological testing as methods of assessing brain function, and the rationale for the use of neuropsychological assessment in this thesis. The neuropsychological tasks that were selected for this study are described within Section 6.3, along with evidence suggesting that the selected tasks measure brain lateralized functioning. Evidence from previous research of sex differences in performance on each of the selected tasks is also presented within Section 6.3.

6.2 Neuroimaging

There is no doubt that neuroimaging techniques such as PET and fMRI have added a new dimension to the assessment of brain-behaviour relationships. Studies using these techniques have often yielded results that complement earlier neuropsychological findings from research on both neurologically normal participants and brain-lesion patients (Chee, et al., 1999; Cuenod, et al., 1995; Fujii, et al., 2002; Harris, et al., 2000). Despite the reasonably consistent findings of neuroimaging studies with earlier
neuropsychological research, such techniques are not exempt from practical and methodological
limitations.

Questions have been raised about some of the fundamental assumptions that govern the application of
brain-imaging research, and the ability to infer fundamental information from activation patterns. One of
the main assumptions governing interpretation is that increases in cerebral blood flow (CBF) reflects
excitatory processes where the greater the increase, the greater the contribution of that cerebral area to
the task being performed (Fiez, 2001; Sergent, 1994). As argued by Sergent, however, the more
specialized cerebral structure in a given operation might in fact need less energy and thus not result in an
increase in CBF. Similarly, Sergent argued that the more practiced or habituated the participant is with the
task, the less energy that would be needed to perform the task and the less activation that may be
recorded. Neuroimaging research also assumes that the absence of a change in CBF implies no change
in cerebral activity (Fiez; Sergent). Whilst this is often a valid assumption, it has been argued that it does
not account for the possibility that increases and decreases in neuronal activity within a particular area
might be canceling themselves out and result in no detectable change, despite the fact that they were
actually involved in the task being performed (Sergent).

A number of methodological limitations also impact the accuracy and usefulness of the interpretations from
neuroimaging research. One of the more common methods used to draw inferences regarding cognitive
function from activation patterns, is the subtraction method. This method requires that two tasks
(experimental and control) differing along only one dimension be completed. The activation created by the
control condition is subtracted from that created by the experimental task, and the resultant regions where
activity levels differ significantly across the two conditions are thought to be relevant to the cognitive
process involved in the experimental task (Sergent, 1994). The validity of this method has been
questioned, as it cannot be known whether the observed differences are related to the cognitive processes
used to perform the experimental task or to other factors (Fiez, 2001; Poldrack, 2000; Sergent). For
example, participants are often asked to remember task instructions and experimental procedures, factors
which involve working memory which may subsequently activate the prefrontal cortex. Although many
methods of brain behaviour assessment require participants to remember task instructions, Sergent argues that the activation of such frontal structures may not necessarily occur for tasks that are performed in less artificial conditions. In addition, the subtraction method does not subtract out sensory, motor, or linguistic processes from the experimental task (Cabeza & Nyberg, 1997). Furthermore, changes in physiology may be influenced by factors such as time of day, drugs, and fatigue. Therefore, these assumptions require further validation prior to using neuroimaging as a test of neuropsychological theories of higher cognitive function.

Technical limitations have also been found with neuroimaging techniques in terms of temporal and spatial resolution, and volume scanned. The low temporal resolution of PET conceals the dynamic unfolding of information processing, thus making it difficult to detect small changes (Sergent, 1994). Furthermore, whilst PET scanners generally cover the whole horizontal dimension of the brain, they miss parts of the vertical dimension, including the top frontal and parietal areas close to the central sulcus, and the lower regions of the temporal pole and ventral cerebellum (Cabeza & Nyberg, 1997).

The more obvious limitations that are associated with the use of neuroimaging techniques, for the research reported in this thesis, are the expense involved with neuroimaging, and the impracticality of transporting clinically depressed inpatients from their clinic to the location holding the neuroimaging equipment. It is highly unlikely that the clinic treating the clinically depressed inpatients would have permitted their patients to leave the clinic for the purpose of this testing.

Functional neuroimaging holds considerable potential for advancing our understanding of the functional organization of the brain. The inherent problems in drawing functional conclusions from activational patterns, however, suggests that at this point in time, neuroimaging does not provide us with sufficiently more information than that provided through neuropsychological assessment. Neuropsychological testing has been a valued method of contributing to our knowledge on brain functioning. Further it is inexpensive and can be brought to the location of the clinically depressed inpatients. For these reasons, neuropsychological testing was employed in the research reported in this dissertation.
6.3 Neuropsychological assessment – tasks selected for this research

Neuropsychology involves the study of the relationship between brain function and observable behaviour. In its simplest form, neuropsychological assessment selects and utilizes standardized tasks in order to answer questions on which hypotheses are based (Lezak, 1995). The use of neuropsychological tasks, in the research reported in this thesis, allowed for flexibility in the testing time, which was important given the fact that fatigue is a symptom of depression (DSM-IV; A.P.A., 2000). Furthermore, the use of neuropsychological tasks allowed testing to be brought to the participant, which was important given that all but one of the clinically depressed patients were inpatients.

The primary aim of this dissertation was to examine disturbed brain lateralized cognitive and emotional functioning in clinical depression, and to examine such disturbed brain lateralization for each sex of the clinically depressed group. It was imperative that the tasks utilized in the research of this dissertation were measures of brain lateralized function. It was also important that the set of tasks included measures of the areas known to be involved with depression, these being the frontal lobe of both hemispheres and the posterior right hemisphere (RH).

Although no task relies solely upon the activation of a single hemisphere, some tasks rely more on the functioning of one hemisphere than the other. The tasks selected for the research of this thesis were: the mental rotation task (MRT) as a measure of RH performance, specifically the right parietal lobe (Cooper & Humphreys, 2000; Ditunno & Mann, 1990; Jordan, et al., 2001; Papanicolaou, et al., 1987; Tagaris, et al., 1997); the verbal fluency task (phonemic and semantic fluency) to measure left hemisphere (LH) performance, in which phonemic fluency is a measure of left frontal lobe performance (Benton, 1968; Elgren & Risberg, 1998; Milner, 1964; Schlösser, et al., 2002), and semantic fluency is a measure of left temporal lobe performance (Fedio, August, Patronas, Sato, & Kufta, 1997; Pihlajämäki, et al., 2000; Troyer, Moscovitch, Winocur, Alexander, & Stuss, 1998); and the chimeric faces task as a measure of frontal lobe performance (Figure 6.1). As well as being a measure of frontal lobe function, the chimeric
faces task involves emotional processing and will thus also provide information on brain lateralization for emotional processing, as it has for previous research (Campbell, 1978; Christman & Hackworth, 1993; David, 1989; Drebing, Federman, Edington, & Terzian, 1997; Moreno, et al., 1990). Although semantic fluency is a measure of left temporal lobe performance, which is not an area of the brain recognized as being dysfunctional in depression, it was included as an additional measure of lateralized verbal abilities in the LH. The selection of these tasks was influenced by previous literature that has indicated that these tasks measure brain lateralized functioning, and produce sex differences in performance. Each of the neuropsychological tasks used in the research of this thesis will be outlined within Section 6.3. Section 6.3.1 outlines the selection of the MRT as a measure of lateralized spatial abilities in the RH. Section 6.3.2 outlines the selection of the verbal fluency task as a measure of lateralized verbal abilities in the LH. Lastly, Section 6.3.3 outlines the selection of the chimeric faces task as a measure of emotional processing in the frontal lobe. Factors that have been found to affect performance on each of the tasks are briefly outlined as they subsequently influenced the design of the task, particularly the stimuli selected for each. Evidence that each task measures brain lateralized performance and produces sex differences in task performance is also presented.
IMAGE NOT AVAILABLE – SEE PRINT VERSION

Figure 6.1. Diagram of the depressed brain (Lior & Nachson, 1999) and the tasks selected to measure each area’s performance.

6.3.1 Neuropsychological measure of RH performance

The neuropsychological task selected to measure the performance of the RH was the MRT. Originally created by Shepard and Metzler in 1971, the MRT has become one of the most widely used tests of spatial ability. The MRT measures a person’s ability to imagine what an object will look like when it is rotated in space (Kail, Pellegrino, & Carter, 1980). It has shown moderate to strong correlations with other tasks of spatial ability, such as the Identical blocks test, Card rotations test, and the Block Design subtest of the WAIS-R. Conversely, the MRT has shown weak to no correlation with tasks of verbal ability such as the Vocabulary, Word Endings, and Verbal Reasonings (Vandenberg & Kuse, 1978). The MRT is considered to be a more specific test of spatial ability, as it does not rely on verbal or motor skills to the same degree as some other spatial tests, such as the Paper Folding Task, the Card Rotation Task, or Block Design (Kaufman, 1990; Peters, et al., 1995).
Traditionally, the MRT presents a pair of 2D or 3D objects, one as a reference and one as a comparison, in differing angular orientations. The participant is asked to mentally rotate and compare the comparison object to the reference and decide whether or not they are the same despite rotation. The time taken to determine whether or not the two objects are the same, despite differing in their orientations, is used as the measure of task performance. Stimuli used as distractors (objects that are not the same as the reference object) are either mirror images of the reference shape or completely different objects. Mirror images are more commonly used however, as the inspection of distractors based on different objects, may allow participants to complete the task by feature comparison rather than by orientation and mental rotation (Cooper & Shepard, 1975; Fisher & Pellegrino, 1988).

The main empirical observation in mental rotation research is that RT for “same” pairs increases with increases in the angle of rotation (Figure 6.2). This observation is typically interpreted as evidence that the task stimuli has been mentally rotated from one orientation to another by mental manipulation, which involves the smooth, analog process of passing the stimuli through intermediate orientations (Cooper, 1976; Cooper & Shepard, 1975; Shepard & Metzler, 1971).

The intercept and slope of the mental rotation linear relationship between RT and angle of rotation has often been used to characterise differences between groups of participants (Kail, et al., 1979). By definition, no mental rotation occurs at the intercept, therefore the intercept reflects the time necessary to encode and compare the stimulus pairs, and to respond. Assuming that RT is constant across the two types of stimuli, differences between intercepts are thought to reflect differences at the encoding and comparison stages (Kail, et al.). The slope of the mental rotation response time function is commonly interpreted as reflecting the rate of mental rotation of the sample, with shallower slopes representing faster rates of rotation (Kail, et al.).
An attribute of the MRT that is thought to affect performance is the dimensionality of the stimuli presented. Three-dimensional stimuli are more complex than 2D stimuli and have been found to affect the time taken to encode the stimuli (as indicated by the intercept). This was illustrated by Shepard and Metzler (1988) who found that participants mentally rotated 3D shapes as fast as 2D shapes, both when making a decision about a single rotated shape, or about two rotated shapes. However, in both cases, the intercept was longer for the 3D than the 2D stimuli.

Another attribute found to affect mental rotation performance is the familiarity of the stimuli being rotated. Bethell-Fox and Shepard (1988) found that the time required to encode, and mentally rotate unfamiliar matrices increased (that is, take longer) with stimulus complexity. As the matrices became more familiar however, RTs and error rates reduced. Bethell-Fox and Shepard concluded that familiarity improves the generation of an internal representation of an object, where the participant may form more integrated, holistic representations of the object, enabling it to be rotated more efficiently in an analog fashion. Parsons (1987, 1994) also found that familiarity of the stimuli affects MRT performance so that the more familiar the stimuli, the faster they can be rotated. When asked to rotate images of body parts, Parsons
found that participants rotated the images faster if the parts could be rotated in natural ways, than in ways that would be awkward to perform physically. Similarly, the mental rotation of letters has been reported to be faster than the mental rotation of unfamiliar figures (Blough & Slavin, 1987; Kail, Carter, & Pellegrino, 1979). However, letters in unfamiliar orientations have been observed to take longer to rotate than letters in familiar orientations (Desrocher, Smith & Taylor, 1995).

A similar observation was made by Kail, et al. (1979), who compared the mental rotation performance of PMA characters (unfamiliar letter-like characters from the Spatial Relations Test of the Primary Mental Abilities battery) to that of familiar alphanumerical symbols. The overall classic mental rotation linear relationship between RT and angle of rotation was observed for both the alphanumerical and PMA characters, however RT at the intercept was approximately 300 msec slower for the PMA characters. Kail, et al. attributed the delay in encoding the PMA characters to the stimuli being unfamiliar in comparison to the alphanumerical characters.

In summary, the MRT is a spatial visualization task, which employs either 2D or 3D stimulus pairs for participants to transform into internal representations, and cognitively manipulate to determine whether or not they are the same despite rotation. Participants typically take longer to respond to 3D stimuli than 2D stimuli, but regardless of the dimensionality, RT has consistently been reported to increase with increases in angular difference between the stimuli.

6.3.1.1 The MRT and brain lateralization

The available evidence suggests that the RH, particularly the parietal cortex, is fundamentally involved in mental rotation. Evidence from patients with brain lesions, divided visual field paradigms with neurologically normal participants, and functional neuroimaging experiments indicates that the right parietal lobe is integral to the performance on spatial tasks, such as the MRT.
A strong visual field effect was reported by Corballis and Sergent (1988), who found that a patient with complete forebrain commissurotomy was unable to mentally rotate alphanumeric characters that were presented to the right visual field (RVF). The patient, however, was able to mentally rotate the alphanumeric characters when they were presented to the left visual field (LVF). Similarly, Ditunno and Mann (1990) (Experiment Two) found that patients with right parietal lesions mentally rotated non-verbal 2D stimuli significantly slower, than control participants, and patients with left parietal lesions.

Right hemisphere specialization for mental rotation was again implicated by the study of Cooper and Humphreys (2000), who examined the performance of a patient with a RH lesion affecting the inferior parietal lobe, on a MRT which used an “L” shape (same and mirror-imaged) as the stimulus. Compared to the control group, the RH lesion patient rotated the stimuli significantly slower, and was approximately 400 msec slower at encoding the stimuli. Based on their finding, Cooper and Humphreys concluded that the impact of the spatial processes on recognition of angular variations decrease in a patient with right parietal lesion, along with the ability to discriminate small differences in orientation between stimuli.

Divided visual field studies on neurologically normal participants have further implicated dominant RH involvement for mental rotation. One of the most reported divided visual field studies in mental rotation research is that conducted by Cohen (1975b). Cohen presented alphanumeric stimuli to the LVF or RVF of normal participants, and found that overall RT was faster when stimuli were presented to the LVF than to the RVF. There was no significant visual field difference in the rate of mental rotation however. Cohen deduced that the RH performed mental rotation, and that the longer RTs obtained from stimuli presented to the RVF, was due to callosal relay of the information from the LH to the RH where mental rotation would have been performed.

Similarly, Ditunno and Mann (1990) (Experiment One) found that participants mentally rotated simple 2D figures faster and more accurately when they were presented to the LVF than to the RVF. The researchers acknowledged that their results were consistent with the absolute structural model of brain lateralization, which would propose that the mental rotation stimuli was transferred from the LH, to the
“spatial” specialized RH for processing (Kimura, 1966). Despite being consistent with the absolute structural model of brain lateralization, the researchers argued that their results were more likely representative of the relative specialization model of brain lateralization. This being because the difference in RT between the RH and the LH was greater than 20 msec, the time the researchers postulate for corpus callosal transfer time. Therefore the LH would have processed as much of the task as it was capable of processing, before transferring the information over to the RH to complete (Ditunno & Mann). In any case, a RH advantage for mental rotation was demonstrated.

Functional MRI and PET studies have further highlighted the right parietal lobe as integral for mental rotation. Tagaris, et al., (1997) used fMRI to examine the cortical activation patterns as participants performed a MRT using 3D stimuli that was similar to those produced by Shepard and Metzler (1971). Although the right parietal lobe was not the only region implicated by the fMRI, the researchers indicated that it was the region specifically associated with the performance on the MRT. Jordan, et al. (2001) later replicated these results when examining whole-head fMRI recordings while participants performed three different mental rotation tasks, each varying in type of stimuli used. Cortical activation converged to demonstrate regions in the right superior and inferior parietal lobe which were similarly activated during all three mental rotation tasks. Based on the results, Jordan, et al. concluded that the right parietal lobe was dominant when performing the MRT, and the use of differing stimuli did not inevitably evoke activation outside the parietal core regions.

Such fMRI findings have complemented those obtained using rCBF and further strengthened the view that mental rotation is a task dominated by the RH. One such rCBF study was conducted by Papanicolaou, et al., (1987) who recorded evoked potentials to strobe lights while participants performed a MRT. Results from both the evoked potential and rCBF data indicated that activation was greater over the right, than over the left parietal region when the participants performed the task. The researchers later replicated this rCBF finding, when observing greater blood flow in the RH than the LH as participants performed a series of visuospatial tasks, where the most marked asymmetry was observed as the participants performed the MRT (Deutsch, Bourbon, Papanicolaou, & Eisenberg, 1988).
Despite the large amount of evidence implicating the dominance of the RH in mental rotation, this finding has not always been produced. Fisher and Pellegrino (1988), and Voyer (1995) observed a RVF advantage in the mental rotation of alphanumeric stimuli and argued a LH advantage for mental rotation. The researchers subsequently argued that the RVF advantage may have been due to the fact that the participants were highly practiced at mental rotation. Fisher and Pellegrino suggested that being very experienced may have fostered a switch in strategy from RH to LH superiority, especially if a “verbal” strategy was adopted.

This reversal in hemispheric dominance may also be linked to the nature of the stimuli being processed. For example, stimuli of a verbal nature may enhance LH processing and obscure any RH asymmetry. This was the observation of Corballis and McLaren (1984) who found a shift toward a relative LVF advantage in RT when verbal stimuli (alphabnumerics) were replaced by nonverbal stimuli. Furthermore, the processing of 3D stimuli may be conducted using a piecemeal, analytic strategy performed by the LH, rather than a holistic strategy performed by the RH. This may account for the findings of Mehta and Newcombe (1991), who found that the mental rotation of 3D stimuli was impaired for patients with LH lesions, but not for patients with RH lesions.

Although not an absolute finding, the bulk of the mental rotation literature suggests a superiority of the RH for mental rotation, particularly of the right parietal lobe. Despite some of the inconsistent findings, the MRT remains one of the most popular neuropsychological tasks for measuring RH performance and was selected as a reliable measure of RH performance for the research reported in this thesis.
6.3.1.2 The MRT and sex differences in performance

The MRT has been reported to favour males in task performance (Bryden, et al., 1990; Delgrado & Prieto, 1996; Dollinger, 1995; Kail, et al., 1979; McGlone & Davidson, 1973; Peters, et al., 1995). The dominance by males on the MRT has often been attributed to differences in brain lateralization between the sexes, where the lateralization of spatial skills to the RH is proposed to be more efficient that the bilateral representation of spatial skills (Levy, 1969, 1976; Levy & Reid, 1978; McGlone, 1980; Springer & Deutsch, 1993).

Sex differences in the performance of the MRT have been found using various stimuli, with pronounced sex differences being observed with the use of the 2D figures from Thurstone’s PMA Test (Blough & Slavin, 1987; Kail, et al., 1979), in which males mentally rotated the stimuli significantly faster than females. This was observed by Kail, et al. who compared the performance of males and females on a MRT which used PMA characters and alphanumeric symbols. As expected, males performed significantly faster than the females for both stimulus types, however, the sex difference was larger for the PMA stimuli. The researchers attributed the sex difference in performance to the rotation operation, since the slopes, not the intercepts, differed between the sexes. While attributing the sex difference in rate of rotation to differing spatial abilities between the sexes, Kail, et al. further argued that the use of alphanumeric stimuli may reduce observable sex differences in spatial performance. This being because the alphanumeric stimuli are highly familiar verbal stimuli which may enhance the performance of females, given their superior processing of verbal material. Similarly, Goldberg and Costa (1981), and Linn and Petersen (1985) propose that females’ superiority for dealing with letter stimuli, like alphanumerics, reduces the sex difference observed in mental rotation performance.

The sex difference results of Kail, et al. (1979) were later replicated by Blough and Slavin (1987), who also used the PMA figures as stimuli in the MRT to investigate sex differences in visuospatial performance. Like the findings of Kail, et al., females were significantly slower at mentally rotating the stimuli than the males, and no significant sex difference was evident on the intercept. The researchers concluded that the
sex difference in performance on the MRT could be attributed to the performance of the mental rotation operation. Bryden, et al. (1990) also observed a male dominance on the mental rotation slope when examining the effect of differing figural complexity (number of blocks on a 3D figure) and angular rotations on mental rotation.

The male advantage in mental rotation has been a common, but not conclusive finding. When examining factors that may influence the mental rotation of two asymmetrical black and white line drawings, Jones and Anuza (1982) found that RT increased with angle of rotation for both sexes, however such increases were not significantly different between the sexes. In accounting for the non-significant sex difference in mental rotation performance, the researchers suggested that independent stimulation of the hemispheres in a divided visual field paradigm, such as theirs, might cue the hemisphere and lead females to adopt an appropriate strategy for dealing with spatial problems. When examining the effect of the divided field versus central presentation of the stimuli, however, Jones and Anuza found that presenting stimuli centrally did not restore the sex difference in mental rotation. The researchers also argued that the presentation of the stimuli at 100 msec might have been too rapid, causing the information to fade from short-term memory, and the results to be representative of a loss of sensory information, rather than of mental rotation.

Uecker and Obrzut (1993) also found that the mental rotation of stick figure stimuli did not differ significantly between males and females. The researchers argued that the lack of a sex difference in their study may be due to the stick figures being verbally encoded familiar stimuli. Such verbally familiar stimuli may enhance the performance of females to subsequently reduce any differences in mental rotation between the sexes (Uecker & Obrzut). Although it might be argued that a sex difference may be more likely to be found using unfamiliar stimuli, Desrocher, et al. (1995) failed to find a sex difference in overall RT during mental rotation or in RTs to each angle of rotation for both familiar (letters) and unfamiliar (PMA) stimuli. Even though the results were not statistically significant between the sexes, the findings of Desrocher, et al. did indicate that females were slightly faster in overall RT than the males for the familiar letter stimuli, whereas males were faster in overall RT than the females for the unfamiliar PMA stimuli.
The researchers argued that the small sample (ten males, ten females) used in their study may have contributed to the lack of significant sex differences.

Despite the research that has failed to find a significant sex difference in mental rotation performance, it is generally accepted that males perform better than females on spatial tasks, such as the MRT, due to their greater lateralization for spatial functioning in the RH (Kimura, 1969; Lansdell, 1961; McGlone, 1977, 1980). It has been proposed that greater lateralization in the RH for spatial functioning is more efficient than the bilateralization of spatial functions (Levy, 1969, 1976; Levy & Reid, 1978; Springer & Deutsch, 1993).

6.3.2 Neuropsychological measure of LH performance

The neuropsychological task selected to measure the performance of the LH was the verbal fluency task. Verbal fluency tasks have become important clinical tools in the neuropsychological assessment of LH functioning. The verbal fluency task measures the ability to make verbal associations to specified letters (phonemic fluency) and categories (semantic fluency). It has been found to correlate strongly with other verbal tasks such as the WAIS-R Vocabulary and Digit Span subtests, the Selective Reminding test, and the Seashore Rhythm tests, suggesting that it is a measure of verbal ability subserved by an inter-relationship between attention and long-term verbal memory (Ruff, Light, Parker, & Levin, 1997).

Generally, participants are presented with a letter (or category) for which they are asked to produce as many exemplars as possible within a given time limit, usually one minute (Audenaert, et al., 2000; Benito-Cuadrado, Estebo-Castillo, Böhm, Cejudo-Bolivar, & Peña-Casanova, 2002; Lezak, 1995; Ruff, et al., 1997; Sumerall, Timmons, James, Ewing, & Oehlert, 1997). Task performance is measured by the total number of correct responses generated within the given time limit. As semantic fluency requires not only discriminating words from non-words, but also discriminating some category words from other category words, it is considered more effort demanding than phonemic fluency, and likely to result in fewer
generated words (Calev, Nigal & Chazan, 1989). Additionally, semantic fluency is restricted to category size, however phonemic fluency is not.

Popular forms of the verbal fluency task, such as the FAS task (administers the letters F, A, and S), utilize up to three to four letters and categories, whereas short forms of the verbal fluency task administer only one letter and one category (Acevado, et al., 2000; Harrison, et al., 2000; Herlitz, et al., 1997). Performance on the longer verbal fluency task (FAS), has been found to correlate highly with scores obtained from a verbal fluency task using just one letter, suggesting that no particular advantage obtains from using the longer, three letter version of the verbal fluency task (Harrison, et al.). However, the longer verbal fluency tasks were found to be more reliable for repeat testing (Harrison, et al.).

An attribute of the verbal fluency task that is thought to affect performance is the letter and category used (Roselli, et al., 2002). In the English language, fewer words begin with the letters J and U in comparison to F, A, T, P and S (Cauthen, 1978; Ruff, et al., 1997). Therefore, some letters are more difficult than others to use as a basis from which to generate words for phonemic fluency, and would thus limit the number of words produced. Cauthen administered an eight letter phonemic verbal fluency task to fifty-one participants and reported that the letter “S” produced the higher generation of words. Within a one-minute duration, the average number of words beginning with the letter “S” was 16.2 words for participants aged between 20 and 59 years of age. For participants aged 60 years and older, the average word production decreased to approximately 11.2 words per minute. Similarly, in a more recent study comparing cross-linguistic performance on verbal fluency tasks, Roselli, et al. reported that for the English-speaking group within their study, the letter “A” was significantly more difficult to produce exemplars for than the letters “S” and “F”. The letter that was the easiest to produce exemplars for was the letter “S”.

The type of category used has also been reported to affect performance on semantic fluency. Acevado, et al., (2000) investigated the performance of 424 English and 278 Spanish-speaking participants on three of the most frequently used categories in semantic fluency tasks: animals, vegetables, and fruit. The researchers reported that regardless of primary language, more exemplars were generated for the
category “animals” than for “fruits” or “vegetables”, suggesting that retrieval of exemplars from the former category is less difficult. Based on the results, Acevedo, et al. concluded that different category measures are not equivalent and recommended that where research only allows time for one category, animal fluency should be the category of choice as it is not a difficult category for which to generate exemplars, and it is not affected by primary language.

The literature suggests that stimuli that offer many exemplars and are easy to perform should be used in the verbal fluency task. The use of difficult letters or categories may hamper performance and make interpretation of the results difficult. The next section presents evidence suggesting that verbal fluency is a measure of LH performance.

6.3.2.1 Verbal fluency and brain lateralization

Verbal fluency measures are among the most sensitive for disclosing cerebral dysfunction (Audenaert, et al., 2000; Cauthen, 1978; Pendleton, Heaton, Lehman & Hulihan, 1982). Phonemic fluency is thought to be a test of left frontal lobe functioning, and semantic fluency a test of left temporal lobe functioning. Milner (1964) was among the first researchers to associate focal cerebral lesions with performance on a standardized fluency test, the Thurstone Word Fluency Test. Milner reported that patients who had partial left frontal lobectomies, as treatment for focal seizure disorders, performed significantly poorer on phonemic fluency than patients with right frontal lobectomies. This finding was later replicated by Benton (1968), who found that patients with left frontal and bilateral frontal lesions produced significantly fewer words on a phonemic verbal fluency test than patients with right frontal lesions.

Similarly, Schlösser, et al., (2002) observed that patients with frontal lobe tumors were able to perform the phonemic fluency task, however, their average word production rate was 5.5 words per minute, significantly lower than that of the neurologically normal control group at 14.8 words per minute. The results indicated that tumors in the frontal lobe, in the vicinity of language related regions, did not alter activation responses, but had a significant negative effect on performance. Whilst the findings of Benton
(1968), Milner (1964), and Schlösser, et al., implicate the left frontal lobe in phonemic verbal fluency performance, the studies were limited in only measuring the performance of the frontal lobe. Further research was performed to determine whether other brain regions were involved in verbal fluency, to which the involvement of the left temporal lobe in semantic fluency was discovered (Fedio, et al., 1997; Pihlajamäki, et al., 2000; Troyer, et al., 1998).

Troyer, et al. (1998) compared the phonemic and semantic fluency performance of patients with focal frontal lobe lesions and patients with unilateral temporal lobe lesions, to the performance of a neurologically normal control sample. Consistent with the earlier findings of Benton (1968) and Milner (1964), the patients with frontal lobe lesions generated significantly fewer words for phonemic fluency than the patients with temporal lobe lesions and the control group. This result confirmed the more specific role of the frontal lobe in the performance of phonemic verbal fluency. The findings for semantic fluency were suggestive of a more specific role of the left temporal lobe, as patients with lesions to this region produced significantly fewer words than patients with right temporal lesions and the control group. The implication of left temporal lobe involvement for semantic fluency replicated the earlier study of Fedio, et al. (1997) who administered intracarotid injection of a low dosage of amobarbital to patients who had temporal lobectomy, and asked them to generate words from a diverse range of categories. Injection disabling the LH resulted in increased errors and significantly fewer words than when the RH was disabled.

Neuroimaging studies on normal participants have further confirmed that the left frontal and temporal lobe are the neuroanatomical centers of activation that appear to be linked specifically to verbal fluency processes. Elfgren and Risberg (1998) used rCBF measurements of participants to elucidate the involvement of the frontal lobe during the performance of phonemic fluency. The results indicated that phonemic fluency activated mainly the left prefrontal cortex. Similar findings were obtained by Schlosser, et al., (1998) who recorded whole brain fMRI as participants performed a phonemic fluency task. Although there were individual task related regional changes in each participant, the area showing the most significant and consistent change was the left prefrontal cortex in each case.
Pihlajamäki, et al., (2000) measured fMRI in normal participants to study the brain activation areas involved in the performance of a semantic fluency task involving five differing categories: clothes, animals, furniture, plants, and food. Consistent with lesion research, the left medial temporal lobe was predominantly engaged in the retrieval process during semantic fluency.

The majority of research investigating brain laterality and brain regions involved with verbal fluency has implied the dominance of the LH. A LH advantage has not always been reported however, with some researchers finding no hemispheric differences, or more pronounced deficits with RH lesions. Vilikki and Holst (1994) failed to find any significant differences between patients with left and right anterior and posterior lesions for the generation of animal names or words beginning with S. In fact the inspection of individual test results indicated that several patients with left frontal lesions performed at a superior level on these verbal fluency tasks. Joanette and Goulet (1986) found that the patients with RH damage in their study were impaired on semantic fluency, however, the researchers failed to replicate this finding in a later study when randomizing the presentation order and controlling for level of productivity (Goulet, Joanette, Sabourin, & Giroux, 1997). Despite the contrasting findings, the relative consistency of findings from research recruiting differing groups of participants, and using differing stimuli and research methods, strengthen the view that phonemic fluency is a measure of the left frontal lobe and semantic fluency is a measure of the left temporal lobe.

6.3.2.2 Verbal fluency and sex differences in performance

Females have generally been found to perform better on verbal tasks in comparison to males, to which the verbal fluency task is one. The female advantage on such verbal tasks has often been attributed to differences in brain lateralization between the sexes, where the bilateralization of verbal functioning in females is proposed to be more efficient than unilateral specialization of language in males (Springer & Deutsch, 1993).
Such a female advantage for verbal fluency was observed by Herlitz, et al. (1997) when screening their participants’ global cognitive status, which also involved administering the Block Design subtest. Participants were asked to produce as many words as possible beginning with the letter “A” for phonemic fluency, and as many five-letter words beginning with the letter “M” for semantic fluency, within a one-minute time frame for each condition. For both the verbal fluency and Block Design tasks, a significant main effect for sex was observed, where the females performed significantly better than the males on both the phonemic and semantic fluency tasks, and the males performed significantly better than the females on the Block Design task.

In attempt to replicate the findings of Herlitz, et al. (1997), Herlitz, et al. (1999) presented participants with a series of episodic memory tasks that were either verbal or visuospatial in nature. Of these tasks, the “FAS” verbal fluency task was included as a verbal task, and a MRT included as a visuospatial task. A significant sex difference in performance was not found for all of the tasks, however females were found to generate significantly more words on the verbal fluency task than the males, and the males were found to perform significantly more accurately on the mental rotation task than the females.

There has been some suggestion that sex differences observed in semantic fluency may be influenced by the category selected rather than being representative of a sex difference in verbal ability. For example, Capitani, Laiacona, and Barbarotto (1999) found that of the categories “animals”, “fruits”, “tools”, and “vehicles”, females performed significantly better on the category “fruits”, and males performed significantly better on the category “tools”. The researchers suggested that a general effect of experience may be responsible for their finding, noting however, that experience does not really account for the female advantage for the “fruit” category. They further proposed that the participants may place themselves in a particular context such as a workshop for tools, or a greengrocer for fruit, and use autobiographical experiences to help generate the words. If this is the case then consideration should be given to the category selected for semantic fluency. The inference of a sex difference in semantic fluency could only really be reliably made if the category is free from a possible gender “experience” bias.
Similar findings were obtained by Acevado, et al. (2000) when examining performance on varying semantic fluency categories. The researchers reported a significant sex effect in which females produced significantly more words than males for the categories “vegetables” and “fruits”. Performance on the category “animals” however was comparable between the sexes. The finding of Acevado, et al. partially replicate the earlier study of Monsch, et al., (1992) who used the same categories however found that females produced higher total fluency scores for all categories compared to the males, even for the category “animals”. One could assume that the category “animals” is free from any environmental gender “experience” bias, where one sex has more exposure to animals than the other. Therefore the female advantage for the semantic category “animals” could be argued to be more representative of an advantage of better verbal ability, rather than more exposure to and thus knowledge of animals.

The finding of a female advantage in performance on the verbal fluency task has not always been reported, with some researchers finding no influence of sex on verbal fluency performance. Demarkis and Harrison (1997) failed to find a statistically significant sex difference on three differing verbal fluency measures (the Controlled Oral Word Association Test (COWA), the Design Fluency Test, and the Ruff Figural Test). Similarly, when examining the effects of age and sex on phonemic verbal fluency performance (using the letters “S” and “T”), Roberts and Bell (2002) found no significant sex difference in performance. The finding was contrary to the researcher’s predictions, which they argued may have been the result of a small sample size (sixteen males, sixteen females). Whilst the small sample size may have been responsible for the results of Roberts and Bell, it does not account for the findings of Harrison, et al. (2000) who recruited a sample size of 365 (199 females, 166 males), and also failed to find a significant sex difference in the performance of both phonemic (using the letter “B”) and semantic (using the category “animals”) fluency.

Despite the findings of no significant sex difference in verbal fluency performance, females are more commonly found to perform better than males on verbal related tasks, such as the verbal fluency task. Based on the findings of a female advantage in verbal functioning, it has been proposed that
bilateralization for verbal functioning is more efficient than the unilateral specialization of verbal functions (McGlone, 1980; Springer & Deutsch, 1993).

6.3.3 Neuropsychological measure of frontal lobe performance

Emotional faces have been commonly used in tasks examining frontal lobe function in emotional processing. Despite the relatively consistent finding that emotional stimuli is predominantly processed by the frontal lobe (Canli, et al., 1998; Davidson, et al., 1979), brain laterality findings from neuropsychological research using emotive facial stimuli are inconsistent. The findings have either supported the RH hypothesis or the valence hypothesis of brain lateralization for emotional processing, or failed to offer full support to either. Section 6.3.3.1 will outline the different methods that have been used to administer facial stimuli for the purpose of investigating brain lateralization for emotional processing. Section 6.3.3.2 will then present findings of brain lateralized performance, and sex differences in brain lateralization for emotional processing from studies using emotional facial expressions for stimuli.

6.3.3.1 Dynamics and structure of research using emotive facial stimuli

There are a variety of techniques reported in the literature for investigating brain lateralization for emotion processing using emotional faces. Two of the most common are the divided visual field technique and the chimeric faces paradigm. The divided visual field technique characteristically involves presenting a picture of a full face to the left or right of a central fixation point (LVF or RVF), thus projecting the picture to the contralateral hemisphere. The tasks demands may vary from asking participants to decide whether the face displayed a positive or negative emotional expression (Wedding & Stalans, 1985), or whether it matched an earlier centrally presented target face (Ley & Bryden, 1979). A manual response indicates which visual field (and therefore hemisphere) produced the faster and more accurate responses (Campbell, 1978). A variation of this technique involves presenting an emotive face to one visual field whilst concurrently presenting a neutral face to the opposite visual field (Reuter-Lorenz & Davidson, 1981;
Reuter-Lorenz, et al., 1983), and asking participants to identify which visual field contained the emotional face.

An alternate method for investigating brain lateralization for emotion processing is the chimeric faces paradigm, which capitalizes on the fact that faces are roughly symmetrical about a vertical axis (Campbell, 1978). The chimeric faces paradigm involves the central presentation of an artificial face showing different emotions on the right and left side of the face. Characteristically, a chimeric face is presented over a central fixation point for a brief duration so that one half of the face is presented to one visual field, and the other half of the face is presented to the opposite visual field. Participants are asked to indicate the emotion they believed was being expressed on each chimeric face. Similar to the divided visual field technique, a manual response indicates which emotion in which visual field was identified faster and more accurately by the participant, and more importantly, which hemisphere was processing which emotion (Drebing, et al., 1997). The chimeric face paradigm was selected for the research reported in this dissertation, as it involves the emotional identification from a single face, in contrast to some divided visual field techniques that present two faces, which often requires the participants to work from memory. Furthermore, the chimeric faces paradigm is more representative of the types of judgements made in daily social interactions (Drebing, et al.), thus making it a more valid ecological measure of perceptual ability and brain lateralization for emotional processing.

Research using facial stimuli for the purposes of examining brain lateralization for emotional processing have traditionally used photographs of models displaying an emotional expression (Drebing, et al., 1997; Hugdahl, Iversen, & Johnsen, 1993; Moretti, et al., 1996; Natale, Gur, & Gur, 1983; Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, et al., 1983; Wedding & Stalans, 1985), whereas a few studies have used cartoon emotional faces for stimuli (David, 1989; Ley & Bryden, 1979). Despite the fact that similar findings have been reported between cartoon and the photograph faces, it has been argued that cartoon stimuli might not be appropriate for examining brain lateralization for emotional processing (Patterson & Bradshaw, 1975; Safer, 1981). Safer argued that the RH superiority often reported from studies using cartoon faces may not be truly representing a RH superiority for emotional processing, but rather a RH
superiority for recognizing the line orientations used to represent and exaggerate the key features of an emotional expression, such as the upward turning of the mouth in a happy expression. Furthermore, Patterson and Bradshaw argue that schematic cartoon drawings may contain less detail, so that judgements that may be based on the presence of one feature (such as a muscular feature) cannot be observed.

The most common facial stimuli that have been used in emotion research are those developed by Ekman and Friesen (1976) in The Pictures of Facial Affect database. The Pictures of Facial Affect database contains examples of seven greyscale facial emotions (happy, sad, anger, fear, disgust, surprise, and neutral) that are each expressed by fourteen different models (six male, eight female), with the exception of sadness and fear, which are expressed by thirteen models (Calder, Burton, Miller, Young, & Akamatsu, 2001). These facial expressions were posed by trained models and have been found to be reliable and valid representations (Ekman & Friesen). Ekman (1994) has shown that each emotion expressed in The Pictures of Facial Affect database is associated with distinct facial musculatures that are recognized by a number of cultures throughout the world.

There is debate in regards to the effect of open and closed-mouth face stimuli on responses. When investigating hemispheric differences using the chimeric faces task, Drebing, et al. (1997) only presented faces with a closed mouth expression, arguing that the presentation of a chimera with one half showing an open-mouth and the other half a closed-mouth would appear obviously unnatural to the participant and would ultimately make them aware to the chimera. Ley and Bryden (1979) made a more direct comparison by presenting both open and closed-mouth happy and sad whole faces tachistoscopically to the visual fields. The researchers found that visual field differences remained the same regardless of whether the expression presented an open or closed-mouth expression. Reuter-Lorenz, et al. (1983) also examined the effect of open and closed-mouth happy expressions in a divided visual field paradigm and reported that open-mouth happy faces were discriminated more rapidly and more accurately than the closed-mouth expressions. There was no difference, however, in the magnitude of visual field responses.
for the open and closed-mouth faces. Reuter-Lorenz et al. concluded that cue saliency did not appear to be a critical factor in determining the size and direction of perceptual asymmetries.

Findings from both the divided visual field technique and chimeric face paradigm have been mixed. The brain laterality findings from each method are discussed next.

6.3.3.2 Brain lateralization for emotional processing of facial stimuli

Previous studies that have focused on the brain regions involved in emotional processing have found that patients with frontal lobe lesions show impaired emotional processing. Hornak, Rolls, and Wade (1996) found that patients with ventral frontal lobe damage showed impaired performance when attempting to identify facial and vocal emotions. In contrast, patients with brain damage outside the frontal lobes were relatively unimpaired on the task.

Similarly, Hopkins, Dywan, and Segalowitz (2002) examined the ability of patients with closed head injury, affecting the orbital and ventromedial regions of the prefrontal cortex, to identify the emotions of facial expressions. While monitoring electrodermal activity, patients were presented with angry, fearful, disgust and happy faces from The Pictures of Facial Affect database (Ekman & Friesen, 1976), and were asked to choose a word from a list that best described the facial expression. The results indicated that the patients with closed head injury had difficulty identifying the emotional facial expression, especially in comparison to the neurologically normal controls. The poorer performance of the patients was also associated with a failure to increase electrodermal activity.

The involvement of the frontal lobe in the perception of emotion from facial expressions has also been implicated by neuroimaging research. A PET study by George, et al. (1993) found that during an expression-matching task involving normal participants, the inferior frontal gyri was bilaterally activated. Similarly, Kesler-West, et al. (2001) used fMRI to identify regions involved in the perception of negative and positive emotions, and found that differences in activation as a function of the emotional category was
most evident in the frontal lobes. Also using fMRI, Gorno-Tempini, et al. (2001) found that the frontal lobe was predominantly activated when participants made explicit judgements about emotions on facial expressions. Specifically, the bilateral orbitofrontal cortex was activated when participants made explicit judgements of happy expressions, and the right frontal and insular cortex was involved for all judgements of emotional expression (neutral, disgust, or happy).

Despite the relatively consistent findings that emotional processing predominantly activates the frontal lobe (Canli, et al., 1998; Davidson, et al., 1979), findings from neuropsychological research using the divided visual field technique and chimeric faces paradigm are mixed. The findings have either supported the RH hypothesis or valence hypothesis of brain lateralization for emotional processing, or failed to offer full support to either.

Research employing the chimeric faces paradigm to investigate brain lateralization for emotional processing has generally found results supportive of the RH hypothesis. Campbell (1978) was among the first to use chimeric faces to investigate hemispheric differences in processing emotional faces. Participants were presented with a half happy, half neutral chimeric face for 150 msec, followed by its mirror image for another 150 msec, and asked to judge which of the pair appeared happier. Campbell found that there was a consistent bias towards choosing the chimera with the happy expressions on the left of the face, indicating a LVF advantage for judging affect. This result was replicated by Christman and Hackworth (1993), and Moreno, Borod, Welkowitz, and Alpert (1990), who developed a similar task including both positive and negative facial expressions, and asked participants to identify the more emotional face.

Support for the RH hypothesis was also provided by the studies of David (1989), and Drebing, et al. (1997), who also presented chimeric faces, showing positive and negative emotional expressions matched with a neutral expression, centrally at 500 msec. Participants were asked to identify the emotion shown by each chimeric face. Using accuracy as a dependent variable, the researchers from both studies found that there was a stronger tendency for participants to report the chimera as expressing the emotion that
was presented to their LVF. Both David, and Drebing, et al. concluded that their research supported the hypothesis that the RH is specialized for the processing of both positive and negative affect.

Using a different technique that involved a “same” or “different” judgement, Ley and Bryden (1979) presented cartoon line drawings of positive and negative emotional expressions unilaterally for 85 msec to participants, who were asked to compare this target face to a subsequent centrally presented face. Participants were then asked to decide whether the emotional expressions on the two faces were the same or different. Using accuracy as a dependent variable, a significant LVF superiority for emotional recognition was found to support the RH hypothesis of brain lateralization for emotional processing.

In contrast, research using the divided visual field technique has generally found results supporting the valence hypothesis of brain lateralization for emotional processing. As mentioned in Chapter Three, the most cited research supporting the valence hypothesis is that of Reuter-Lorenz and colleagues. Reuter-Lorenz and Davidson (1981) presented either a happy or sad emotional face expression to one visual field, and simultaneously presented a neutral expression of the same model to the opposite visual field. Participants were asked to identify which of the two faces (thus visual field) displayed the most intense affect. The results reported a marginal LVF advantage for sad expressions, and a significant RVF advantage for happy expressions. In a subsequent study, Reuter-Lorenz, et al. (1983) asked participants to identify which side (thus visual field) contained the emotional face. Using accuracy and RT as dependent variables, the researchers found a significant LVF advantage for the recognition of sad expressions, and a significant RVF advantage for the recognition of happy expressions. Reuter-Lorenz et al. (1981; 1983) concluded that there is a differential hemispheric specialization for emotion, as predicted by the valence hypothesis of brain lateralization for emotional processing.

The study of Wedding and Stalans (1985) also offered support to the valence hypothesis after using a visual field technique where slides of happy or sad faces were presented to either the LVF or RVF, and participants were asked to determine whether the emotion of the face was positive or negative. The researchers found a significant main effect for visual field, with the participants responding significantly
faster to faces presented to the RVF than the LVF. Further, a significant visual field by emotion interaction was observed, where positive faces were identified significantly faster when shown in the RVF than in the LVF, and positive faces were also identified significantly faster than negative faces shown in the RVF. Although not significant, there was a trend showing faster responses to negative faces that were shown in the LVF than in the RVF, and faster responses to negative than positive faces that were shown in the LVF.

Research examining brain lateralization of emotional processing has not always produced clear results in favour of either the RH or valence hypothesis. This was the case for Moretti, et al. (1996) who employed a very similar methodology to Reuter-Lorenz and Davidson (1981), and Reuter-Lorenz, et al. (1983) in attempt to replicate their support for the valence hypothesis. The results reported no visual field differences for happy expressions, however found that sad expressions were processed faster and more accurately when shown in the LVF than in the RVF. Moretti, et al. concluded that their findings did not clearly distinguish between either the RH or valence hypothesis, given that both predict a RH advantage for processing negative expressions and neither predicts a lack of visual field differences for positive expressions. The only reported differences in methodology between the studies of Moretti, et al. and Reuter-Lorenz, et al. (1981, 1983), was that Moretti, et al. presented the stimuli for 300 msec, whereas Reuter-Lorenz et al. (1981, 1983) did not present stimuli at a fixed duration. Furthermore, Reuter-Lorenz et al. (1981, 1983) presented the stimuli repeatedly due to a small stimulus set, whereas the facial stimuli used by Moretti, et al. were presented once to each visual field. Sullivan and McKeever (1985) argue that stimulus repetition may be necessary for RVF superiority for processing happy expressions to emerge under some conditions. Moretti, et al. however, argue that stimulus repetition is unlikely to account for their failure to replicate the LH advantage for recognizing the happy expressions, given that they were successful at replicating the RH advantage for recognizing the sad expressions.
6.3.3.3 Sex differences in brain lateralization for processing emotional faces

There is evidence to suggest that females are better than males at identifying and discriminating facial affect (Ladavas, et al., 1980; Rahman, et al., 2004; Thayer & Johnsen, 2000). Whether this means that there is a sex difference in brain lateralization for emotional processing however, remains unclear.

Sex differences in the brain lateralization of processing emotional faces have rarely been directly examined, and when it has, results have been inconsistent. The few studies that have examined sex differences in brain lateralization for processing emotional faces have generally used a variation of the divided visual field paradigm.

Safer (1981) hypothesised that females would be superior to males in recognizing emotions presented to the LH, as they integrate emotional experiences with verbal descriptions, thus using a verbal strategy for decoding emotional expressions. In contrast, Safer predicted that males would have relatively greater RH specialization for recognizing emotions, as they distance themselves from verbal emotional expression and description. To test this hypothesis, Safer used a “same” or “different” divided visual field paradigm where an emotive face (positive or negative) was presented centrally for eight seconds. The presentation of the emotive face was briefly followed by a laterally presented face for 50 msec or 150 msec1 and the participants were asked to decide whether the pair displayed the same emotion or not. As expected, examination of participant’s accuracy showed a significant RH advantage for the males, whereas there was no visual field difference observed for the females. The females however were significantly more accurate than the males when the second laterally presented expression was displayed to the RVF, which Safer attributed to females superior access to LH verbal codes for emotion.

The findings of Safer (1981) are in direct contrast to the findings of Ladavas, et al. (1980). Ladavas, et al. presented blocks of emotive faces to the visual fields separately and asked participants to respond to

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1 Two stimulus display times were used however no significant differences in accuracy was observed between the two display times
those that matched the target emotion allocated to that block. Ladavas, et al. found a significant LVF superiority in emotional processing for the females, but not for the male participants. No consistent brain lateral asymmetry for emotional processing was observed for the males.

Using a similar divided visual field paradigm to Safer (1981), Burton and Levy (1989) presented an emotive face centrally for 500 msec, which was replaced by a central fixation cross, followed by the presentation of a lateral emotive face (positive or negative) for 200 msec. As with the study of Safer, participants were asked to decide if the laterally presented face matched the central “target” face. The researchers found that females were more likely to show the pattern of emotional processing proposed by the valence hypothesis, by responding faster to negative facial expressions (sad, angry) presented to the LVF, and faster to positive facial expressions (content, delight) presented to the RVF. This pattern was also observed for males, however, it did not reach statistical significance. The researchers argued that the results are reflective of a reactive inhibition and counteraction of the emotional response in males, where the greater the emotional elicitation, the greater the reactive inhibition. Whereas for the females, the greater the emotional elicitation, the greater the facilitation, and the faster the RTs.

To add to such contrasting findings, many studies have failed to find any significant sex difference in brain lateralization for emotional processing. Such studies include that of Drebing, et al. (1997) who used a chimeric faces paradigm, and Wedding and Stalans (1985) who employed a divided visual field paradigm. Wedding and Stalans argued that the conflicting sex difference findings in the literature are likely to be due to sampling differences. The studies that have found a sex difference in brain lateralization for emotional processing, however, have had comparable sample sizes with approximately equal numbers of male and female participants. It is more likely that the methodological differences that have likely contributed to the conflicting RH and valence hypotheses in general have also had an impact on findings regarding sex differences in brain lateralization for emotional processing. Furthermore, such variance in findings, especially among studies using very similar methodologies, suggests that a strong and clear sex difference in brain lateralization for emotional processing simply may not exist.
CHAPTER SEVEN
EXPERIMENT ONE
SEX DIFFERENCES IN BRAIN LATERALIZATION FOR SPATIAL, VERBAL, AND EMOTIONAL PROCESSING IN A NON-DEPRESSED GROUP

7.1 Chapter Seven – Experiment One overview

Experiment One investigates sex differences in brain lateralization for spatial and verbal processing. Experiment One also examines brain lateralization for emotional processing, in particular to determine whether there is a sex difference in brain lateralization for emotional processing. Sex differences in brain lateralization for spatial, verbal and emotional processing was examined by comparing the performance of males and females on the mental rotation task (MRT), the verbal fluency task, and the chimeric faces task.

As outlined in Chapter Two (section 2.4.2), males have commonly been reported to perform better than females on tasks involving spatial abilities, such as the MRT (Blough & Slavin, 1987; Bryden, et al., 1990; Delgrado & Prieto, 1996; Dollinger, 1995; Kail, et al., 1979; Maccoby & Jacklin, 1974). The superior performance of males than females on spatial tasks has been attributed to their stronger laterialized spatial processes in the right hemisphere (RH) (Kimura, 1969; Lansdell, 1961; McGlone, 1977, 1980). It has been proposed that spatial functioning is more efficient than bilateral specialization for spatial functioning (Levy, 1969, 1976; Levy & Reid 1978; Springer & Deutsch, 1993). In contrast to spatial tasks, females have commonly been reported to perform better than males on tasks of a verbal nature, such as the verbal fluency task (Acevado, et al., 2000; Herlitz, et al., 1997, 1999; Monsch, et al., 1992). The superior performance of females on verbal tasks has been attributed to their bilateralization of verbal functioning, which is assumed more efficient than the unilateral specialization for verbal functioning in males (Springer & Deutsch, 1993). Using the MRT as a RH measure of spatial functioning, and the verbal fluency task as a left hemisphere (LH) measure of verbal functioning, it was hypothesised that:
H1: The male participants will mentally rotate the stimuli in the MRT significantly faster than the female participants.

H2: The female participants will generate significantly more words for both phonemic and semantic verbal fluency than the male participants.

In contrast to sex differences in brain lateralization for spatial and verbal functioning, sex differences in brain lateralization for emotional processing have not been as consistently reported in the literature. For example, a divided visual field study by Burton and Levy (1989) produced findings that were consistent with the valence hypothesis for both males and females, although the valence effect was only significant for the males. In contrast, an fMRI study by Lee et al. (2002) reported strong brain laterality in support of the valence hypothesis for males, however, for the females a LH advantage for processing both happy and sad emotions was observed. The chimeric faces paradigm has been a common tool for investigating brain lateralization for emotional processing, yet it has rarely been used to specifically examine sex differences in brain lateralization for emotional processing. Drebing, et al. (1997) used a chimeric faces task to examine brain lateralization for emotional processing, and reported no significant sex differences.

It became a research aim of Experiment One to further investigate sex differences in brain lateralization for emotional processing for each sex, through the use of a chimeric faces task. The chimeric faces paradigm has the advantage of being more representative of the types of judgements made in social interactions (Drebing, et al.). One of the larger limitations of earlier research that has used chimeric faces to investigate brain lateralization for emotional processing has been the administration of a single positive target emotion (Christman & Hackworth; Wirsen, Klinteberg, Levander, & Schalling, 1990). The use of a single positive target emotion fails to account for brain lateralization for processing negative affect (Campbell; Chiang, Ballantyne & Trauner, 2000). Another limitation has been the exposure of chimeric face stimuli to participants for a duration longer than 150 msec (Drebing, et al.). Exposing chimeric face stimuli for a duration longer than 150 msec does not control for reflexive horizontal saccades, which could
potentially expose the emotions on the chimera to both hemispheres (Currie, et al., 1993; Nicholls, 1994). Such limitations are accounted for in the chimeric faces task used in this dissertation.

Past research that has presented chimeric faces to participants to investigate brain lateralization for emotional processing has generally supported the RH hypothesis (Campbell, 1978; Christman & Hackworth, 1993; David, 1989; Drebing, et al., 1997; Moreno, et al., 1990). Despite the changes made in methodology to improve the chimeric faces task used in this dissertation, it was expected that the RH hypothesis would be supported by the results of Experiment One. Therefore it was hypothesised that:

H₃: Responses will be significantly faster and significantly more accurate to happy and sad emotional expressions shown in the left visual field (LVF) than in the right visual field (RVF).

Due to the inconsistent findings in the literature, a directional hypothesis predicting a sex difference in brain lateralization for emotional processing could not be justified.

7.2 Methods

7.2.1 Participants

The sample comprised sixty participants (thirty males, thirty females), recruited from Swinburne University of Technology, and from members of the public through poster advertisement or verbal informing of the research. No payment was offered for participation. All participants verbally confirmed meeting the inclusion criteria which included having: no previous knowledge of the tasks employed in the study (or exposure of the tasks within the six months prior to testing), normal or corrected vision, no neurological history including epilepsy, no history of psychiatric/psychological treatment, and no history of psychosis.

Participants interested in participating were given an information sheet outlining the research and the requirements of their participation. Prior to the neuropsychological assessment, all participants signed a
consent form and were informed that their participation and individual results would remain confidential. Participants were asked to complete a demographic questionnaire documenting their age, sex, educational background, and first spoken language.

Given that handedness has been found to be related to brain laterality (Bryden, 1965; Gur et al., 1982; Knecht, et al., 2000), the majority of research examining brain laterality have recruited right-handed participants, as left-handed participants are more likely to show inconsistent brain laterality patterns (reversed or bilateral) (Bryden; Keane, 1999). Thus, as findings are likely to be more reliable from a sample of right-handed people, participants were also asked to complete the Edinburgh Handedness Inventory to ensure that they were right-hand dominant.

The focus of Experiment One was to examine sex differences in brain lateralization for a non-depressed group, with the intention that participants from this group would be used to form a matched non-depressed control group in Experiment Two. Therefore, the participants from Experiment One were interviewed and rated on the Hamilton Rating Scale for Depression (HAMD) and the Montgomery and Åsberg Depression Rating Scale (MÅDRS) to ensure that they did not possess symptoms of clinical depression (HAMD score ≤ 7, MÅDRS score ≤ 8) (Bech, Kastrup, & Rafaelsen, 1986; Mittman, et al., 1997; Muller, et al., 2000). The candidate was trained by a psychiatrist on the HAMD and MÅDRS interview technique and scale ratings prior to initial testing, and was checked by a psychiatrist for consistency twice during the testing duration.

The demographic characteristics for each sex are shown in Table 7.1.
Table 7.1

Participant mean age, education, HAMD, MÅDRS, premorbid IQ and handedness demography for the non-depressed males and females, and significance levels for demographic comparisons between the sexes.

<table>
<thead>
<tr>
<th></th>
<th>Males (n=30)</th>
<th>Females (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>38.77</td>
<td>16.63</td>
</tr>
<tr>
<td>HAMD score</td>
<td>2.50</td>
<td>1.85</td>
</tr>
<tr>
<td>MÅDRS score</td>
<td>2.13</td>
<td>2.21</td>
</tr>
<tr>
<td>Years of education*</td>
<td>5.65</td>
<td>3.60</td>
</tr>
<tr>
<td>Vocab</td>
<td>41.50</td>
<td>11.54</td>
</tr>
<tr>
<td>Handedness</td>
<td>71.17</td>
<td>25.84</td>
</tr>
</tbody>
</table>

N = 60

*years of education represents years spent at secondary and tertiary (if attended)

A series of one-way ANOVAs were calculated to identify whether there was a sex difference for each of the demographics presented in Table 7.1. Scores on the HAMD and MÅDRS indicated that both the males and females obtained mean scores indicative of having no depressive symptoms (refer to section 7.2.2.2 for HAMD gradations and section 7.2.2.3 for MÅDRS gradations). Mean years of education was found to differ significantly between the sexes, with education level being higher for females than for males. Despite each sex presenting mean handedness quotients indicative of strong right-handedness (Oldfield, 1971), the preference for right handedness of the females was significantly stronger than that of the males. In addition, females scored significantly higher than the males on the Vocabulary subtest of the Wechsler Abbreviated Scale of Intelligence (WASI).

Of the group, English was the predominant first spoken language (n=54). The first spoken language for six of the participants was a language other than English (Italian n=2 (both male), Philippi no n=1 (female), Cambodian n=1 (female), Russian n=1 (male), Cantonese n=1 (male)), however, these participants also spoke English.
7.2.2 Materials and Procedure

After completing the demographic questionnaire, participants completed the Edinburgh Handedness Inventory (Oldfield, 1971), and were rated on the HAMD and MÅDRS. The participants also completed the MRT, verbal fluency task, and chimeric faces task in the same testing session. These neuropsychological tasks were presented in random order to control for order and fatigue effects.

In addition, participants completed the Vocabulary subtest of the WASI, which was administered as a measure of premorbid intelligence (the level of intellectual function prior to the emergence of psychotic / depressive symptoms) for the groups in Experiment Two. The purpose of administering the Vocabulary subtest in Experiment Two was to ensure that any significant differences observed between the depressed and control groups on the experimental tasks were due to clinical depression and not to differences in IQ. The Vocabulary subtest was completed in the one testing session with the other selected neuropsychological tasks, and although its purpose was mainly for screening premorbid IQ in Experiment Two, differences between the control males and females for this experiment was also screened. Each scale and task will be outlined in this section.

7.2.2.1 The Edinburgh Handedness Inventory

The Edinburgh Handedness Inventory (Oldfield, 1971) was used to assess each participant’s handedness. The Edinburgh Handedness Inventory assesses the participants’ preferred hand by examining which hand the participant uses dominantly across a range of twelve activities (e.g. writing, using a toothbrush, using a broom). The participants’ Laterality Quotient (LQ) for hand preference (H) is then calculated using the equation:

\[
H = 100 \times \frac{\text{Sum of } R - \text{Sum of } L}{\text{Sum of } R + \text{Sum of } L}
\]
where R corresponds to right hand and L corresponds to left hand (Oldfield). Handedness quotients range from +100 (right-handed for all items) to −100 (totally left-handed). The closer the quotient is to zero, the less lateralized the participant is for handedness (Keane, 1999). The mean handedness quotient for each sex in this experiment (Table 7.1) is indicative of strong right-handedness (Oldfield).

7.2.2.2 The Hamilton Rating Scale for Depression (HAMD)

Participants were interviewed and rated on the HAMD to screen for depressive symptoms. The 17 items on the HAMD are measured on either five-point (0-4) or three-point (0-2) scales. The three-point scale was used where quantification of the variable was difficult. If a symptom was present, a score of 2 was given; if absent, the score was 0. If the presence of the symptom was doubtful or trivial, a score of 1 was entered. Where more detailed information can be obtained, a five-point scale was used, where: 2 indicates mild symptoms, 3 moderate symptoms, and 4 severe symptoms (Hamilton, 1960). Both intensity and frequency of the symptoms influenced the rating.

The method of assessment on the HAMD was based on an interview, which began with an open-ended question and continued with follow-up questions (probes), until enough information was obtained to score each item with confidence. When thorough probing failed, ratings were rated down (i.e. rated 2 instead of 3). Symptoms were not rated twice, and clinical judgement overrode the participants’ opinion when determining the presence or absence of a symptom (Veroff, et al., 2001). The score for the participant was obtained by summing the scores from the three- or five-point scales for each item (Hamilton, 1960; Veroff, et al., 2001). The higher the score, the more severe the depression. The following gradations are commonly used when analysing the scores on the 17-item HAMD, and were used in the present research: no symptoms = ≤ 7, mild = 8 - 15, moderate = ≥ 16, and severe ≥ 28 (Bech, et al., 1986; Mittman, et al., 1997; Muller, et al., 2000).
7.2.2.3 The Montgomery and Åsberg Rating Scale for Depression (MÅDRS)

The MÅDRS was used in conjunction with the HAMD (refer to section 4.2.1.3 in Chapter Four) to rate and screen depressive symptoms in each participant. Assessment on the MÅDRS was also based on an interview, which followed the same approach as the HAMD. Ten items were rated on a seven-point (0-6) scale and the score was obtained by summing the ratings for each item (Montgomery & Åsberg, 1979; Snaith, 1993). The following severity gradations for scores on the MÅDRS have been reported to be comparable to the HAMD-17 and were used in the present research: no symptoms = ≤ 8, mild = 9-17, moderate = ≥ 18, and severe to very severe = ≥ 35 - 60 (Mittmann, et al., 1997; Muller, et al., 2000).

7.2.2.4 Measure of premorbid intelligence – WASI Vocabulary subtest

The WASI Vocabulary subtest was used as a measure of premorbid intelligence in this research. The Vocabulary subtest of the WASI is recognized as a good measure of crystallized intelligence and general intelligence, and has an average reliability coefficient of 0.94 (The Psychological Corporation, 1999). The Vocabulary subtest is a 42-item task in which participants are asked to orally define a set of visually presented words that are also read aloud by the investigator, and which are arranged in order of difficulty. Participant responses were recorded verbatim in the WASI record form. All participants started at Item 9, which is the starting point for participants over 9 years of age. The task proceeded until the end or until the participant obtained five consecutive scores of 0 (discontinue criterion). Scoring was dependent on the accuracy and detail provided for each word (The Psychological Corporation). A reverse sequence was applied when the participant failed to obtain perfect scores on the first two starting items, which was a prerequisite for moving onto the more difficult items. In this case, participants were asked to complete the proceeding easier items until two consecutive perfect scores were obtained. The Vocabulary subtest required approximately 10 minutes to complete.
7.2.2.5 Mental Rotation Task (MRT)

The MRT was used in the present research as a RH measure of spatial functioning and was based on the MRT used by Kail, et al. (1979, 1980). Like Kail, et al. (1979; 1980), the PMA characters (from the Spatial Relations Test of the Primary Mental Abilities battery (Thurstone, 1958)) were selected as stimuli for the MRT. The PMA characters are simple, 2D objects which unlike the common alphanumerical stimuli, are unfamiliar in the sense of not having readily available verbal labels. The use of familiar, verbal like stimuli could potentially reduce observable sex differences in spatial performance, as verbal stimuli may enhance the performance of females (Kail, et al., 1979), given their superior processing of verbal material (Acevado, et al., 2000; Herlitz, et al., 1997, 1999; Monsch, et al., 1992). The PMA stimuli have been found to be suitable stimuli for mental rotation (Kail, et al., 1979, 1980).

Images of the eight PMA characters were digitally scanned from a figure given in the paper by Kail, et al. (1979). Bitmap images for each character were imported into True Type font format using Fontographer, and stroke rendering was then optimised manually. A ninth PMA-like character was created manually with the same computer package for the purpose of practice presentations. Mirror images of the nine characters were also created. All eighteen characters were placed into one True Type font file. Presentation image files were created using Coral Draw 7.

Based on the MRT design of Kail, et al. (1979; 1980), seventy-two stimulus screen image files served as the stimuli for the MRT task, comprising a set of nine image files for each of eight PMA characters. Each image file contained a pair of characters from the PMA font displayed in 96 pt size. Characters were oriented vertically in the middle of the screen image, with an orienting cross drawn in the centre of the screen. Within each set of nine image files, six showed PMA characters that were identical, however the upper character was rotated compared to the lower reference character at either 0, 30, 60, 90, 120 or 150 degrees. The remaining three image files showed PMA characters that were mirror images in which the upper character was rotated compared to the lower reference character at either 0, 90, or 150 degrees. Therefore the resulting set of 72 screens consisted of 48 images in which the stimuli were identical, and 24
images in which they were mirror images. A 2:1 ratio of identical to mirror-image stimulus screens was used by Kail, et al. to reduce the number of trials and thus reduce task duration, and attempt to avoid participant fatigue. Given that the MRT was also to be administered in Experiment Two to clinical depressed patients, accounting for fatigue was of important given that fatigue is a symptom of clinical depression (A.P.A., 2000). Therefore the 2:1 ratio of identical to mirror-image stimulus screens was suitable for the MRT used in Experiments One and Two.

The nine PMA characters used in the MRT are displayed in Figure 7.1 and their mirror images in Figure 7.2.
Figure 7.1. The eight PMA characters from the study of Kail, et al. (1979), used in the MRT, together with the ninth practice PMA-like figure used in the practice sessions.

Figure 7.2. The PMA mirror images used in the MRT.
The MRT stimuli were randomly presented on an IBM PC using a modified version of the “pic” program from the PXL package by Irnel (1993). The computer monitor was positioned approximately one meter from where the participant was seated. Participants were asked to determine whether the stimuli were identical (despite rotation) or whether they were different (mirror-imaged).

Nine practice trials using a PMA-like character (six same, three different) were presented to participants in which they received feedback as to the correctness of their response. Further, if a response was incorrect, the experimenter demonstrated to the participant why this was the case. The practice trials incorporated a PMA-like character not otherwise used in the test set, in order to avoid exposure to the test set and thus to avoid a practice effect. After the practice trials, the test series began. Participants were asked to respond as accurately as possible, while also encouraged to respond as fast as possible.

A hand held response box containing two horizontally aligned buttons was attached to the computer’s game port to record the participant’s responses. If the participant believed that the two stimuli were the same, they were asked to press the button labelled “yes”. If they believed that the two stimuli were not the same (therefore mirror-imaged), they were asked to press the button labelled “no”. Button press responses on the response box were made using the right hand.

Each trial included sequential presentation of four screens: a blank wait screen, a second orienting screen which was followed by the task screen, and lastly, a feedback screen for practice trials (correct or incorrect) (Figure 7.3), or a cross in the study trials indicating that the response was registered (Figure 7.4). The 72 image files were presented in a random order which varied per participant in order to control for order effects. The onset of presentation of each image file activated a millisecond counter, which was used to measure the latency of the participant’s response. The next trial began 1000 msec after the participant responded. The MRT required approximately 10 minutes to complete.
Figure 7.3. Schematic outline of the display screens used in the MRT practice trials. NOTE: PMA IMAGE IN SCREEN THREE NOT AVAILABLE - SEE PRINT VERSION

Figure 7.4. Schematic outline of the display screens used in the MRT study trials. NOTE: PMA IMAGE IN SCREEN THREE NOT AVAILABLE - SEE PRINT VERSION
7.2.2.6 Verbal Fluency task

The verbal fluency task in Experiment One was used as a LH measure of verbal functioning. Participants were informed that the verbal fluency task consisted of two one minute tasks. The first was a phonemic condition in which the participant was asked to verbally generate as many words as possible that started with the letter “s”. The second was a semantic condition, in which the participant was asked to verbally produce as many names of animals (insects were accepted) as possible that began with the letter “s”. The participant was asked to stop after one minute had expired for each verbal fluency condition. The semantic fluency task followed the phonemic fluency task for every participant.

Participant responses were recorded verbatim. Words that had two or more meanings were accepted if repeated by the participant and if the alternate meaning was indicated (Ruff, et al., 1997). The scores were derived by adding the correct number of words stated. Words could not include names of people or places, numbers, or repeated words (Goulet, et al., 1997; Ruff, et al.). These words were considered as errors and were not included in the word count. Repeated words with the addition of a suffix were not included if both had the same meaning. For example, “eat” and “eating” have the same meaning compared to “build” and a “building”.

7.2.2.7 Chimeric faces task

The chimeric faces task was used in this research as a measure of brain lateralization for emotional processing. The chimeric faces stimuli used in the chimeric faces task were constructed from The Pictures of Facial Affect database (Ekman & Friesen, 1976), which contains only whole faces. Only three of the seven emotions contained in The Pictures of Facial Affect database were used, specifically, happiness, sadness and neutral expressions. The emotional expressions in the database were posed by fourteen different adult models, except for sadness, which was posed by thirteen adult models (Ekman & Friesen). Of the happy whole faces, ten displayed open-mouth smiles and the remaining four displayed closed-mouth smiles. Of the sad whole faces, one model presented an open-mouth sad expression.
Chimeric faces were created using Paintshop Pro 4 in the following manner: photographs of a whole emotive face and a whole neutral face from the same model, were split vertically down the middle and joined so that one half of the composite contained an emotional expression (happy or sad) and the other half contained the neutral expression (Figure 7.5).

The stimulus set therefore comprised 54 chimeric face image files (14 happy/neutral, 14 neutral/happy, 13 sad/neutral, and 13 neutral/sad). The happy, sad, and neutral whole face expressions from each of the models were also included in the stimulus set, for the sole purpose of screening out participants who could not identify the emotional expressions under the test conditions. Therefore, the stimulus set also included 41 whole face image files (14 happy, 14 neutral, and 13 sad expressions), to total 95 stimulus screens.

Each stimulus image file was presented centrally on a computer screen for a duration of 150 msec. An orienting cross was positioned in the centre of the screen prior to the face image being presented. Participants were asked to fixate on the orienting cross, so that one half of the chimeric face was presented to one visual field, and the other half of the chimeric face presented to the opposite visual field. A hand held response box with four buttons was attached to the computer’s game port to record the participant’s responses. The buttons were labelled: “Sad”, “Neutral”, “Happy”, and “Don’t Know” respectively, and were horizontally aligned on the response box. Participants were asked to indicate which emotion the face image was displaying (happy, sad or neutral) by pressing the button corresponding to that emotion. Even though a “don't know” button was available, participants were encouraged to choose a specific answer if possible. Button press responses on the response box were made using the right hand which was screened to be the preferred hand. Participants were advised to respond as accurately as possible while also being encouraged to respond rapidly. To familiarise the participant with the task conditions, five practice trials using a whole neutral face from the Yale Faces database face were presented prior to commencing the task. Using a “practice” face not included in the test trials avoided any potential practice or familiarity effects.
CONSTRUCTION OF CHIMERIC FACES

IMAGE NOT AVAILABLE – SEE PRINT VERSION

Figure 7.5. Outline of the construction of the chimeric faces using a neutral and happy whole face example.
Images in the chimeric faces task were presented on an IBM PC using a modified version of the “pic” program from the PXL package by Irel (1993). The chimeric faces stimuli were 19cm in height and 13cm in width. When performing the chimeric faces task, participants sat approximately one metre from the computer screen. Using the formula: \( \tan (\text{visual angle of stimulus}) = 2 \times \text{stimulus width (cm)} / \text{viewing distance (cm)} \), the chimeric faces stimuli projected at a visual angle of 12.85°, that is, 6.43° to the left and right of central fixation.

Each trial comprised five sequential screens: a blank wait screen, an orienting screen which was followed by the task screen, a masking screen and response feedback screen which displayed a central cross to indicate that the response had been recorded (Figure 7.6). A masking screen was presented following stimulus administration, in order to obliterate the phosphor afterglow of the presented image, which would otherwise extend the stimulus display latency of 150 msec. In order to control for possible order effects, the 95 image files were presented in random order, which varied for each participant. The presentation of each task image activated a millisecond counter, which was used to measure the latency of the participant’s response. The next trial began 1000 msec after the participant responded. The chimeric faces task took approximately 10 to 15 minutes to complete.
Figure 7.6. Schematic outline of the display screens used in the chimeric faces task. NOTE: FACE IN SCREEN THREE NOT AVAILABLE – SEE PRINT VERSION
Faces rating task

The faces in the Pictures of Facial Affect database (Ekman & Friesen, 1976) were standardized by Ekman and Friesen using two judgement procedures administered to “U.S. born college students”. The first judgement procedure presented each face for 10 seconds to participants, who were asked to select one of six emotions that they believed was expressed by each face. The percentage of observers judging each of the six emotions was calculated for each slide. The second judgement procedure also presented each face for 10 seconds to each participant. The answer sheet for the second procedure listed the same six emotions that were listed for the first judgement procedure, however, each emotion was presented on a seven point scale, with neutral at one end, and the intended emotion at the other. Participants were asked to rate each face slide on each of the six emotion scales. For example, the participant could rate a slide as displaying maximum sadness on the sadness scale, but as neutral on all other emotion scales. In another example, the participant could rate a slide as maximum on all six emotion scales, or some degree between the extremes. Each participant’s ratings were reduced to a single judgement for each slide. If the same intensity rating was given to more than one emotion, or there was not a difference of at least two points between the ratings of two emotions expressed on the face, the data from that participant was excluded from analysis for that face slide. Ekman and Friesen found that the photographs in The Pictures of Facial Affect database were judged to show the intended emotion by at least 70% of the participants, and therefore concluded that the faces in The Pictures of Faces Affect database have high inter-reliability.

To determine whether the faces used in the chimeric faces task of the present research were rated by the participants as representing their nominal emotional category, the faces rating task was created. If brain lateralization was to be evident for the processing of the happy and sad facial expressions in this experiment, it was important to use faces that were representative of their intended emotion. In addition, The Pictures of Facial Affect (Ekman & Friesen, 1976) are thirty years old and were standardized using a group of “U.S. born college students”. It was therefore important to ensure that the participants in this experiment, who were not all college students, could distinguish between the happy, sad, and neutral faces, thus validating whether the faces represented their nominal emotional category. If the faces are a
reliable representation of their nominal emotional category, then similar ratings were expected to be obtained, even if a slightly different judgement procedure was used.

The faces rating task consisted of a booklet of 12.5cm x 8.5cm print outs of each of the happy, sad, and neutral whole faces presented in the chimeric faces task. Participants were asked to verbally rate how happy or how sad each face in the booklet appeared, using a 7-poing Likert type scale (3 = very happy, 2 = moderately happy, 1 = slightly happy, 0 = neutral, -1 = slightly sad, -2 = moderately sad, -3 = very sad). Participants were permitted to view each face for as long as they needed in order to rate them.

Four faces rating task booklets were created, with the order of face presentation balanced for each in attempt to control for possible order effects. The order of booklet presentation was balanced across all participants. The faces rating task was presented to half of the group before administering the chimeric faces task, and to half of the group at the completion the task. The faces rating task took approximately five minutes to complete.

7.2.3 Data screening

7.2.3.1 Mental Rotation Task (MRT)

The dependent measure in the MRT was mean RTs for correct “same” responses which was examined across angle of rotation and sex of the participant. The study of Kail, et al. (1980), to which the MRT in Experiments One and Two was based, indicated that the mirror-image stimuli were included as “catch trials” and were thus not analysed in their research. Further, Voyer and Bryden (1990) argue that mirror-image trials are undefined in terms of orientation in mental rotation, given that the comparison stimulus can never match the standard stimulus. Analysing only correct same trials has been common practice in past mental rotation research (Jolicoeur, Regehr, Smith, & Smith, 1985; Kail, et al., 1979, 1980) and thus was practiced in Experiments One and Two.
Participant mean accuracy percentiles for the "same" angles combined were firstly screened to determine whether there were any participants with extremely low accuracy to indicate that they may not have understood the task. As there was a choice of two buttons ("yes" and "no"), there was a random chance that the participants would obtain at least 50% accuracy (chance responding). Therefore, an overall accuracy percentage of less than 50% was used to indicate any participant who may not have understood the task. Of the group, no participants obtained an overall accuracy percentage lower than 50%. Participant accuracy scores to each mirror-image angle of rotation was also checked to ensure that participants were not pushing one button throughout the testing session. For example, a participant may have pushed the "same" button for each trial, thus possibly not understanding the task. No participants were found to push one button throughout the MRT.

For each participant, a mean RT was calculated for each angle of rotation using correct "same" trials only. Trial RTs that were longer than three SDs from the participant's mean RT for the respective angle, and that were less than 300 msec, were excluded, and the participant's mean RT for that angle of rotation recalculated. No trials produced RTs that were longer than three SDs from the mean or shorter than 300 msec.

The participant mean RTs for each angle of rotation were then examined for missing values, and fit between their distributions and the assumptions of ANOVA. There were two missing values in the data set, for the angles 60° and 150°, both by male participants, which were treated as missing values and were not replaced. The distributions of RT for each angle of rotation for each sex were evaluated using skewness and kurtosis statistics, histograms and box plots. Participant mean RT values that were longer than three SDs from the group mean for that angle and sex, were considered outliers, to which their inclusion resulted in increased skewness and kurtosis. To reduce the impact of these outliers, their RT value was changed to the next extreme score that fell within the acceptable range of that angle's distribution for that sex (within three SDs of the group mean). This allowed the outlier to remain deviant but to be within three SDs of the group mean, and subsequently reduce the skewness and kurtosis values (Tabachnick & Fidell, 2001) to be near normal. Further, as the participant accuracy scores indicated that
the participants with outlier RTs obtained acceptable accuracy scores, exclusion of these participants would not have been appropriate.

Using linear regression, slope and intercept values of the function relating RT to angle of rotation were also calculated for each participant, using the mean RTs for each angle derived from the correct “same” responses. Distribution statistics indicated that there was an outlier greater than three SDs from the group mean for both the males and the females on both the slope and the intercept. The outlier for the males on the slope resulted in higher kurtosis. Truncating these outlier values was considered, however, as examination of the slope and intercept of these participants was to complement ANOVA analyses of the mean RT values to which the slope and intercept values were generated, altering the outliers may not be a true reflection of the slope and intercept presented in the mean RT ANOVA analyses and graphical presentations. Therefore, as the outliers were not truncated, the validity of the ANOVA analyses comparing the MRT slopes and intercepts between the sexes was confirmed with the use of the Mann-Whitney non-parametric test.

The relationship between RT and accuracy on the MRT was examined for each angle of rotation for each sex, in order to check for possible speed-accuracy trade-offs. There were few significant correlations, which were weak to moderate. In addition, some of the significant correlations between RT and accuracy were negative, indicating that there was no speed-accuracy trade-off for these conditions. Refer to Appendix A.1.1 for the correlation table.

Analyses on the participant’s accuracy rates for each angle of rotation and sex were calculated as an additional means of confirming that there were no speed-accuracy trade-offs for the MRT. These analyses are reported in section 7.3.1 of the results. Accuracy rates were calculated as the total correct by the participant for the given angle, divided by the total possible correct for that angle. To meet the normality assumptions of ANOVA for such analyses, accuracy rate outliers (outside three SDs from the group mean) for each angle for each sex were truncated to the next most extreme score within three SDs of the mean.
Truncating the accuracy rate outliers had minimal effect on the group mean, however rendered skewness and kurtosis to be close to normal.

7.2.3.2  Verbal fluency task

The dependent measure in the verbal fluency task was the number of words generated for phonemic and semantic verbal fluency by each sex.

There were no missing values within the verbal fluency data set. The distributions of the number of words generated for phonemic and semantic fluency for each sex produced near normal skewness and kurtosis values. For each sex, no outliers were evident for phonemic fluency, and no outliers greater or less than three SDs from the group mean evident for semantic fluency. A review of the total number of phonemic and semantic errors produced by each participant indicated that there was one male participant with phonemic and semantic fluency error scores, and one female with a phonemic error score that fell three SDs from the group mean for errors for that sex. These participants however, produced a total number of words for phonemic and semantic fluency that were comparable, or better than, the remainder of the sample who obtained few errors. Therefore, exclusion of these participants would not have been appropriate as there was no evidence of dysfunction. Hence, no participants were excluded from the analyses conducted on the verbal fluency task.

7.2.3.3  Chimeric faces task

Faces rating task

Whole faces that were not rated by the participants in this experiment as representing the emotion that they were categorised as by Ekman and Friesen (1976) in The Pictures of Facial Affect (happy, sad, or neutral), were removed from analysis to reduce error variance. When determining the reliability of the photos in The Pictures of Facial Affect database, Ekman and Friesen found that each photo was judged to
show the intended emotion by at least 70% of the observers. Therefore, using the same criteria as Ekman and Friesen, the photographs in which there was not a consensus of at least 70% of the group in this experiment (n=60) that the photo represented either a happy, sad, or neutral expression, were excluded from statistical analyses.

The frequency of each Likert-scale rating was obtained for each emotion of each face. Frequencies were then collapsed into the ratings that represented each emotion. Specifically, frequencies from the ratings “-3” and “-2” were collapsed to represent the emotion “sad”, frequencies from the rating “0” represented “neutral”, and ratings “2” and “3” were collapsed to represent the emotion “happy”. As a rating of “1” (slightly happy) or “-1” (slightly sad) represented a weak rating, it was considered to be a borderline rating between neutral and the intended emotion. Therefore, ratings on the Likert type scale were weighted so that the frequencies of “1” and “-1” were split between neutral and the intended emotion. This allowed an approximate equal weighting on the Likert scale for each emotion.

The frequency table of sad, neutral, and happy ratings for each whole face indicated that two out of the forty-one faces (one happy, one sad) were not rated by at least 70% of the sample to represent their nominal emotion. These faces were therefore not included in the chimeric face analyses, reducing the chimeric face stimulus set that was analysed from 54 to 50 chimeras. The two faces were also not included in the screening of participants which was based on accuracy responses to the whole face stimuli, thus reducing the whole face stimulus set from 41 whole faces to 39 whole faces.

Before examining whether the face ratings differed significantly between the emotions, the distributions of the participants mean rating for each emotion were examined to meet the normality assumptions of analysis of variance (ANOVA). The normality assumptions of ANOVA were evaluated using skewness and kurtosis statistics, histograms, and box plots. Ratings greater or less than three SDs from the group (n=60) mean rating for that emotion were truncated to the next most extreme but acceptable score (within three SDs). This allowed the score to remain deviant however within the acceptable range (Tabachnick &
Fidell, 2001), and reduced skewness and kurtosis to be near normal. Further, truncating the values had minimal impact on the overall group mean. Of the values, five were changed.

A one-way ANOVA with emotion rating as a within-subjects factor indicated that the mean ratings for the happy, sad, and neutral faces were significantly different from each other ($F (1, 59) = 3437.13$, $p<0.001$, partial $\eta^2 = 0.98$). Post-hoc contrasts indicated that there were significant differences in ratings between the sad and happy faces ($F (1, 59) = 1563.37$, $p<0.001$, partial $\eta^2 = 0.96$); sad: $M = -2.05$, $SD = 0.40$; happy: $M = 2.47$, $SD = 0.28$), sad and neutral faces ($F (1, 59) = 2853.03$, $p<0.001$, partial $\eta^2 = 0.98$), neutral: $M = -0.14$, $SD = 0.24$), and the happy and neutral faces ($F (1, 59) = 2853.03$, $p<0.001$, partial $\eta^2 = 0.98$).

A post-hoc one-way ANOVA indicated that there was a significant difference ($F (1, 59) = 322.12$, $p<0.001$, partial $\eta^2 = 0.85$) in the ratings for happy faces that presented teeth ($M = 2.70$, $SD = 0.28$) and those that did not present teeth ($M = 1.68$, $SD = 0.48$). However further post-hoc one-way ANOVAs indicated that ratings for happy faces were significantly different from the neutral faces regardless of whether the happy faces displayed teeth ($F (1, 59) = 726.42$, $p<0.001$, partial $\eta^2 = 0.93$). Therefore happy faces displaying teeth and no teeth were collapsed for subsequent analyses.

Reactions time and accuracy data of the chimeric faces task

Research investigating hemispheric asymmetries for emotional processing using emotional facial expressions have varied as to which dependent variable was measured, usually RT or accuracy. Both RT and accuracy were examined in this experiment to account for possible variation in findings for each

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2 The assumption of sphericity was violated ($p<0.001$) therefore the Huynh-Feldt statistic is reported with adjusted degrees of freedom
3 For happy face comparisons between open and closed mouth faces, one participant’s mean rating value for the happy open-mouth values had to be truncated. This truncated value was only applied to the happy open and closed mouth comparisons to meet the normality assumption of ANOVA.
dependent variable. All analyses on accuracy were conducted on the participants’ accuracy rates (total correct by participant divided by the total possible correct).

Participant recognition accuracy percentiles for each of the whole face emotional expressions were firstly screened to determine whether there were any participants with extremely low accuracy. Extremely low accuracy may have been indicative of the participant not understanding the task, or the participant being unable to recognising one of the emotions. Whole faces were used to screen for low accuracy scores, rather than chimeric faces, as low accuracy to an emotion shown in one visual field may actually be the result of a higher accuracy score being obtained to the same emotion shown in the opposing visual field. Further, whole faces are representative of the types of emotional expressions viewed in social interactions, and thus would be a more reliable way to examine whether a participant could identify the emotion. As there was a choice of four response buttons (“happy”, “neutral”, “sad”, and “don’t know”), there was a random chance that participants would obtain at least 25% recognition accuracy (chance responding) for each whole face emotion. Therefore an accuracy percentage of less than 25% for any of the three emotions would be interpreted as the participant not understanding the task, or being unable to identify the emotion. There were no participants with an accuracy percentile lower than 25% for the emotional recognition of each of the whole faces.

Although accuracy for the whole faces was used as the basis for identifying participants who did not understand the task or who was unable to identify an emotion, inspection of the accuracy data for the chimeric faces data indicated that there was one participant who obtained extremely low accuracy across the four visual field / emotion chimeric face conditions combined (<10% accuracy), suggesting that the participant did not understand the task. This participant was subsequently excluded from all RT and accuracy rate analyses. Therefore the final group in which analyses were conducted comprised fifty-nine participants (twenty-nine males, thirty females)\(^4\).

\(^4\) The same statistical differences in demographics between the sexes were present for the sample size of \(n=59\).
The chimeric faces task RT and accuracy rate data was screened separately for each sex in this experiment, given that analyses were conducted on each sex. For each participant, a mean RT for each visual field / emotion condition of the chimeric faces was calculated using correct responses only. Trial RTs that were longer than three SDs from that participant’s mean RT for the respective visual field / emotion condition, and that were less than 300 msec were excluded, and the participants’ mean RT for that visual field / emotion was recalculated. Based on these RT exclusion criteria, four chimeric face trials (three male, 1 female) were excluded from analyses. Responses from the “Don’t know” button were not included in any analysis. From the sample size of fifty-nine and using the valid face stimuli, only 1.9% of trials were entered as “Don’t know”.

Prior to statistical analyses, the participants mean RT and accuracy scores for each visual field / emotion condition for the chimeric faces, were examined for each sex for missing values and fit between their distributions and the normality assumptions of ANOVA. Where participants did not get any trials correct, their RT was treated as a missing case, although an accuracy score of zero was entered. Therefore, there were no missing cases for the accuracy data. Similarly, the data of any participant who only received one correct trial was also treated as a missing value for the RT data given that no SD could be generated. There were six missing values for the chimeric faces RT data (one for right visual field (RVF) happy by a male, three for RVF sad by two males and one female, and two for left visual field (LVF) happy by a male and a female), which were not replaced, and were treated as missing values.

The RT and accuracy rate distributions for each visual field / emotion condition for each sex were examined using skewness and kurtosis statistics, histograms, and box plots. Participant mean RT values that were longer than three SDs from the group mean for their sex were considered outliers to which their inclusion resulted in increased skewness and kurtosis. These values were subsequently truncated (Tabachnick & Fidell, 2001) to the next extreme score that fell within the acceptable range for that visual field / emotion, for that sex (within three SDs from the group mean for that sex). Truncating the outliers allowed the values to be retained, and rendered the distribution to near normal to have acceptable, low
skewness and kurtosis. The accuracy rates produced by each sex for each visual field / emotion condition produced skewness and kurtosis values that were near normal.

In order to explore the relationship between RT and accuracy for the chimeric faces task, RT-accuracy correlations were calculated for each visual field / emotion condition for each sex. There were few significant correlations, and those that were significant were weak. Furthermore, the significant correlations were negative, indicating that there were no speed-accuracy trade-offs between the two dependent variables. Thus both dependent variables were analysed and reported separately. Refer to Appendix A.1.1 for the specific correlation findings.

7.2.4 Data analysis

Information on the tests and procedures used to meet the assumptions of the statistical analyses conducted in this experiment is provided in Appendix A.2.1. Analyses in this experiment were two-tailed but corrections were not made for multiple analyses. All effects were considered statistically significant at the p<=0.05 significance level.

7.3 Results

7.3.1 Mental Rotation Task (MRT)

As Figure 7.7 shows, a positive linear relationship between RT and angle of rotation was evident for both the males and females. The relationship between the mean RTs and angle of rotation was significant and highly linear for both the males (r(6) = 0.99, p<0.001), and the females (r(6) = 0.96, p<0.01).
Figure 7.7. Linear regression line and mean RTs and SEM as a function of angle of rotation in the MRT for the males and females - Experiment One.

Table 7.2 presents the mean RTs and SDs for each angle of rotation for each sex separately.

Table 7.2.

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>Males (n=28)</th>
<th>Males (n=28)</th>
<th>Females (n=30)</th>
<th>Females (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>0°</td>
<td>1738.63</td>
<td>959.99</td>
<td>1580.92</td>
<td>970.19</td>
</tr>
<tr>
<td>30°</td>
<td>2173.64</td>
<td>1265.56</td>
<td>2350.08</td>
<td>1538.42</td>
</tr>
<tr>
<td>60°</td>
<td>2217.50</td>
<td>767.26</td>
<td>2475.23</td>
<td>1131.37</td>
</tr>
<tr>
<td>90°</td>
<td>2629.82</td>
<td>1325.41</td>
<td>2635.74</td>
<td>1391.25</td>
</tr>
<tr>
<td>120°</td>
<td>2850.65</td>
<td>1529.42</td>
<td>2897.80</td>
<td>1475.95</td>
</tr>
<tr>
<td>150°</td>
<td>3040.99</td>
<td>1627.51</td>
<td>3495.43</td>
<td>1834.44</td>
</tr>
<tr>
<td>Overall</td>
<td>2441.87</td>
<td>1152.31</td>
<td>2572.53</td>
<td>1298.23</td>
</tr>
</tbody>
</table>

Note: As there were two missing values within the data set (one for a male for 150° and one for another male for 60°), the ANOVA ran on males n=28 and females n=30 rather than on males n=30 and females n=30. Therefore the means of the sample sizes ran by the ANOVA are reported.
As shown in Table 7.2, RTs increased with increases in angle of rotation for each sex. To determine whether RTs differed significantly with angle of rotation, and between each sex, a $6 \times 2$ (angle of rotation) x 2 (sex: male, female) mixed-design ANOVA, with sex as a between-subjects factor and angle as a within-subjects factor, was calculated on the participants mean RTs. A significant main effect for angle was observed ($F(2.96, 165.58) = 46.20, p < 0.001$, partial $\eta^2 = 0.45$), with post-hoc paired t-tests indicating that RTs increased significantly with increases in angular rotation. There was the exception of RTs between $30^\circ$ to $60^\circ$, which did not significantly differ. The post-hoc paired t-tests comparing RTs between each increasing angle are presented in Table 7.3, along with the group mean RTs and SDs for each angle. As illustrated in Table 7.2, there was little difference in overall RT between the sexes, which was further displayed by a non-significant main effect for sex ($F(1, 56) = 0.16, p = 0.69$). No significant interaction was evident between angle of rotation and sex ($F(2.96, 165.58) = 1.72, p = 0.17$).

Table 7.3.

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>M</th>
<th>SD</th>
<th>t (57)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>1644.25</td>
<td>917.45</td>
<td>-6.47</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>30°</td>
<td>2224.54</td>
<td>1284.23</td>
<td>-1.20</td>
<td>0.23</td>
</tr>
<tr>
<td>60°</td>
<td>2350.81</td>
<td>973.12</td>
<td>-3.24</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>90°</td>
<td>2632.88</td>
<td>1347.92</td>
<td>-2.82</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>120°</td>
<td>2851.45</td>
<td>1415.71</td>
<td>-4.60</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>150°</td>
<td>3276.05</td>
<td>1737.60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A one-way ANOVA comparing the mental rotation slopes between the males and females further confirmed the non-significant sex difference in the rate of mental rotation ($F(1, 56) = 1.20, p=0.28$), despite the mean slope value for males ($M = 8.53$ msec/degree, $SD = 7.88$) being faster than the mean slope value for females ($M = 10.84$ msec/degree, $SD = 8.14$). A one-way ANOVA on the MRT intercepts also indicated that there was no significant sex difference in the time taken to encode, compare and respond to the stimuli ($F(1, 56) = 0.03, p=0.88$), with the intercept values being comparable between the sexes (males: $M = 1802.21$ msec, $SD = 911.46$; females: $M = 1759.94$ msec, $SD = 1102.33$). Given the violation in the normality assumption of ANOVA for the slope and intercept of both sexes, the validity of the non-significant sex difference findings were confirmed by the non-parametric Mann-Whitney test (Slope: $Z = -0.88, p = 0.38$; Intercept: $Z = -0.95, p = 0.34$).

**Accuracy**

To check for possible speed–accuracy trade-offs for each sex, a 6 (angle of rotation) x 2 (sex: male, female) mixed-design ANOVA, with sex as a between-subjects factor, and angle as a within-subjects factor was calculated on participant accuracy rates. The results indicated that there was no significant main effect for sex ($F(1, 58) = 0.62, p = 0.43$), with accuracy not differing significantly between the males ($M = 90.56\%, SD = 8.38$) and females ($M = 92.22\%, SD = 8.00$). There was a significant main effect for angle ($F(2.88,166.87) = 15.72, p<0.001, \eta^2 = 0.21$), with accuracy rates generally reducing with increases in angle of rotation. The post-hoc paired t-tests comparing accuracy between each increasing angle of rotation are presented in Table 7.4, along with the group mean accuracy and SDs for each angle. The general decrease in accuracy with increasing angle of rotation is the opposite trend to what would be expected if there was a speed-accuracy trade-off. The ANOVA also indicated that there was no significant interaction between angle of rotation and sex ($F(2.88,166.87) = 1.21, p = 0.31$).

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5 Analyses on the intercept and slope were conducted on $n=58$ which is what the mixed-design ANOVA ran on due to two missing cases.
Table 7.4.

Group Mean accuracy and SDs as a function of angle of rotation in the MRT and t-tests comparing accuracy between each increasing angle of rotation – Experiment One.

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>M</th>
<th>SD</th>
<th>t (59)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>97.74%</td>
<td>4.81</td>
<td>2.82</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>30°</td>
<td>94.79%</td>
<td>8.70</td>
<td>1.38</td>
<td>0.17</td>
</tr>
<tr>
<td>60°</td>
<td>93.13%</td>
<td>9.04</td>
<td>-1.56</td>
<td>0.12</td>
</tr>
<tr>
<td>90°</td>
<td>95.42%</td>
<td>7.96</td>
<td>3.73</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>120°</td>
<td>87.29%</td>
<td>16.35</td>
<td>2.81</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>150°</td>
<td>81.67%</td>
<td>21.28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.3.2 Verbal fluency task

The mean number of words and SDs produced for phonemic and semantic verbal fluency are presented in Table 7.5 for each sex separately.

Table 7.5.

Means number of words and SDs produced by the males and females for phonemic and semantic verbal fluency – Experiment One.

<table>
<thead>
<tr>
<th></th>
<th>Males (n = 30)</th>
<th>Females (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Phonemic fluency</td>
<td>14.37</td>
<td>6.51</td>
</tr>
<tr>
<td>Semantic fluency</td>
<td>3.70</td>
<td>2.37</td>
</tr>
</tbody>
</table>
As shown in Table 7.5, females produced more words than males for both phonemic and semantic verbal fluency. One-way ANOVAs, with sex as a between-subjects factor, indicated that the female advantage in verbal fluency was significant for both phonemic fluency ($F(1, 58) = 5.12, p<0.05$, partial $\eta^2 = 0.08$), and semantic fluency ($F(1, 58) = 4.98, p<0.05$, partial $\eta^2 = 0.08$).

### 7.3.3 Chimeric faces task

Reaction time and accuracy analyses were conducted separately. All analyses for accuracy were conducted on the participants’ accuracy rates (total correct by participant for the given visual field / emotion chimeric face condition, divided by the total possible correct for that visual field / emotion condition). The accuracy rates were converted into percentiles for tabulated and graphical presentations (multiplying the accuracy rate by 100) to make interpretation easier.

The purpose of the chimeric faces task was to analyse visual field differences in the recognition of happy and sad emotions, in order to examine brain lateralization for processing positive and negative affect. Therefore, analyses of visual field differences in the recognition of the neutral expressions were not conducted.

#### 7.3.3.1 Chimeric faces - Reaction time

The mean RTs and SDs to the happy and sad emotional expressions presented to each visual field by the chimeric face stimuli are presented in Table 7.6 for each sex separately.
Table 7.6.

Mean RTs (msec) and SDs to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the males and females - Experiment One.

<table>
<thead>
<tr>
<th></th>
<th>Males (n = 25)</th>
<th>Females (n = 28)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Happy</td>
<td>1292.52</td>
<td>466.26</td>
</tr>
<tr>
<td>LVF</td>
<td>1279.50</td>
<td>522.15</td>
</tr>
<tr>
<td>RVF</td>
<td>1305.54</td>
<td>456.26</td>
</tr>
<tr>
<td>Sad</td>
<td>1315.77</td>
<td>357.39</td>
</tr>
<tr>
<td>LVF</td>
<td>1190.30</td>
<td>251.95</td>
</tr>
<tr>
<td>RVF</td>
<td>1441.25</td>
<td>560.43</td>
</tr>
</tbody>
</table>

Overall

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LVF</td>
<td>1234.90</td>
<td>337.93</td>
</tr>
<tr>
<td>RVF</td>
<td>1373.40</td>
<td>484.17</td>
</tr>
</tbody>
</table>

Note: As there were six missing values within the data set (four for the males, and two for the females), the ANOVA ran on males n=25 and females n=28 rather than males n=29 and females n=30. Therefore the means of the sample sizes ran by the ANOVA are reported.

Note: Mean RTs in rows labelled “Happy” and “Sad” are of overall RTs for these emotions.

To investigate whether there were significant sex differences in RT for hemispheric processing of the happy and sad emotional expressions, a 2 (emotion: happy, sad) x 2 (visual field: LVF, RVF) x 2 (sex: male, female) mixed-design ANOVA, with sex as a between-subjects factor and visual field and emotion as within-subjects factors, was calculated on the participants mean RT data for the chimeric face stimuli. The main effects and interactions from this analysis are presented in Table 7.7.
Table 7.7.
Main effects and interactions from the 2 (emotion) x 2 (visual field) x 2 (sex) mixed-design ANOVA for the chimeric faces task RT data – Experiment One

<table>
<thead>
<tr>
<th>Main effects &amp; interactions</th>
<th>F (1, 51)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>0.61</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td>Emotion</td>
<td>2.73</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Visual field</td>
<td>7.30</td>
<td>&lt;0.01</td>
<td>0.13</td>
</tr>
<tr>
<td>Visual field x emotion</td>
<td>1.70</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Visual field x sex</td>
<td>4.23</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Emotion x sex</td>
<td>0.99</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x sex</td>
<td>2.23</td>
<td>0.14</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 7.7, there was no significant main effect for sex (male: \( M = 1304.15 \) msec, \( SD = 398.15 \); female: \( M = 1221.27 \) msec, \( SD = 375.20 \)), or for emotion (happy: \( M = 1230.03 \) msec, \( SD = 420.08 \); sad: \( M = 1290.69 \) msec, \( SD = 390.98 \)). There was a significant main effect for visual field, with responses being significantly faster to expressions shown in the LVF (\( M = 1222.72 \) msec, \( SD = 370.65 \)) than in the RVF (\( M = 1298.00 \) msec, \( SD = 427.09 \)). The only significant interaction between the variables was for visual field and sex, which approached statistical significance. The interaction between visual field and sex is presented in Figure 7.8.
Post-hoc t-tests were used to further assess the significant visual field by sex interaction. Post-hoc paired t-tests comparing RTs between each visual field for each sex showed that the males responded significantly faster ($t(24) = 2.76, p<0.05$) to expressions presented in the LVF than in the RVF. For the females, there was no significant difference ($t(27) = 1.20, p=0.24$) in RT between visual field presentations. Post-hoc independent t-tests comparing the RTs to each visual field between the sexes showed that there were no significant differences in RT between the sexes for identifying the emotions presented in the LVF ($t(51) = 0.50, p=0.62$) or in the RVF ($t(51) = 1.22, p=0.23$). As can be observed in Figure 7.6, the standard errors of the mean RTs produced by each sex for RVF presentations were large, thus potentially inhibiting the finding of a significant difference. Refer to Table 7.6 for the mean RTs to each visual field for each sex.
The mean RTs to the happy and sad expressions shown in each visual field are presented in Figure 7.9 for each sex.

Figure 7.9. Mean RTs and SEM to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the males and females - Experiment One.

Figure 7.9 indicates that the significant LVF advantage in RT observed for the males in Figure 7.8 was largely generated by the greater visual field difference in RT to sad than happy emotional expressions. Although the interaction between visual field, emotion, and sex was not significant, Figure 7.9 and the means in Table 7.6 indicate that the difference in RTs to visual field presentations of happy and sad expressions differed between the sexes, in particular to sad expressions. With a low observed power of 0.31 for the three-way interaction, it is possible that there was not enough statistical power to detect a
significant interaction between visual field, emotion, and sex. To further assess the three-way interaction, paired t-tests were calculated for each sex to compare differences in RT to visual presentations of the happy expressions and to the sad expressions. The paired t-tests showed that the males recognised sad expressions significantly faster when they were shown in the LVF than in the RVF (t (24) = 2.54, p<0.05), however, there was no significant visual field difference in RT to happy expressions (t (24) = 0.43, p=0.67). For the females, there were no significant visual field differences in RT for identifying happy (t (27) =0.42, p=0.68) or sad expressions (t (27) = 0.21, p=0.84). Within each visual field for the males, happy expressions were recognised significantly faster than the sad expressions presented in the RVF (t (24) = -2.08, p=0.05), and there was no significant difference in RT to the happy and sad expressions shown in the LVF (t (24) = 0.96, p=0.35). Within each visual field for the females, there was no significant difference in RTs to the happy and sad expressions presented in the RVF (t (27) =-1.07, p=0.29) or in the LVF (t (27) = -1.66, p=0.11).
7.3.3.2 Chimeric faces - Accuracy

The mean percentage correct and SDs for the recognition of happy and sad emotional expressions shown in each visual field by the chimeric face stimuli are presented in Table 7.8 for each sex separately.

Table 7.8.

Mean recognition accuracy (percentage correct) and SDs to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the males and females - Experiment One.

<table>
<thead>
<tr>
<th></th>
<th>Males (n = 29)</th>
<th>Females (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Happy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>64.72%</td>
<td>19.21</td>
</tr>
<tr>
<td>LVF</td>
<td>66.31%</td>
<td>24.53</td>
</tr>
<tr>
<td>RVF</td>
<td>63.13%</td>
<td>22.74</td>
</tr>
<tr>
<td>Sad</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>44.40%</td>
<td>16.15</td>
</tr>
<tr>
<td>LVF</td>
<td>47.41%</td>
<td>16.83</td>
</tr>
<tr>
<td>RVF</td>
<td>41.38%</td>
<td>19.98</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LVF</td>
<td>56.86%</td>
<td>16.36</td>
</tr>
<tr>
<td>RVF</td>
<td>52.25%</td>
<td>15.59</td>
</tr>
</tbody>
</table>

Note: the total number of possible correct responses was thirteen for happy expressions and twelve for sad emotions in each visual field.

Note: Mean accuracy in rows labelled “Happy” and “Sad” is of overall accuracy for these emotions.

To investigate whether there were significant sex differences in recognition accuracy hemispheric processing of the happy and sad emotional expressions, a 2 (emotion: happy, sad) x 2 (visual field: LVF, RVF) x 2 (sex: male, female) mixed-design ANOVA, with sex as a between-subjects factor and visual field and emotion as within-subjects factors, was calculated on the participant’s mean accuracy rates for the chimeric face stimuli. The main effects and interactions from this analysis are presented in Table 7.9.
Table 7.9.

Main effects and interactions from the 2 (emotion) x 2 (visual field) x 2 (sex) mixed-design ANOVA for the chimeric faces task accuracy rate data – Experiment One.

<table>
<thead>
<tr>
<th>Main effects &amp; interactions</th>
<th>F (1, 57)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>4.42</td>
<td>&lt;0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>Emotion</td>
<td>23.22</td>
<td>&lt;0.001</td>
<td>0.29</td>
</tr>
<tr>
<td>Visual field</td>
<td>10.16</td>
<td>&lt;0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>Visual field x emotion</td>
<td>0.60</td>
<td>0.44</td>
<td></td>
</tr>
<tr>
<td>Visual field x sex</td>
<td>1.92</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Emotion x sex</td>
<td>1.30</td>
<td>0.26</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x sex</td>
<td>2.26</td>
<td>0.14</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 7.9, a significant main effect was observed for sex, with the females ($M = 61.55\%$, $SD = 12.81$) responding with significantly greater accuracy than the males ($M = 54.56\%$, $SD = 12.71$). A significant main effect was also observed for emotion, with responses being significantly more accurate to happy expressions ($M = 66.30\%$, $SD = 20.32$) than to sad expressions ($M = 49.93\%$, $SD = 16.64$). A significant main effect was observed for visual field, with responses being significantly more accurate to expressions shown in the LVF ($M = 62.22\%$, $SD = 17.42$) than in the RVF ($M = 54.01\%$, $SD = 15.41$). No significant interactions between the variables sex, emotion, and visual field were observed. The mean recognition accuracy of happy and sad expressions shown in each visual field is presented in Figure 7.10 for each sex.
Figure 7.10. Mean recognition accuracy (percentage correct) and SEM to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the males and females - Experiment One.

Although the interaction between visual field, emotion, and sex was not significant, Figure 7.10 and the means presented in Table 7.8 indicate that recognition accuracy to visual field presentations of the happy and sad expressions differed between the sexes, in particular to the happy expressions. With a low observed power of 0.32 for the three-way interaction, it is possible that there was not enough statistical power to detect a significant interaction between visual field, emotion, and sex. To further assess the three-way interaction, paired t-tests were calculated for each sex to compare recognition accuracy between visual field presentations of happy and sad expressions. For the females, happy expressions were recognised with significantly greater accuracy when presented in the LVF than in the RVF ($t(29) = -3.04, p<0.01$), although no significant visual field difference in recognition accuracy was observed for sad
expressions ($t(29) = -1.75, p=0.09$). For the males, there was no significant difference in recognition accuracy to visual field presentations of the happy expressions ($t(28) = -0.62, p=0.54$), or the sad expressions ($t(28) = -1.81, p=0.08$). Within each visual field for the males, happy expressions were recognised with significantly greater accuracy than sad expressions shown in the RVF ($t(28) = 3.99, p<0.001$), and in the LVF ($t(28) = 3.85, p=0.001$). For the females, there was no significant difference in recognition accuracy to happy and sad expressions shown in the RVF ($t(29) = 1.19, p=0.24$). Happy expressions however, were recognised significantly more accurately than sad expressions shown in the LVF ($t(29) = 3.53, p=0.001$).

7.3.4 Effects of significant demographic differences between the sexes

As indicated in demographics Table 7.1, the mean number of years of education, handedness and vocabulary $t$-scores differed significantly between the males and females. It is therefore possible that the significant differences observed between the sexes on the phonemic and semantic verbal fluency tasks, for the RT analyses of the chimeric faces task (significant visual field by sex interaction), and for the accuracy analyses of the chimeric faces (significant main effect for sex), were confounded by significant sex differences in years of education, handedness and Vocabulary.

Years of education, handedness and Vocabulary were assessed for suitability as a covariate by firstly examining whether they were related to the dependent variables of the verbal fluency task and the chimeric faces task for each sex. Using Pearson’s $r$ and scatterplots, a linear relationship between the dependent variable and confounding variable (years of education, handedness or Vocabulary) would indicate that the confounding variable was possibly influencing the observed sex difference in task performance. A linear relationship between the dependent variable and confounding variable would thus warrant further assessment of the use of the confounding variable, as a covariate in analysis of covariance (ANCOVA). Where the assumptions of ANCOVA were violated, an alternative to ANCOVA was implemented. The alternative to ANCOVA involved categorising the confounding variable into a categorical variable, and using it as an additional independent variable in factorial ANOVA (Tabachnick &
Fidell, 2001). Frequency tables were used to determine the categories of each demographic variable. An attempt was made to have as many participants in each category as possible, and also to make the categories as balanced as possible between the males and females. In the factorial ANOVAs, the interaction between the categorised variable (years of education, handedness or Vocabulary) and sex is the only effect of interest. An interaction would indicate that the differences in years of education, handedness and Vocabulary had an impact on the performance of each sex, and that further analysis would be required. The proceeding Sections 7.3.4.1, 7.3.4.2 and 7.3.4.3 examine whether years of education, handedness, and Vocabulary respectively, met the assumptions of ANCOVA. These sections also outline how the demographic variables were categorised for factorial ANOVA, if they violated the assumptions of ANCOVA. The results for each analysis assessing whether the demographic variables of years of education, handedness, and Vocabulary were confounding the observed sex differences in task performance are also presented.

7.3.4.1 Years of education

To determine whether years of education should be treated as a covariate, the relationship between years of education and the dependent variables of the verbal fluency task, and chimeric faces task, were examined. For both the males and females, Pearson’s r indicated no significant linear relationship between years of education and semantic verbal fluency. Also for each sex, Pearson’s r indicated no significant linear relationships between years of education and RTs to each visual field / emotion condition of the chimeric faces task. These findings suggest that the significant main effect for sex for the semantic verbal fluency analysis, and the interaction between sex and visual field from the RT analyses of the chimeric faces task, were not influenced by a difference between the sexes in years of education. Further treatment of years of education as a covariate for the semantic verbal fluency task, and for RT analyses of the chimeric faces task was therefore, not necessary. For the males, a significant linear relationship between years of education and phonemic verbal fluency was observed ($r (30) = 0.58, p=0.001$), along with a significant linear relationship between years of education and accuracy to the LVF happy faces of the chimeric faces task ($r (29) = 0.54, p<0.01$). Therefore, years of education may have influenced
phonemic verbal fluency, and accuracy to the chimeric faces, for males. As such, years of education was further examined for use as a covariate in ANCOVA.

An assumption of ANCOVA is that the covariate (years of education) is unrelated to the independent variable (sex of the participant). A correlation analysis using Kendall's Tau-b indicated a weak, yet significant relationship between the independent variable and covariate for the verbal fluency task ($\zeta (60) = 0.22, p<0.05$), and for the chimeric faces task ($\zeta (59) = 0.23, p<0.05$). Therefore, the assumption of ANCOVA that there be no relationship between the covariate and independent variable was violated. An additional assumption of ANCOVA is that there is a linear relationship between the dependent variable and the covariate for both sexes. As previously mentioned, Pearson's $r$ and scatterplots showed a significant linear relationship between years of education and phonemic verbal fluency, and between years of education and accuracy to LVF happy faces of the chimeric faces task, for the males only. A linear relationship between these conditions was not observed for the females, thus violating the assumption that a linear relationship would be observed between the dependent variable and covariate for both sexes.

Another assumption of ANCOVA is that there is homogeneity of regression slopes, in which the relationship of the dependent variable to the covariate is the same for each sex. Inspection of scatterplots indicated that the homogeneity of regression slopes assumption was violated for phonemic verbal fluency, and the accuracy rates to each visual field / emotion condition of the chimeric faces task. Due to the violations of the assumptions of ANCOVA, years of education was inappropriate for use as a covariate in ANCOVA. Years of education was subsequently converted into a categorical independent variable for use in a factorial ANOVA.

Years of education was categorised into three categories: $\leq$4 years, 5-9 years, $\geq$ 10 years. The sample size for each category is depicted in Table 7.10. Note that there was one participant who was excluded from the accuracy analyses of the chimeric faces task due to extremely low accuracy. Years of education still differed significantly between the males and females after the exclusion of this participant. The change in sample size for the category in which there was a missing participant for the chimeric faces task, is indicated in brackets in Table 7.10.
Table 7.10

<table>
<thead>
<tr>
<th>Sex</th>
<th>&lt;=4</th>
<th>5-9</th>
<th>&gt;=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>12</td>
<td>14 (13)</td>
<td>4</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>N=60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A 2 (sex) x 3 (years of education category) factorial ANOVA was calculated on the number of words generated for phonemic verbal fluency. No significant interaction was found between sex and years of education for phonemic fluency ($F(2, 54) = 2.69, p=0.08$), indicating that the relationship between years of education and phonemic verbal fluency did not differ between the sexes. A 2 (visual field) x 2 (emotion) x 2 (sex) x 3 (years of education) mixed-design ANOVA, calculated on the accuracy rates of the chimeric faces task, indicated no significant interaction between sex and years of education ($F(2, 53) = 0.03, p=0.98$). Therefore, the relationship between years of education and accuracy on the chimeric faces task, did not differ significantly between the sexes. The factorial ANOVAs showed that the significant difference in years of education between the males and females did not confound the sex difference findings observed on the phonemic verbal fluency task, and on the accuracy analyses of the chimeric faces task.

7.3.4.2 Handedness

To determine whether handedness should be treated as a covariate, the relationship between handedness and the dependent variables of the verbal fluency task, and chimeric faces task, were examined. For both the males and females, Pearson’s $r$ indicated no significant linear relationship between handedness and phonemic verbal fluency, or between handedness and semantic verbal fluency. Also for each sex, Pearson’s $r$ indicated no significant linear relationships between handedness and RTs to each visual field / emotion condition of the chimeric faces task. These findings suggest that the significant main effect for sex observed for the verbal fluency task, and the significant interaction between sex and visual field
observed for the RT analyses of the chimeric faces task, was not influenced by handedness. Further treatment of handedness as a covariate for the verbal fluency task, and RT analyses of the chimeric faces task, was therefore not necessary. For the males, a significant linear relationship between handedness and accuracy to RVF sad faces of the chimeric faces task ($r (29) = 0.44, \ p<0.05$) was observed. Therefore, handedness may have influenced the recognition accuracy of males to the chimeric faces. As such, handedness was examined for further use as a covariate in ANCOVA.

The assumption of ANCOVA that the covariate (handedness) is unrelated to the independent variable (sex) was firstly examined. A correlation analysis using Kendall’s Tau-b indicated that there was no significant relationship between handedness and sex for the chimeric faces task ($\xi (59) = 0.18, \ p=0.12$), thus not violating the assumption. The assumption of ANCOVA that the covariate is linearly related to the dependent variable for both sexes, was then investigated for the accuracy rates to each visual field / emotion condition of the chimeric faces task. As previously mentioned, Pearson’s $r$ and scatterplots showed a significant linear relationship between handedness and accuracy to RVF sad faces of the chimeric faces task for the males only. A linear relationship between these conditions was not observed for females, thus violating the assumption that a linear relationship would be observed between the dependent variable and covariate for both sexes. The homogeneity of regression slopes assumption of ANCOVA was also violated for the accuracy rates to each visual field / emotion condition of the chimeric faces task. Due to the violations of the assumptions of ANCOVA, handedness was inappropriate for use as a covariate in ANCOVA. Handedness was subsequently converted into a categorical independent variable for use in a factorial ANOVA.

Handedness scores were categorised into three categories: $<=70$, $71 - 90$, $>91$. The sample size for each category is depicted in Table 7.11. The change in sample size for the category in which a participant was excluded from the accuracy analyses of the chimeric faces task, due to low accuracy, is indicated in brackets in Table 7.11. Handedness still differed significantly between the males and females after the exclusion of this participant.
Table 7.11

Sample sizes for categorised handedness by sex of the participant – Experiment One.

<table>
<thead>
<tr>
<th>Handedness category</th>
<th>Sex</th>
<th>&lt;=70</th>
<th>71 - 90</th>
<th>&gt;=91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>14</td>
<td>5 (4)</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>15</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>N=60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A 2 (visual field) x 2 (emotion) x 2 (sex) x 3 (handedness category) mixed-factorial ANOVA, calculated on the accuracy rates of the chimeric faces task, indicated no significant interaction between sex and handedness ($F (2, 53) = 0.07, p=0.94$). This finding suggests that the significant difference in handedness between the males and females, did not impact the participant’s recognition accuracy on the chimeric faces task, and thus did not confound the significant interaction between visual field and sex.

7.3.4.3 Premorbid IQ / Vocabulary

To determine whether Vocabulary should be treated as a covariate, the relationship between Vocabulary and the dependent variables of the verbal fluency task, and chimeric faces task, were examined. For each sex, Pearson’s r indicated no significant linear relationships between Vocabulary and accuracy to each visual field / emotion condition of the chimeric faces task. Therefore, the significant interaction between visual field and sex from the accuracy analyses of the chimeric faces task, was not confounded by a difference between the males and females in Vocabulary. Further treatment of Vocabulary as a covariate for the accuracy analyses of the chimeric faces task was not necessary. For the males, a significant linear relationship between Vocabulary and phonemic verbal fluency ($r (30) = 0.48, p<0.01$) was observed. For the females, a significant linear relationship between Vocabulary and semantic verbal fluency ($r (30) = 0.50, p<0.01$) was observed, along with a significant linear relationship between Vocabulary and RTs to LVF sad faces of the chimeric faces task ($r (25) = -0.41, p<0.05$). Therefore, Vocabulary may have influenced phonemic verbal fluency for males, and semantic verbal fluency for females. Vocabulary may
have also influenced the RTs of females to the chimeric faces. As such, Vocabulary was examined for further use as a covariate in ANCOVA.

The assumption of ANCOVA that the covariate (Vocabulary) is unrelated to the independent variable (sex) was firstly examined. A correlation analysis using Kendell’s Tau-b indicated a weak, yet significant relationship between the independent variable and covariate for the verbal fluency task ($\zeta (60) = 0.27, p<0.05$), and the chimeric faces task ($\zeta (53) = 0.32, p<0.01$). Therefore, the assumption of ANCOVA that there be no relationship between the covariate and independent variable was violated. The assumption of ANCOVA that the covariate is linearly related to the dependent variable for both sexes was then investigated for the verbal fluency task, and the RTs to each visual field / emotion condition of the chimeric faces task. As previously mentioned, Pearson’s $r$ and scatterplots showed a significant linear relationship between Vocabulary and phonemic verbal fluency for the males only. Further, a significant linear relationship between Vocabulary and semantic verbal fluency, and between Vocabulary and RTs to the LVF sad faces of the chimeric faces task, was observed for the females only. Therefore, the assumption that a linear relationship would be observed between the dependent variable and covariate for both sexes was violated. The assumption of ANCOVA that there is homogeneity of regression slopes was also violated for the RTs to each visual field / emotion condition of the chimeric faces task. Due to the violations of the assumptions of ANCOVA, Vocabulary was inappropriate for use as a covariate in ANCOVA. Vocabulary was subsequently converted into a categorical independent variable for use in a factorial ANOVA.

Vocabulary was categorised into three categories: <40, 41 - 50, 51+. The sample size for each group is depicted in Table 7.12. The change in sample size for the categories in which there was a missing case for the RTs on the chimeric faces task (and excluded male participant from category 3 (51+ Vocabulary t-score)) are indicated in brackets in Table 7.12. Vocabulary still differed significantly between the males and females after the exclusion of the participants.
A 2 (sex) x 3 (Vocabulary category) factorial ANOVA was calculated on the number of words generated for phonemic and semantic verbal fluency performance. No significant interaction was observed between sex and Vocabulary for both phonemic verbal fluency ($F(2, 54) = 0.50, p=0.61$), and semantic verbal fluency ($F(2, 54) = 0.46, p=0.64$). Therefore, the significant difference in Vocabulary between the males and females did not confound the sex difference findings observed on the verbal fluency task.

A 2 (visual field) x 2 (emotion) x 2 (sex) x 3 (Vocabulary category) mixed-factorial ANOVA calculated on RTs from the chimeric faces task, showed a significant interaction between sex and Vocabulary ($F(2, 47) = 3.57, p<0.05$, partial $\eta^2 = 0.13$). This finding indicates that the significant visual field by sex interaction, observed from the RT analyses of the chimeric faces task, may have been confounded by the significant sex difference in Vocabulary. Inspection of the mixed-design ANOVA showed that even after including Vocabulary as an independent variable, the interaction between visual field and sex was still significant ($F(1, 47) = 4.52, p<0.05$, partial $\eta^2 = 0.09$). Separate 2 (visual field) x 2 (emotion) x 2 (sex) mixed-factorial ANOVAs, calculated on the mean RT data of participants from each Vocabulary category, showed that a significant visual field by sex interaction was evident for the category of participants who obtained Vocabulary t-scores between 41 – 50 ($F(1, 18) = 4.92, p<0.05$, partial $\eta^2 = 0.22$). No significant sex differences in RTs to visual field presentations were observed for participants with Vocabulary t-scores ≤ 40 ($F(1, 15) = 0.86, p=0.37$), or ≥ 51 ($F(1, 14) = 0.72, p=0.41$). Paired t-tests showed that the males within the 41 - 50 Vocabulary category responded significantly faster ($t(9) = 2.53, p<0.05$) to expressions shown to the LVF ($M = 1097.42$ msec, $SD = 286.36$) than the RVF ($M = 1302.51$ msec, $SD = 496.72$). No
significant difference in RTs to expressions shown to the LVF ($M = 1544.77$ msec, $SD = 383.91$) and RVF ($M = 1512.43$ msec, $SD = 362.91$) was observed for the females ($t(9) = -0.46$, $p=0.66$). Between the sexes, there was no significant difference in RTs to expressions shown to the RVF ($t(18) = -1.08$, $p=0.30$), however, the males responded significantly faster than did the females to LVF presentations ($t(18) = -2.95$, $p<0.01$).

7.3.4.4 Missing cases and demographics

As indicated in the MRT analyses and RT analyses of the chimeric faces task, there were missing cases within these datasets that were not replaced. The ANOVA analyses excluded participants with a missing case from the dataset, thus reducing the sample sizes from those reported in demographic Table 7.1. It is possible that the significant sex differences in the demographics reported in Table 7.1 changed with the reduced sample sizes. If so, there may be an additional demographic that differed significantly between the males and females that needs to be considered as a covariate.

One-way ANOVAs were recalculated comparing the demographics between the males and females of the smaller sample sizes of the MRT (males $n=28$, females $n=30$), and RT analyses of the chimeric faces task (males $n=25$, females $n=28$). For the reduced sample sizes of both the MRT analyses, and RT analyses of the chimeric faces task, the same significant sex differences in demographics that were reported in Table 7.1 for the original sample size (males $n=30$, females $n=30$) were found. There was the exception of handedness, however, which was no longer significantly different between the sexes for the reduced sample size of the chimeric faces task. There were no additional covariates that had to be considered for the analyses of Experiment One.
7.4 Discussion

The aim of Experiment One was to examine sex differences in brain lateralization for spatial and verbal functioning, by comparing task performance between the males and females on the MRT, and on the verbal fluency task. In addition, it was the aim of Experiment One to further examine brain lateralization for emotional processing, and examine sex differences in brain lateralization for emotional processing, by comparing task performance between the males and females on the chimeric faces task.

Sex differences in brain lateralization for spatial and verbal functioning

For the MRT, a positive linear relationship between RT and angle of rotation was observed for each sex, with RTs increasing with increases in angle of rotation. This finding indicates that both the males and females were in fact mentally rotating the PMA stimuli (Cooper, 1976; Cooper & Shepard, 1975; Shepard & Metzler, 1971). Despite the slight male advantage in overall RT, and also on the mental rotation slope, the difference was not large enough to produce a significant sex difference in mental rotation performance. Therefore, the hypothesis that the male participants would mentally rotate the stimuli significantly faster than the female participants was not supported by the results of Experiment One. There was also no significant sex difference on the mental rotation intercept, thus in the time taken to encode the PMA stimuli. There were no strong non-significant trends showing a difference between the males and females in mental rotation performance, to indicate that the large SDs and SEM contributed to the failure to detect a significant sex difference in performance.

The failure to find a significant male advantage in performance on the MRT, more particularly for the rate of mental rotation, is inconsistent with the majority of past literature that has reported a sex difference in mental rotation (Blough & Slavin, 1987; Bryden, et al., 1990; Delgrado & Prieto, 1996; Dollinger, 1995; Kail, et al., 1979; Maccoby & Jacklin, 1974). In the past, the finding of no sex difference, or a reduced male advantage in mental rotation, has often been attributed to the stimuli used in the MRT. Stimuli of a verbal nature have been argued to enhance the performance of females, given their superior processing
for verbal material (Kail, et al., 1979; Uecker & Obrzut, 1993). Such improvement in performance by the females is assumed to reduce the sex difference in mental rotation performance. Whilst this explanation may be applicable to studies using alphanumeric characters (Desrocher, et al., 1995; Kail, et al., 1979), or stick figures (Uecker & Obrzut), it does not adequately explain the failure to observe a significant sex difference in performance on the MRT in Experiment One. The PMA stimuli used in the MRT of Experiment One are believed to be unfamiliar in the sense of being relatively free of verbal labels (Kail, et al.). In addition, a significant male advantage in the rate of mental rotation has been reported in past mental rotation research that has administered PMA stimuli (Blough & Slavin; Kail, et al.).

It would be difficult to argue that there were too few trials in the MRT of Experiment One to detect a significant sex difference in mental rotation performance. The number of trials administered in the MRT was equal to the number of PMA stimulus trials administered by Kail, et al. (1979), and greater than the number of PMA stimulus trials administered by Blough and Slavin (1987), who both reported a male advantage in mental rotation. It was expected that the sample size used in Experiment One was large enough to detect a significant sex difference in mental rotation performance. This being because a significant male advantage in mental rotation has been reported from past research that has used comparable or smaller sample sizes. For example, using the PMA stimuli, Blough and Slavin administered a MRT to a sample of thirty males and thirty females and observed the typically reported male advantage in mental rotation. Using differing stimuli in a MRT, Bryden, et al. (1989) observed a male advantage in the rate of rotation from a sample of ten males and ten females. Also, Dollinger (1995) observed a male advantage in overall RT on a MRT from a sample of approximately eighteen males, and eighteen females. Although it was expected that the sample size was large enough to detect a significant sex difference in performance on the MRT, it is possible that it was not.

Sex differences in cognitive performance, such as spatial functioning, have been a common observation, however they have also generally been statistically weak. The failure to observe a sex difference in

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6 The p for males and females was not clearly stated in the paper of Dollinger (1995) however the paper indicated that there were <=18 of each sex.
performance on the MRT does not necessarily mean that there is no sex difference in brain lateralization for spatial functioning. In fact, the extensive amount of literature reporting a male advantage in mental rotation would suggest that this is not the case. In the case of this experiment, it is likely that any sex difference in mental rotation performance (male advantage in overall RT and mental rotation slope) was just too weak to reach statistical significance.

The hypothesis that the female participants would generate significantly more words than the male participants for phonemic and semantic verbal fluency was supported by the results of Experiment One. The significantly better performance by females for phonemic and semantic fluency is consistent with past research reporting a sex difference in verbal fluency (Acevado, et al., 2000; Herlitz, et al., 1997, 1999; Monsch, et al., 1992), and female advantage on verbal tasks. The superior performance of females on verbal tasks has been attributed to their bilateralization of verbal processing, which is assumed more efficient than the unilateral processing of verbal stimuli (Springer & Deutsch, 1993) for males (Gur, et al., 1982; Inglis & Lawson, 1981, 1982; Lauber, et al., 1994; McGlone, 1977, 1980; Shaywitz, et al., 1995).

In summary, the results of Experiment One partially replicated the sex differences in cognitive functioning that have been indicative of sex differences in brain lateralization for spatial and verbal functioning. More specifically, a female advantage for verbal functioning was observed, however a male advantage for spatial functioning was not observed.

*Sex differences in brain lateralization for emotional processing*

The results showed that overall, responses were faster and more accurate to expressions shown in the LVF than in the RVF, regardless of emotion and sex. Therefore, consistent with the majority of past research that has used chimeric face paradigms to investigate brain lateralization for emotional processing (Campbell, 1978; Christman & Hackworth, 1993; David, 1989; Drebing, et al., 1997; Moreno, et al., 1990; Wirsén, et al., 1990), the results of Experiment One support the RH hypothesis. That is, that the RH is more specialized than the LH for processing emotional stimuli, regardless of valence.
Support for the RH hypothesis, from the results of Experiment One, validates the findings from earlier chimeric face research in which the methodology may have arguably contributed to a RH advantage. One limitation in the methodology of past research has been the exposure of the chimeric face stimuli for a duration longer than 150 msec. Displaying the chimeric face stimuli for longer than 150 msec does not control for reflexive horizontal saccadic eye movements, which may ultimately expose the emotions of the chimera to both hemispheres (Currie, et al., 1993; Nicholls, 1994) and result in unreliable findings of brain lateralization for emotional processing. The research of Drebing, et al. (1997) did not take the stimulus exposure duration into consideration, with the researchers presenting chimeric faces to participants for a duration of 500 msec. The display duration of 500 msec would have been ample time to expose the face stimuli as chimeras. The odd appearance of a chimera may encourage the participant to examine the face in more detail and as a consequence, increase saccadic eye movements, or induce facial processing, which has been found to be a function of the RH (Geffen, et al., 1971; Kolb, Milner, & Taylor, 1983).

Past research has also differed in the type of task question that has been asked of the participant. Task questions have ranged from asking the participant: “what is the expressed emotion on the chimera?”; “which chimera is more expressive?”; “are the two chimeras the same?” Wirsén, et al. (1990) argued that the task of judging which face of a pair looks more emotionally expressive (Campbell, 1978; Christman, & Hackworth, 1993; Moreno, et al., 1990), may be predominantly activating facial processing, a function of the RH (Geffen, et al., 1971; Kolb, et al., 1983). The activation of facial processing presumably produces an attentional bias to the contralateral side in free viewing of the stimuli, thus producing a LVF bias. In contrast, tachistoscopic chimeric experiments involve directing the emotional stimuli to one or the other hemisphere, for participants to identify an emotion, thus avoiding an attentional bias. Similarly, Reuter-Lorenz, et al. (1983) argued that research using a same-different paradigm, in which participants decide whether the emotions expressed by two faces were the same or different, may also be inducing the dominant facial processing of the RH, as it involves facial comparisons. Wedding and Stalans (1985) argue that the matching requirement of deciding which face of a pair was more expressive, or whether two faces were the same or different, would typically be responded to in a holistic manner, a form of
processing generally performed by the RH. Wedding and Stalans further argue that asking a participant to simply detect an emotion allows for a measure of emotion perception that is less confounded by cognitive factors. While research that has asked participants to identify the emotion of an expression have not produced a uniform finding (Drebing, et al., 1997; Wedding & Stalans), the differences may be attributable to other methodological differences between the studies, such as differences in the duration of stimulus presentation and the stimulus presentation technique.

Whilst validating the RH hypothesis, the results of Experiment One reject the valence hypothesis of brain lateralization for emotional processing. The main source of support for the valence hypothesis has been the research of Reuter-Lorenz and Davidson (1981), and Reuter-Lorenz, et al. (1983). The most obvious difference in methodology between the studies of Reuter-Lorenz, et al., (1981, 1983), and the research of Experiment One, is the method of stimulus presentation. Unlike the chimeric faces paradigm used in Experiment One, Reuter-Lorenz, et al. (1981; 1983) used a bilateral presentation paradigm where pairs of faces (one neutral and one happy or sad expression), were presented simultaneously so that one face appeared in each visual field. Participants were asked to identify which of the two faces displayed the more intense emotional expression. While the differing stimulus presentation techniques between Experiment One and the research of Reuter-Lorenz, et al. is the most obvious account for the differing findings between these studies, it should be noted that support for the RH hypothesis has been observed from research using a bilateral presentation technique (Corina, 1989). Therefore, variance in the method of stimulus presentation between Experiment One and the research of Reuter-Lorenz, et al. may not account for the different findings of brain lateralization for emotional processing.

The reliability of the findings of Reuter-Lorenz, et al. (1981, 1983) has been questioned, due to many researchers failing to replicate the same valence effect. Despite using a very similar research design to that used by Reuter-Lorenz, et al. (1981, 1983), McLaren and Bryson (1987) failed to replicate the RVF advantage for processing happy expressions, instead observing a LVF advantage for processing happy and sad expressions. Also using a very similar methodology to that of Reuter-Lorenz, et al. (1981, 1983), Moretti, et al. (1996) failed to observe a visual field bias for the processing of happy expressions, yet
observed a LVF advantage for the processing of sad expressions. It is noted that the research designs of McLaren and Bryson, and Moretti, et al., made small methodological changes to the research design used by Reuter-Lorenz et al. (1981, 1983). Rather than asking participants to identify the more emotional face from a pair of faces, McLaren and Bryson asked participants to select faces that made them feel better or worse. Whereas Reuter-Lorenz et al. (1981, 1983) presented the face stimuli until the participant responded, Moretti, et al. presented the face stimuli for a duration of 300 msec. In addition, Moretti, et al. used a larger stimulus set than Reuter-Lorenz, et al., presenting the facial stimuli only once to each visual field. In contrast, Reuter-Lorenz et al. (1981, 1983) used a small face stimulus set, and presented their stimuli repeatedly to the visual fields. The failure to replicate the findings of Reuter-Lorenz, et al. (1981, 1983), brings into question the strength of a valence effect in the brain lateralization for emotional processing, if small methodological changes could potentially alter the findings.

Unlike the sex differences observed in brain lateralization for spatial and verbal functioning, findings from previous research on sex differences in brain lateralization for emotional processing have been inconsistent. Therefore, a directional hypothesis predicting a difference between males and females in performance on the chimeric faces task in this experiment could not be justifed.

The females in Experiment One were found to respond with significantly greater accuracy than the males when identifying the emotional expressions on the chimeras. No significant main effect for sex was observed for the RT analyses, however the females were slightly faster than the males in overall RT to the emotional expressions on the chimeras. It has been argued that females, who have been found to be more emotionally expressive than males (Barr & Kleck, 1995; Buck, et al., 1974; Kring & Gordon, 1998; Moscovitch & Olds, 1982), possess the complementary ability to make fine discriminations when judging emotional stimuli (Cupchik & Poulos, 1984). In contrast, males are believed to separate their expressive emotional reactions from their emotional experiences, thus lacking the discriminating ability of females (Cupchik & Poulos). In the past, when one sex has performed better than the other on a task of spatial or verbal skills, the sex difference in performance has often been attributed to a sex difference in brain lateralization for those skills (Kimura, 1969; McGlone, 1980). The superior performance by females for
emotional recognition, however, has not been clearly linked to a sex difference in brain lateralization for emotional processing.

The significant visual field by sex interaction observed for the RT analyses of the chimeric faces task, implicates a sex difference in brain lateralization for emotional processing. Assessment of this interaction showed that the males responded significantly faster to emotional expressions shown in the LVF than in the RVF, a finding consistent with the RH hypothesis. In contrast, no significant difference in RT was observed between the visual field presentations of emotional expressions for the females. This finding suggests that emotional processing is lateralized to the RH for males, and bilateralized for females. Post-hoc analyses indicated that the significant LVF advantage in RT for the males was stronger for the processing of the sad than of the happy expressions. To explain the stronger lateralization of negative emotions than positive emotions, Borod, Koff, and Buck (1986) argued that negative emotions are related to survival mechanisms and are therefore more lateralized in the brain than positive emotions. Survival mechanisms are presumed to involve gestalt and synthetic processing, a function of the RH, than discrete analysis, which is a function of the LH (Borod & Koff, 1984). A differing explanation was provided by Szelag and Wasilewski (1992), who suggested that a reduced hemispheric difference for the processing of happy expressions was due to two competing factors: the specialization of the LH for processing positive emotions (valence hypothesis approach) being somewhat neutralized by the specialization of the RH for processing faces. In contrast to the proposal of Szelag and Wasilewski, it could be argued that the RH is specialized for processing positive emotions (RH hypothesis approach), and the RH is somewhat neutralized by the LH processing the characteristics of the happy expression (Asthana, 2001). For example, the LH has been found to be dominant for processing simple, discrete stimuli such as a smile (Loretta & Danny, 1985). Further, positive emotions have been suggested to be more communicative (a function of the LH) than emotional (Borod, 1992). While these explanations may each account for the stronger lateralization of sad than happy emotional processing, the results of this experiment suggest that the explanation should account for sex, with brain lateralization for emotional processing differing by sex. For example, the account by Borod, et al. (1986) that the stronger lateralization for processing sad
emotions was related to survival mechanisms could be related to the evolutionary theories that males were once responsible for hunting and gathering of food which was essential for survival.

In contrast to the RT analyses, no significant interactions were observed between visual field, emotion, and sex for recognition accuracy of the chimeric faces, implying no sex differences in brain lateralization for emotional processing. The significant main effect for visual field more specifically suggests that for both males and females, there is a RH advantage in recognition accuracy for processing happy and sad expressions. Post-hoc analyses indicated that the LVF advantage in recognition accuracy for the females, was stronger for the recognition of happy than sad expressions, and also stronger than the recognition accuracy of males to happy expressions. Therefore, in direct contrast to the RT findings, the females appeared to be more lateralized in the RH than the males, and for the recognition accuracy of happy than sad emotional stimuli.

Overall, the RT and accuracy rate analyses showed a consistent RH dominance for emotional processing for the males. In contrast, the RT and accuracy rate analyses showed an inconsistent pattern of brain lateralization for emotional processing for the females, with the RT data implicating bilateralization for emotional processing, and the accuracy rate data implicating a RH dominance for emotional processing. Based on the mixed findings for the females, it might be argued that findings of sex differences in brain lateralization for emotional processing, may vary depending on the dependent variable used. For example, RT and accuracy may measure differing stages of emotional processing, which may differ for each sex. Further, unlike accuracy, RT involves a motor component (button presses) in the recording of emotional processing. It may be possible that there is a sex difference in motor performance in responding to the emotional expressions, thus resulting in a differing sex difference result in RT to that observed for accuracy. A review of the literature, however, shows that similar patterns of brain lateralization for emotional processing have been observed for females across studies that have used differing dependent variables. This can be illustrated by the similar brain laterality findings observed between the RT analyses of Experiment One, and the accuracy analyses (laterality indices) from the study of Safer (1981). The RT analyses of Experiment One, and the accuracy analyses from the study of Safer,
both implicate bilateral involvement for emotional processing for females. A review of the literature also shows that findings of brain lateralization for emotional processing for females can differ between studies that have used the same dependent variable. This can be illustrated by the differing brain laterality findings observed between the RT analyses of Experiment One, and the RT analyses of Burton and Levy (1989). Whereas the RT analyses of Experiment One implicate bilateral involvement of emotional processing for females, the RT analyses of Burton and Levy were consistent with the valence hypothesis for both males and females. Therefore, attributing the varying brain lateralization results of the females in Experiment One to the differing dependent variables of RT and accuracy is not justified by the literature.

As discussed, the method of stimulus presentation, the duration of stimulus presentation, and type of task question have varied greatly in previous research that has investigated brain lateralization for emotional processing. Such methodological differences between studies may effect the cognitive strategy used by each sex to process the emotional faces, and thus may influence which hemisphere is activated to process the task. For example, Safer (1981), and Burton and Levy (1989) both employed a “same/different” paradigm, in which an emotional face is displayed centrally for a set duration, and is followed by a laterally presented emotional face. Participants are asked whether the laterally presented face was the same, or different, to the centrally presented face. The results of the females differed between these studies, with Safer observing bilateral processing of emotional stimuli by females, and Burton and Levy obtaining findings supportive of the valence hypothesis for females. Although the method of stimulus presentation was similar between the studies of Safer, and Burton and Levy, the stimulus presentation durations between these studies varied, potentially contributing to the variance in findings.

Examination of the influence of significantly differing Vocabulary scores (IQ) between the males and females of Experiment One, indicated that the visual field by sex interaction observed for the RT analyses of the chimeric faces task was only evident for participants who obtained a Vocabulary t-score between 41 – 50. No significant interaction between visual field and sex was evident for participants with Vocabulary t-scores outside this range. This finding suggests that there may be a relationship between intelligence and emotional processing, or between verbal and emotional processing, which may vary between males and
females. Investigation of the relationship between intelligence and emotional processing, and how it effects brain lateralization for emotional processing should be investigated in future research.

It is important to note that the chimeric faces task used in the present research confounds asymmetries in facial expression (facial movement) with asymmetries in the perception of emotion. There is evidence suggesting that the left hemiface is more emotionally expressive than the right hemiface (Borod, Haywood & Koff, 1997; Heller & Levy, 1981; Indersmitten & Gur, 2003; Moreno, Borod, Welkowitz, & Alpert, 1990; Sackeim & Gur, 1978; Sackeim, Gur & Saucy, 1978). Neuroanatomically, both hemispheres have ipsilateral and contralateral projections innervating facial muscles, in which there is a greater preponderance of contralateral projections (Indersmitten & Gur, 2003; Sackeim, et al., 1978). As such, the findings of more intense emotional expressions on the left hemiface have been led to infer RH superiority for the production of emotional expressions.

In regards to the chimeric faces task, the left side of the model's face which is more vivid in emotional expression, is projected to the RVF of the participant, thus to the LH which is believed relatively inferior in the processing of emotional information, especially by the RH hypothesis. As such, asymmetry of facial expression could have counteracted asymmetry in the perception of emotion observed in this experiment.

In terms of the hypotheses of emotional processing, support for the RH hypothesis of emotional processing for both happy and sad emotional processing would have been weakened by the asymmetry of emotional expression showing stronger emotional expressions in the RVF than in the LVF. Although the valence hypothesis was not supported by this experiment, in terms of facial asymmetry, a stronger emotional expression shown in the RVF could have weakened responses to sad faces shown in the LVF but strengthened responses to the happy faces shown in the RVF. As such, interpretation of the results in terms of brain lateralization for emotional processing would be confounded.
Although facial asymmetry has largely been observed to be left-sided despite emotional valence, there is also evidence showing that the left side of a model’s face is more expressive for negative emotion and the right side of a model’s face is more expressive for positive emotion. Again, such facial asymmetry confounds brain lateralization for emotion perception. Happy faces shown in the RVF would be less expressive than the happy faces shown in the LVF, possibly resulting in a LVF advantage for the processing of happy expressions. Conversely, sad faces shown in the LVF would be less expressive than sad faces shown in the RVF, thus possibly resulting in a RVF advantage for the processing of sad expressions. In regards to the RH hypothesis, the combined effect of asymmetries for facial emotional expression and emotional perception could subsequently create a stronger LVF advantage for happy expressions and a reduced LVF advantage for sad expressions. The opposite finding was actually observed for the overall group RT analyses of brain lateralization for emotional processing, with a stronger LVF advantage being observed for the processing of sad than happy faces. The sex difference accuracy rate results, however, showed a stronger LVF advantage for the processing of happy than sad expressions for the females, suggesting that facial asymmetry may differ by sex.

Future research that uses facial stimuli to investigate brain lateralization for emotional processing is advised to present the faces in both normal orientation and also in mirror reversed orientation. Presenting both the normal and mirror reversed orientation of the facial stimuli would balance out any asymmetries of facial expression, thus not confounding the asymmetries of emotion perception.

In summary, the contrasting sex difference findings between the dependent variables of the chimeric faces task in Experiment One, and also between the findings of previous research, brings into question whether a strong sex difference in brain lateralization for emotional processing exists. If a strong sex difference, or even a similarity between the sexes for brain lateralization for emotional processing exists, it would have been expected to be observed across various methodologies, and not result in such contrasting findings as evident in the literature. Subsequent attempts to localize sex differences in brain lateralization for emotional processing may require within-experiment methodological manipulations, in attempt to identify how differences in methodology affect the sex differences observed.
The next experiment, Experiment Two, will investigate whether clinical depression is associated with a disturbance in brain lateralized cognitive and emotional functioning. In addition, Experiment Two will examine the effect that clinical depression has on the brain lateralization of each sex.
CHAPTER EIGHT

EXPERIMENT TWO

BRAIN LATERALIZATION IN CLINICAL DEPRESSION AND SEX DIFFERENCES IN BRAIN LATERALIZATION FOR A CLINICALLY DEPRESSED GROUP

8.1 Chapter Eight – Experiment Two overview

Depressed patients typically perform worse than healthy non-depressed participants on a broad range of tasks, that is, they show a generalised performance deficit. The majority of studies that have compared the performance of depressed and non-depressed participants, on neuropsychological tasks, have generally found the performance deficit of the depressed patients to be stronger on tasks measuring right hemisphere (RH) functioning (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Liotti, et al., 1991; Miller, et al., 1995; Rogers, et al., 2002). Generally, where RH dysfunction with depression has been observed, depressed and control groups have not differed significantly in performance on verbal (left hemisphere (LH)) tasks, but have differed significantly in performance on spatial (RH) tasks, with the performance of the depressed group being significantly poorer. A RH deficit with depression has not been a conclusive finding. Beardon, et al. (2001) found evidence of bilateral dysfunction with depression. Further, Silberman, et al. (1983) observed findings suggesting reversed brain laterality with depression, which the researchers attributed to possible reduced brain laterality with depression, and thus a functional shift in cognitive performance with hemispheric dysfunction.

The aim of Experiment Two was to examine whether clinical depression is associated with impaired RH functioning. This was achieved by comparing performance on the neuropsychological tasks used in Experiment One, between a clinically depressed group and a matched non-depressed control group. Based on the findings from past research, it was predicted that clinical depression would be associated with poorer performance of functions lateralized to the RH. Therefore, in terms of task performance it was hypothesised that:
Hₐ: The depressed group will perform significantly poorer than the non-depressed control group on the task measuring RH functioning, the MRT, by mentally rotating the stimuli significantly slower than the control group.

Hₜ: Performance between the depressed and control groups on the task measuring LH functioning, the verbal fluency task, will not significantly differ, with the number of words generated for phonemic and semantic verbal fluency being non-significantly different between the depressed and control groups.

Hₐ: For the chimeric faces task, the depressed group will respond significantly slower and be significantly less accurate than the control group when identifying the sad and happy expressions presented in the left visual field (LVF).

Hₜ: For the chimeric faces task, the depressed group will respond significantly slower and be significantly less accurate when identifying happy and sad emotional expressions presented in the LVF than in the right visual field (RVF).

It was also the aim of Experiment Two to investigate brain lateralized cognitive and emotional functioning for each sex within a clinically depressed group. A considerable amount of research has been devoted to investigating sex differences in brain lateralization in non-depressed samples, and on the effect of unilateral brain lesions on the brain lateralization of each sex. Research that specifically focuses on the affect of clinical depression on the brain lateralization of each sex, however, is lacking. Evidence from past research on unilateral brain damaged patients (Inglis & Lawson, 1981, 1982; Lewis & Kamptner, 1987; McGlone, 1977) suggests that dysfunction to one of the cerebral hemispheres is likely to result in greater impairment of the functions lateralized to that hemisphere for males, than for females. As females are less lateralized than males, with spatial and verbal abilities shared between the hemispheres (Kimura, 1969; Lansdell, 1961; McGlone, 1977, 1980; Springer & Deutsch, 1993), they are assumed capable of performing the task of the impaired hemisphere to some degree in the unimpaired hemisphere. Whereas,
because males are more lateralized for verbal and spatial abilities than are females (Kimura, 1969; Lansdell; McGlone, 1977, 1980; Springer & Deutsch), assistance by the unimpaired hemisphere to assist the impaired hemisphere is limited, and thus their performance is more impaired than females. There has been a suggestion that brain lateralization may be similar between depressed males and females (Heller, 1993), and that depressed patients may be less lateralized than non-depressed samples (Silberman, et al., 1983). Such proposals have been linked to the higher prevalence of females diagnosed with depression (Silberman, et al.), however, have not been empirically examined.

Based on the findings of previous research that has implicated greater impairment in brain lateralized cognitive functioning for males than females following unilateral brain lesion, it was hypothesized that:

Hₐ: Depressed males will perform significantly poorer than the depressed females on the tasks measuring functions lateralized to the cerebral hemisphere that is impaired during clinical depression

If clinical depression impairs functions lateralized to the RH as expected, then the depressed males will be expected to perform poorer than the depressed females on tasks requiring RH functioning. These being: the MRT, and the recognition of emotional expressions shown in the LVF by the chimeric faces task.

8.2 Methods

8.2.1 Participants

Thirty-nine clinically depressed patients (38 inpatients, 1 outpatient) were recruited from Albert Road Clinic in Melbourne. The process of recruitment of the clinically depressed patients was the same as that used to recruit non-depressed participants, as outlined in section 7.2.1. The inclusion criteria were the same as those outlined for the non-depressed control participants, however, the criteria of having no history of psychiatric treatment and no history of psychosis did not apply for the clinically depressed group. Furthermore, inclusion in the clinically depressed group required a HAMD score ≥ 16; a MÅDRS score ≥ 17; and a psychiatric diagnosis meeting the DSM-IV criteria for depression.
In addition to the scales and questionnaires administered to the non-depressed control participants, the clinically depressed group completed a second questionnaire that assessed their depression and treatment history. The information from the second questionnaire was cross-referenced for accuracy with information obtained from the patients’ treating psychiatrist at weekly inpatient meetings.

The data from two of the clinically depressed patients was omitted from analysis as their handedness quotients indicated that they were left-hand dominant (LQ = -73.91) and ambidextrous (LQ = 0). Another patient experienced fatigue after completing the questionnaires and asked to discontinue their participation in the experiment. Therefore the final group consisted of 36 clinically depressed patients. The data of 36 non-depressed participants from Experiment One was used to form a matched non-depressed control group. The clinically depressed and non-depressed control groups were demographically matched by group. Demographic characteristics for the clinically depressed and control groups are shown in Table 8.1, along with analyses determining whether the demographics differed significantly between the groups.

Table 8.1.

Participant mean age, education, HAMD, MÂDRS, premorbid IQ, and handedness demography for both the depressed and control groups, and significance levels for demographic comparisons between the groups – Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Depression (n= 36)</th>
<th>Control (n=36)</th>
<th>F (1, 70)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>SD</td>
<td>Range</td>
<td>M</td>
<td>SD</td>
<td>Range</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>47.58</td>
<td>13.46</td>
<td>19 - 76</td>
<td>42.56</td>
<td>16.58</td>
</tr>
<tr>
<td>HAMD score</td>
<td>21.39</td>
<td>3.78</td>
<td>16 - 29</td>
<td>2.22</td>
<td>1.82</td>
</tr>
<tr>
<td>MÂDRS score</td>
<td>27.69</td>
<td>7.12</td>
<td>17 - 41</td>
<td>1.89</td>
<td>2.16</td>
</tr>
<tr>
<td>Years of education*</td>
<td>6.77</td>
<td>3.69</td>
<td>0 - 13</td>
<td>5.94</td>
<td>4.29</td>
</tr>
<tr>
<td>Premorbid IQ*</td>
<td>45.31</td>
<td>12.11</td>
<td>20 - 66</td>
<td>44.94</td>
<td>10.88</td>
</tr>
<tr>
<td>Handedness</td>
<td>75.43</td>
<td>27.41</td>
<td>13.04 - 100</td>
<td>79.39</td>
<td>22.12</td>
</tr>
</tbody>
</table>

* years of education represents years spent at secondary and tertiary (if attended)
* Premorbid IQ as measured by the Vocabulary subtest t-score of the Wechsler Abbreviated Scale of Intelligence (WASI)

A series of between groups one-way ANOVAs were conducted to determine whether the clinically depressed and non-depressed control groups differed for the demographics presented in Table 8.1. As
expected, the results showed that there were significant differences between the depressed and control groups for the HAMD and MÅDRS\textsuperscript{7} ratings, with the depressed group obtaining scores indicative of moderate depression, and the control group obtaining ratings indicative of having no depressive symptoms (refer to section 7.2.2.2 for HAMD gradations and section 7.2.2.3 for MÅDRS gradations). There were no other significant differences between the groups for the remaining demographics.

Of the clinically depressed group, English was the predominant first spoken language (n=32). The first spoken language for four of the patients was a language other than English (Italian n=1 (male), Romanian n=1 (female), Czechoslovakian n=1 (male), Turkish n=1 (male)), however, these participants also spoke English. Twenty-two of the patients were diagnosed with Major Depression, eight were diagnosed with Bipolar Depression (with depressed state during testing), one with Post-Natal Depression, and five were diagnosed with Depression co-morbid with Post Traumatic Stress Disorder (PTSD). These patients were all placed under the umbrella of “depressed” and treated as one group. Of the depressed group, three were not taking medication whereas the remaining 33 were taking medication, which vastly differed at the time of testing. The length of depression ranged from three weeks to fifty-four years (re-occurring depressive episodes throughout the fifty-four years). All of the depressed patients were right-handed.

Of the control group, English was the predominant first spoken language (n=33). The first spoken language for three of the participants was a language other than English (Italian n=2, Filipino n=1) however these participants also spoke English. All of the non-depressed participants were right-handed.

As this experiment was also investigating differences in brain lateralization between males and females, the demographics of both groups were also broken down for each sex. The demographics of each sex within the clinically depressed and control groups are presented in Table 8.2, along with analyses determining whether the demographics differed significantly between sex within each group, and also between the same sex across groups (i.e. control males compared to depressed males).

\textsuperscript{7} The validity of the significant group difference for the MÅDRS ratings was confirmed by the non-parametric Mann-Whitney test (Z = -7.33, p <0.001) due to a violation of the homogeneity of normality assumption of ANOVA.
### Table 8.2

Participant mean age, education, HAMD, MÅDRS, premorbid IQ, and handedness demography for males and females of the depressed and control groups, and significance levels for demographic comparisons between the sexes – Experiment Two

<table>
<thead>
<tr>
<th></th>
<th>Depression M (SD)</th>
<th>Range</th>
<th>F (1,34)</th>
<th>p</th>
<th>partial η²</th>
<th>Control M (SD)</th>
<th>Range</th>
<th>F (1,34)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
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<tr>
<td><strong>Age (yrs)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>53.27 (11.27)</td>
<td>40 - 76</td>
<td>5.13</td>
<td>&lt;0.05</td>
<td>0.13</td>
<td>46.11 (16.39)</td>
<td>21 - 65</td>
<td>1.69</td>
<td>0.20</td>
<td>2.05</td>
</tr>
<tr>
<td>Females</td>
<td>43.52 (13.66)</td>
<td>19 - 74</td>
<td>3.91</td>
<td>0.88</td>
<td>0.35</td>
<td>39.00 (16.45)</td>
<td>21 - 78</td>
<td>0.88</td>
<td>0.35</td>
<td></td>
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<tr>
<td><strong>HAMD score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>21.00 (3.93)</td>
<td>16 - 29</td>
<td>0.27</td>
<td>0.61</td>
<td>0.39</td>
<td>2.06 (1.47)</td>
<td>0 - 5</td>
<td>0.30</td>
<td>0.59</td>
<td>359.87</td>
</tr>
<tr>
<td>Females</td>
<td>21.67 (3.75)</td>
<td>16 - 29</td>
<td>2.39</td>
<td>2.15</td>
<td>0.70</td>
<td>371.29 (3.69)</td>
<td>0 - 7</td>
<td>0.70</td>
<td>0.37</td>
<td></td>
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<tr>
<td><strong>MÅDRS score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Males</td>
<td>25.47 (7.55)</td>
<td>17 - 41</td>
<td>2.63</td>
<td>0.11</td>
<td>0.59</td>
<td>1.61 (1.79)</td>
<td>0 - 7</td>
<td>0.59</td>
<td>0.45</td>
<td>169.41</td>
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<tr>
<td>Females</td>
<td>29.29 (6.52)</td>
<td>17 - 40</td>
<td>2.17</td>
<td>2.50</td>
<td>0.80</td>
<td>275.65 (6.52)</td>
<td>0 - 8</td>
<td>0.80</td>
<td>0.68</td>
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<tr>
<td><strong>Years of education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>6.63 (4.14)</td>
<td>0 - 12</td>
<td>0.04</td>
<td>0.85</td>
<td>0.33</td>
<td>4.81 (4.14)</td>
<td>0 - 12</td>
<td>2.66</td>
<td>0.11</td>
<td>1.60</td>
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<tr>
<td>Females</td>
<td>6.87 (3.44)</td>
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<td>7.08</td>
<td>4.24</td>
<td>0.03</td>
<td>0.03 (3.44)</td>
<td>0 - 17</td>
<td>0.03</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td><strong>Premorbid IQ#</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>42.93 (11.52)</td>
<td>21 - 56</td>
<td>0.99</td>
<td>0.33</td>
<td>0.63</td>
<td>42.67 (12.94)</td>
<td>20 - 64</td>
<td>1.61</td>
<td>0.21</td>
<td>0.00</td>
</tr>
<tr>
<td>Females</td>
<td>47.00 (12.50)</td>
<td>20 - 66</td>
<td>47.22</td>
<td>8.08</td>
<td>0.00</td>
<td>47.22 (8.08)</td>
<td>32 - 63</td>
<td>0.00</td>
<td>0.95</td>
<td></td>
</tr>
<tr>
<td><strong>Handedness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>66.58 (31.24)</td>
<td>13.04 - 100</td>
<td>2.82</td>
<td>0.10</td>
<td>1.53</td>
<td>74.86 (26.88)</td>
<td>25 - 100</td>
<td>1.53</td>
<td>0.22</td>
<td>0.67</td>
</tr>
<tr>
<td>Females</td>
<td>81.75 (23.04)</td>
<td>25 - 100</td>
<td>83.92</td>
<td>15.54</td>
<td>0.12</td>
<td>83.92 (15.54)</td>
<td>41.67 - 100</td>
<td>0.12</td>
<td>0.74</td>
<td></td>
</tr>
</tbody>
</table>

Note: depressed group: males n=15, females n=21; control group: males n=18, females n=18

* years of education represents years spent at secondary and tertiary (if attended)

# Premorbid IQ as measured by the Vocabulary subtest t-score of the Wechsler Abbreviated Scale of Intelligence (WASI)

acomparison between the sexes within the depressed group, bcomparison between the sexes within the control group, ccomparison of the same sex between the depressed and control groups, note that the degrees of freedom for males was $F (1, 31)$ and for females was $F (1, 37)$

168
One-way ANOVAs showed that age differed significantly between the depressed males and females, with the depressed males being significantly older than the depressed females. The significant difference in age between the depressed males and females was therefore considered where task performance between the sexes of the depressed group was found to be significantly different. Comparison of the same sex between the depressed and control groups showed significant differences in HAMD and MÅDRS ratings which was expected given that these rating scales were used to distinguish the groups when recruiting. The male and female depressed patients obtained mean HAMD and MÅDRS scores indicative of moderate depression, and the male and female control participants obtained scores indicative of having no depressive symptoms (refer to section 7.2.2.2 for HAMD and MÅDRS gradations).

8.2.2 Materials and Procedure

The experimental method and design for the present experiment was the same as that described in Experiment One. The MRT, verbal fluency task, chimeric faces task, and Vocabulary subtest of the WASI were administered to each participant in the depressed and control groups in one testing session which ran for approximately one hour. The development and administration of these tasks and of the questionnaires / interviews were outlined in Experiment One (section 7.2.2).

8.2.3 Data screening

The procedure for screening the data from each task for both groups was similar to that outlined in Experiment One (section 7.2.3). This section will briefly review such data screening procedures for the groups and sexes in this experiment for each task.

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8 The validity of the significant group difference for the MÅDRS for the males was confirmed by the non-parametric Mann-Whitney test ($Z = -4.91, p<0.001$) due to a violation of the homogeneity of normality assumption of ANOVA.
8.2.3.1 Mental Rotation Task (MRT)

The dependent measure in the MRT was mean RTs for correct “same” responses which were examined across angle of rotation for each group and each sex of each group.

Participant mean accuracy percentiles for all angles combined were screened to determine whether there were any participants who did not understand the task. As explained in Experiment One (section 7.2.3.1), an accuracy percentage of less than 50% was used to determine whether there were any participants who did not understand the task (chance responding). Of the control group, no participant obtained an accuracy percentage lower than 50%. Of the depressed group, two female patients obtained accuracy percentages that were lower than 50% and were thus omitted from analyses on the MRT. Therefore, for the MRT analyses, the final depressed group comprised 34 patients (15 males and 19 females), and the control group contained 36 participants (18 males and 18 females).

For each participant of each group, a mean RT was calculated for each angle of rotation using correct “same” trials only. Trial RTs that were longer than three SDs from the participant’s mean RT for the respective angle, and faster than 300 msec, were excluded and the participant’s mean RT for that angle of rotation recalculated. No trials produced RTs longer than three SDs from the mean or faster than 300 msec.

Participant mean RTs for each angle of rotation were examined for missing values, to which there was one missing value within the data set for the angle 150° for a control male. This value was treated as a missing value and was not replaced. Participant mean RT values that were longer than three SDs from the group mean (either depressed or control group depending on which group the participant belonged) for the respective angle, were considered outliers, to which their inclusion resulted in increased skewness and kurtosis. Outliers were truncated to the next extreme score that fell within the acceptable range of that angle’s distribution for that group and sex (within three SDs from the mean), given that this experiment

---

9 The same statistical differences in demographics between groups and sexes were present for a depressed group sample size of n=34.
was ultimately examining both group and sex differences. Truncating was deemed appropriate given that there were few outliers for either group, and also given that the participants with outlier RTs obtained acceptable accuracy scores. Truncating the outliers rendered the distribution to approximately normal to have low skewness and kurtosis, and also allowed the values to be retained.

Using linear regression, the slope and intercept of the function relating RT to angle of rotation was calculated for each participant, using the mean RTs for each angle derived from the correct “same” responses. The distributions of the slope and intercept showed normal skewness and kurtosis for both the depressed and control groups, with no outliers greater than three SDs from the group mean. Skewness and kurtosis was also normal for each sex of the depressed and control groups, with the exception of the slope for the control males, who obtained a slightly higher kurtosis value due to an outlier greater than three SDs from the group mean for the control males. Truncating this value was considered, however, as examination of the slope and intercept of these participants was to complement the ANOVA analyses of the mean RT values to which the slope and intercept values were generated, altering the outlier may result in an inaccurate reflection of the slope and intercept presented in the mean RT ANOVA analyses and graphical presentations.

The relationship between RT and accuracy on the MRT was examined for each group, and each sex within each group, for each angle of rotation in order to check for any speed-accuracy trade-offs. As few significant correlations were observed, and as those that were significant were weak to moderate, it was assumed that there were no speed-accuracy trade-off that would impact the results. Furthermore, all but two of the significant linear relationships between RT and accuracy were negative, indicating that there was no speed-accuracy trade-off for those conditions. Refer to Appendix A.1.2 for the correlation table.

Analyses of the participants’ accuracy rates for each angle of rotation were conducted as an additional means of confirming that there was no speed-accuracy trade-off for the MRT, and are reported in section 9.3.1 of the results. Accuracy rates were calculated as the total correct by the participant for the given angle, divided by the total possible correct for that that angle. To meet the ANOVA assumption of
normality, accuracy rate outliers for each group were truncated to be within three SDs of the distribution (the next most extreme score) for the sex of that group. Truncating outliers for the accuracy rates had a minimal effect on the group mean and subsequently rendered skewness and kurtosis to be close to normal.

8.2.3.2 Verbal fluency task

The dependent measure in the verbal fluency task was the number of words generated for phonemic and semantic verbal fluency by each group, and each sex within each group.

There were no missing values within the verbal fluency data set for either the depressed or control groups. The distributions for the number of words produced for both phonemic and semantic fluency showed skewness and kurtosis values indicative of normal for each group and each sex within each group. There was a depressed male who obtained a semantic fluency score greater than three SDs from the group mean for depressed males however. Truncating the outlier to the next most extreme score in the distribution (Tabachnick & Fiddell, 2001) had a minimal impact on the group mean for the depressed males, therefore the outlier value was changed and retained within the dataset. A review of the total number of phonemic and semantic errors produced by each participant showed that there was a female depressed patient, and a male control participant, who obtained a phonemic or semantic error score that fell three SDs from the group mean for their sex. However as these participants produced a total number of words for phonemic and semantic fluency that were comparable to the remainder of the sample who obtained few errors, exclusion of these participants would not have been appropriate as there was no evidence of dysfunction. Therefore no participants were excluded from the analyses conducted on the verbal fluency task.
8.2.3.3  Chimeric faces task

The same two faces (one happy, one sad) that were excluded in Experiment One (section 7.2.3.3 Face ratings) were also excluded in this experiment. The screening of the face stimuli based on participant ratings was considered more reliable from the larger sample size in Experiment One, rather than from the smaller sample sizes in this experiment, and from a depressed group.

The screening procedure for checking participants who potentially did not understand the chimeric faces task followed that previously outlined in Experiment One (section 7.2.3.3 Reaction time and accuracy data). An accuracy percentage <25% (chance responding) for the identification of whole face emotional expressions was used to determine whether there were any participants who did not understand the task, or who could not identify the emotional expressions. For the control group, no participants obtained an accuracy percentage <25% for the identification of each whole face expression. For the depressed group, three depressed patients obtained accuracy scores <25% (one with <25% accuracy for recognising the sad and the happy whole face expressions, one with <25% accuracy for recognising the sad whole face expressions, and the other for <25% accuracy for recognising the neutral whole face expressions) and were thus removed from analyses on the chimeric faces task. Therefore, for the chimeric faces task analyses, the sample size for the depressed group was 33 (14 males, 19 females) and for the control group was 36 (18 males, 18 females)\(^{10}\).

For each participant of each group, a mean RT was calculated for each visual field / emotion condition of the chimeric face stimuli, using correct trials only. Trial RTs that were longer than three SDs from the participants mean for the respective chimeric face visual field / emotion condition, or faster than 300 msec, were excluded and the participant mean RT for that visual field / emotion condition recalculated. Using these criteria, three chimeric face trials (two LVF happy, one RVF happy) were omitted for the control group, and two chimeric face trials (one LVF happy, one RVF sad) were omitted for the depressed group.

\(^{10}\) The same statistical differences in demographics between groups were present for a depressed group sample size of \(n=33\). The only statistical change was between the sexes of the depressed group in which age was no longer significantly different (\(p=0.06\))
For the RT data, there were eight missing values for the chimeric faces data (two for LVF happy – one for a female control participant and one for a male control participant; two for RVF happy - one for a male depressed patient and one for a male control participant; and four for RVF sad – one for a male depressed patient, one for a female depressed patient, one for a control male participant and one for a female control participant). The missing values were not replaced and were treated as missing values. There were no missing values for the accuracy rate data.

Participant mean RT values that were longer than three SDs from the group mean (either depressed or control group depending on which group the participant belonged) for the respective chimeric face visual field / emotion condition, were considered outliers to which their inclusion increased skewness and kurtosis. A review of the participant accuracy scores showed that the participants with outlier RTs obtained acceptable accuracy, and therefore exclusion was not appropriate. As there were few outliers, truncating the outliers to the next extreme score that fell within the acceptable range of the distribution for that group and sex (within three SDs from the mean) for that visual field / emotion condition was deemed appropriate. This rendered the distribution to be normal with low skewness and kurtosis, and allowed the values to be retained.

The accuracy rates for both groups (and each sex of each group) for each visual field / emotion condition of the chimeric face produced skewness and kurtosis values that were near normal. The relationship between RT and accuracy was also examined for each group, and for each sex within each group, for each visual field / emotion condition of the chimeric face stimuli. Few significant linear relationships were observed, and those that were significant were negative, indicating that there were no speed-accuracy trade-offs. Refer to Appendix A.1.2 for the specific correlation findings.
8.2.4 Data analysis

The following statistical comparisons had to be log_{10} transformed to avoid violating the homogeneity of intercorrelations assumption of mixed-design ANOVA (Appendix A.2.2): RT analyses for the MRT angle by group by sex comparisons; and the RT analyses of the chimeric faces visual field by emotion by group by sex comparisons. In order to avoid violating the normality assumption of t-tests, the following post-hoc t-tests were log_{10} transformed: MRT paired t-tests examining the significant main effect for angle from the mixed-design ANOVA on participants’ RTs and accuracy rates; chimeric faces task paired and independent t-tests examining the sex by visual field, and visual field by emotion interactions from the mixed-design ANOVA on participants’ RTs. In order to avoid violating the normality assumption of mixed-design ANOVA, the RTs of the chimeric faces task were also log_{10} transformed for analyses examining handedness as a covariate. For clarity of interpretation, the reported means and SDs in the results section are based on untransformed data. The log_{10} transformed means and SDs from the ANOVAs and post-hoc t-tests conducted on the transformed data can be observed in Appendix 3. Refer to Appendix A.2.2 for information on the tests and procedures used to meet the assumptions of the statistical analyses conducted in this experiment. Analyses in this experiment were two-tailed but corrections were not made for multiple analyses. All effects were considered statistically significant at the p<0.05 significance level.

8.3 Results

8.3.1 Mental Rotation Task (MRT)

As Figures 8.1 and 8.2 show, a positive linear relationship between RT and angle of rotation was evident for both the depressed and control groups, and the males and females of each group. The relationship between means RTs and angle of rotation was significantly linear for both the depressed group (r (6) = 0.93, p<0.01) and the control group (r (6) = 0.98, p=0.001). There was a significant linear relationship between the mean RTs and angle of rotation for both the control males (r (6) = 0.99, p<0.001) and females (r (6) = 0.96, p<0.01), and both the depressed males (r (6) = 0.96, p<0.01) and females (r (6) = 0.86, p<0.05).
Figure 8.1. Linear regression line and mean RTs and SEM as a function of angle of rotation in the MRT for both the control and depressed groups - Experiment Two.

Figure 8.2. Linear regression line and mean RTs and SEM as a function of angle of rotation in the MRT for the males and females of the control and depressed groups - Experiment Two.
The mean RTs and SDs for each angle of rotation are presented in Table 8.3 for each group separately, and in Table 8.4 for each sex of each group separately.

Table 8.3.

Mean RTs (msec) and SDs as a function of angle of rotation in the MRT for the control and depressed groups – Experiment Two.

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>Control (n=35)</th>
<th>Depressed (n=34)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>0°</td>
<td>1886.76</td>
<td>1137.11</td>
</tr>
<tr>
<td>30°</td>
<td>2583.04</td>
<td>1723.87</td>
</tr>
<tr>
<td>60°</td>
<td>2581.31</td>
<td>1080.43</td>
</tr>
<tr>
<td>90°</td>
<td>2947.34</td>
<td>1523.26</td>
</tr>
<tr>
<td>120°</td>
<td>3290.65</td>
<td>1887.27</td>
</tr>
<tr>
<td>150°</td>
<td>3716.32</td>
<td>1955.38</td>
</tr>
<tr>
<td>Overall</td>
<td>2834.24</td>
<td>1431.86</td>
</tr>
</tbody>
</table>

Note: As there was one missing value within the data set (for a control male 150°), the ANOVA ran on control group n=35 rather than control group n=36. Therefore the means of the sample size ran by the ANOVA are reported.

Table 8.4.

Mean RTs (msec) and SDs as a function of angle of rotation in the MRT for the males and females of the control and depressed groups – Experiment Two.

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>Control Males (n=17)</th>
<th>Females (n=18)</th>
<th>Depressed Males (n=15)</th>
<th>Females (n=19)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>0°</td>
<td>1858.24</td>
<td>1138.89</td>
<td>1913.70</td>
<td>1167.77</td>
</tr>
<tr>
<td></td>
<td>3522.34</td>
<td>2282.90</td>
<td>3022.92</td>
<td>2022.87</td>
</tr>
<tr>
<td>30°</td>
<td>2276.23</td>
<td>1366.96</td>
<td>2872.80</td>
<td>2000.43</td>
</tr>
<tr>
<td></td>
<td>4131.70</td>
<td>2462.35</td>
<td>4318.51</td>
<td>3090.49</td>
</tr>
<tr>
<td>60°</td>
<td>2318.66</td>
<td>826.75</td>
<td>2829.36</td>
<td>1247.88</td>
</tr>
<tr>
<td></td>
<td>4490.81</td>
<td>2651.65</td>
<td>4691.83</td>
<td>2674.38</td>
</tr>
<tr>
<td>90°</td>
<td>2767.41</td>
<td>1469.19</td>
<td>3117.28</td>
<td>1595.68</td>
</tr>
<tr>
<td></td>
<td>4641.66</td>
<td>2831.89</td>
<td>4796.67</td>
<td>2971.00</td>
</tr>
<tr>
<td>120°</td>
<td>2992.70</td>
<td>1826.35</td>
<td>3572.05</td>
<td>1952.34</td>
</tr>
<tr>
<td></td>
<td>4727.19</td>
<td>2686.69</td>
<td>4984.86</td>
<td>2670.61</td>
</tr>
<tr>
<td>150°</td>
<td>3242.24</td>
<td>1835.22</td>
<td>4164.07</td>
<td>2009.99</td>
</tr>
<tr>
<td></td>
<td>5601.17</td>
<td>3371.50</td>
<td>5052.20</td>
<td>2092.21</td>
</tr>
<tr>
<td>Overall</td>
<td>2575.91</td>
<td>1302.38</td>
<td>3078.21</td>
<td>1540.87</td>
</tr>
<tr>
<td></td>
<td>4519.14</td>
<td>2520.37</td>
<td>4477.83</td>
<td>2294.48</td>
</tr>
</tbody>
</table>

Note: As there was one missing value within the data set (for a control male 150°), the ANOVA ran on control males n=17 rather than control males n=18. Therefore the means of the sample size ran by the ANOVA are reported.
To determine whether mental rotation differed significantly between the groups and between the sexes, a 6 (angle of rotation) x 2 (group: control, depressed) x 2 (sex: male, female) mixed-design ANOVA with group and sex as between-subject factors, and angle as a within-subjects factor, was calculated on the participants mean RT data (log_{10} transformed). The main effects and interactions of this analysis are presented in Table 8.5.

Table 8.5
Main effects and interactions from the 6 (angle) x 2 (group) x 2 (sex) mixed-design ANOVA for the MRT RT data (log_{10} transformed) – Experiment Two.

<table>
<thead>
<tr>
<th>Main effect and interactions</th>
<th>F</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>55.09</td>
<td>&lt;0.001</td>
<td>0.46</td>
</tr>
<tr>
<td>Group</td>
<td>14.04</td>
<td>&lt;0.001</td>
<td>0.18</td>
</tr>
<tr>
<td>Sex</td>
<td>0.42</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Angle x Group</td>
<td>1.23</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>Angle x Sex</td>
<td>1.61</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Group x Sex</td>
<td>0.43</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Angle x Group x Sex</td>
<td>0.37</td>
<td>0.83</td>
<td></td>
</tr>
</tbody>
</table>

Note: The degrees of freedom for the within-subjects factors is F(3.98, 258.92) and for the between-subjects factors is F(1, 65).

As shown in Table 8.5, a significant main effect was observed for angle, with post-hoc paired t-tests indicating that RTs (log_{10} transformed) increased significantly with increases in angular rotation. There was the exception of RTs between 60° and 90°, which did not differ significantly. The overall mean RTs and SDs for each angle, along with the post-hoc paired-tests comparing RTs (log_{10} transformed) between each increasing angle, are presented in Table 8.6. There was also a significant main effect for group, with the control group performing significantly faster overall than the depressed group (Table 8.3). No significant main effect was observed for sex (males: \(M = 3486.80 \text{ msec, } SD = 2171.39\); females: \(M = 3796.94 \text{ msec, } SD = 2063.12\)). There were no significant interactions between the variables angle, group,
and sex. With the exception of the mean RT for the angle 60° for the control group and the control females, RT increased with increases in angular rotation for each group and each sex within each group.

Table 8.6.

Group mean RT (msec) and SDs as a function of angle of rotation in the MRT and t-tests comparing RTs (log<sub>10</sub> transformed) between each increasing angle of rotation – Experiment Two.

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>M</th>
<th>SD</th>
<th>t (68)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>2555.18</td>
<td>1816.62</td>
<td>-6.50</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>30°</td>
<td>3397.59</td>
<td>2441.26</td>
<td>-2.68</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>60°</td>
<td>3577.58</td>
<td>2228.51</td>
<td>-1.52</td>
<td>0.13</td>
</tr>
<tr>
<td>90°</td>
<td>3824.91</td>
<td>2440.32</td>
<td>-2.61</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>120°</td>
<td>4069.46</td>
<td>2407.63</td>
<td>-4.02</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>150°</td>
<td>4493.92</td>
<td>2465.66</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The mean mental rotation slope and intercept values and SDs are presented in Table 8.7 for each group separately, and in Table 8.8 for each sex of each group separately.

Table 8.7

Mean slope and intercept (msec) values and SDs of the linear relationship between RT and angle of rotation for the control and depressed groups - Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 35)</th>
<th>Depressed (n = 34)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2003.05 1208.35</td>
<td>3618.48 2305.69</td>
</tr>
<tr>
<td>Slope</td>
<td>11.08 9.61</td>
<td>11.70 12.83</td>
</tr>
</tbody>
</table>
Table 8.8
Mean slope and intercept (msec) values and SDs of the linear relationship between RT and angle of rotation for the males and females of the control and depressed groups - Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th></th>
<th>Depressed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M males (n=17)</td>
<td>M females (n=18)</td>
<td>M males (n=15)</td>
</tr>
<tr>
<td>Intercept</td>
<td>1896.04</td>
<td>2104.10</td>
<td>3638.33</td>
</tr>
<tr>
<td>Slope</td>
<td>9.07</td>
<td>12.99</td>
<td>11.75</td>
</tr>
</tbody>
</table>

To determine whether the mental rotation slopes and intercepts differed significantly between the groups and between the sexes, a 2 (group: control, depressed) x 2 (sex: male, female) ANOVA with group and sex as between-subjects factors was conducted on the participants slope values and on the participants intercept values separately. The results of these analyses are presented in Table 8.9.

Table 8.9
Main effects and interactions from the 2 (group) x 2 (sex) ANOVA on the mental rotation slopes and intercepts – Experiment Two.

<table>
<thead>
<tr>
<th>Main effect and interactions</th>
<th>F (1, 65)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>0.06</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>0.49</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>Group x sex</td>
<td>0.53</td>
<td>0.47</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intercept</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>13.00</td>
<td>=0.001</td>
<td>0.17</td>
</tr>
<tr>
<td>Sex</td>
<td>0.04</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>Group x sex</td>
<td>0.07</td>
<td>0.79</td>
<td></td>
</tr>
</tbody>
</table>
As shown in Table 8.9, no significant main effect for group was observed for the mental rotation slopes, with the control and depressed groups mentally rotating the stimuli at a comparable rate (Table 8.7). There was also no significant main effect for sex in the rate of mental rotation (males: $M = 10.32$, $SD = 12.19$; females: $M = 12.31$, $SD = 10.42$). No significant interaction was observed between group and sex, supporting the non-significant interactions in RT found between group, sex, and angle in the mixed-design ANOVA.

Also shown in Table 8.9, a significant main effect for group was observed for the mental rotation intercepts, in which the control group were significantly faster on the intercept than the depressed group (Table 8.7). No significant main effect was observed for sex, with the intercepts being similar between the males ($M = 2712.74$, $SD = 1888.89$) and females ($M = 2873.71$, $SD = 2101.83$). Further, no significant interaction was produced between group and sex for the mental rotation intercepts.

**Accuracy**

To check for possible speed-accuracy trade-offs for each group and sex, a 6 (angle of rotation) x 2 (group: control, depressed) x 2 (sex: male, female) mixed-design ANOVA with group and sex as between-subjects factors, and angle as a within-subjects factor was calculated on the participant accuracy rates. The main effects and interactions from this analysis are presented in Table 8.10.
Table 8.10

Main effects and interactions from the 6 (angle) x 2 (group) x 2 (sex) mixed-design ANOVA for the MRT accuracy rate data – Experiment Two.

<table>
<thead>
<tr>
<th>Main effect and interactions</th>
<th>$F$</th>
<th>$p$</th>
<th>partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle</td>
<td>19.20</td>
<td>&lt;0.001</td>
<td>0.23</td>
</tr>
<tr>
<td>Group</td>
<td>3.36</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>0.20</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Angle x Group</td>
<td>1.41</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>Angle x Sex</td>
<td>1.58</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>Group x Sex</td>
<td>1.17</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>Angle x Group x Sex</td>
<td>0.38</td>
<td>0.79</td>
<td></td>
</tr>
</tbody>
</table>

Note: The degrees of freedom for the with-in subjects factors is $F (3.30, 217.93)$ and for the between-subjects factors is $F (1, 66)$.

As shown in Table 8.10, there was no significant main effect for group or for sex, with accuracy rates not differing significantly between the groups (control: $M = 90.47\%$, $SD = 7.23$; depressed: $M = 86.64\%$, $SD = 9.62$), or between the sexes (males: $M = 88.20\%$, $SD = 7.57$; females: $M = 88.97\%$, $SD = 9.57$). There was a significant main effect for angle, with accuracy generally reducing with increases in angle of rotation. This trend is opposite to what would be expected if there was a speed-accuracy trade-off. The overall mean accuracy and SDs for each angle, along with the post-hoc paired t-tests comparing accuracy rates between each increasing angle of rotation are presented in Table 8.11. No significant interactions were observed between the variables angle, group, and sex.
Table 8.11.

Group mean accuracy and SDs as a function of angle of rotation in the MRT and t-tests comparing accuracy between each increasing angle of rotation – Experiment Two.

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>M</th>
<th>SD</th>
<th>t (69)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>95.72%</td>
<td>8.20</td>
<td>3.08</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>30°</td>
<td>91.44%</td>
<td>11.13</td>
<td>1.80</td>
<td>0.08</td>
</tr>
<tr>
<td>60°</td>
<td>88.95%</td>
<td>11.94</td>
<td>-3.10</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>90°</td>
<td>93.41%</td>
<td>8.95</td>
<td>4.49</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>120°</td>
<td>84.47%</td>
<td>16.55</td>
<td>2.98</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>150°</td>
<td>78.57%</td>
<td>20.54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8.3.2 Verbal fluency task

The mean number of words and SDs produced for phonemic and semantic verbal fluency are presented in Table 8.12 for each group separately, and in Table 8.13 for each sex of each group separately.

Table 8.12

Mean number of words and SDs produced by the control and depressed groups for phonemic and semantic verbal fluency - Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 36)</th>
<th>Depressed (n = 36)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Phonemic fluency</td>
<td>16.58</td>
<td>6.22</td>
</tr>
<tr>
<td>Semantic fluency</td>
<td>4.19</td>
<td>2.05</td>
</tr>
</tbody>
</table>
Table 8.13

Means number of words and SDs produced by the males and females of the control and depressed groups for phonemic and semantic verbal fluency - Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th></th>
<th>Depressed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n = 18)</td>
<td>Females (n = 18)</td>
<td>Males (n=15)</td>
<td>Females (n=21)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Phonemic fluency</td>
<td>14.06</td>
<td>7.03</td>
<td>19.11</td>
<td>4.10</td>
</tr>
<tr>
<td>Semantic fluency</td>
<td>3.50</td>
<td>2.48</td>
<td>4.89</td>
<td>1.23</td>
</tr>
</tbody>
</table>

To determine whether verbal fluency differed significantly between groups, and between the sexes, a 2 (group: control, depressed) x 2 (sex: male, female) ANOVA with group and sex as between-subject factors, was calculated on the number of words produced by the participants for phonemic and for semantic verbal fluency separately. The main effects and interactions from these analyses are presented in Table 8.14.

Table 8.14

Main effects and interactions from the 2 (group) x 2 (sex) ANOVA on phonemic and semantic verbal fluency performance – Experiment Two.

<table>
<thead>
<tr>
<th>Main effect and interactions</th>
<th>F (1, 68)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phonemic fluency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>1.56</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>4.94</td>
<td>&lt;0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>Group x sex</td>
<td>1.83</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Semantic fluency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>4.87</td>
<td>&lt;0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>Sex</td>
<td>8.52</td>
<td>&lt;0.01</td>
<td>0.11</td>
</tr>
<tr>
<td>Group x sex</td>
<td>0.08</td>
<td>0.78</td>
<td></td>
</tr>
</tbody>
</table>
As shown in Table 8.14, no significant main effect for group was observed for phonemic fluency, with the control and depressed groups generating a comparable amount of words (Table 8.12). A significant main effect for sex was observed for phonemic fluency, in which the females ($M = 17.13, SD = 6.04$) generated significantly more words than the males ($M = 14.12, SD = 6.02$). There was no significant interaction between group and sex for phonemic verbal fluency. Inspection of the mean number of words produced in Table 8.13, however, shows that the female advantage in phonemic fluency differed between the control and depressed groups. Further assessment of this interaction showed that the better phonemic fluency of females than males was significant for the control group ($t (27.38) = -2.64, p < 0.05$), however, not for the depressed group ($t (34) = -0.59, p = 0.56$). Further, the difference in phonemic fluency between the same sex of each group was found to be non-significant for the males ($t (29.93) = 0.07, p = 0.95$), however, the control females generated significantly more words than the depressed females ($t (33.09) = -2.05, p = 0.05$).

Also shown by Table 8.14, a significant main effect for group was observed for semantic fluency, in which the control group produced significantly more words for semantic fluency than the depressed group (Table 8.12). A significant main effect was also observed for sex in which the females ($M = 4.31, SD = 1.47$) generated significantly more words for semantic fluency than the males ($M = 3.12, SD = 2.25$). There was no significant interaction between group and sex for semantic fluency.

### 8.3.3 Chimeric faces task

As in Experiment One, RT and accuracy analyses were conducted separately. All analyses for accuracy were conducted on the participants’ accuracy rates (total correct by participant for the given visual field / emotion chimeric face condition, divided by the total possible correct for that visual field / emotion condition). The accuracy rates were converted into percentiles for tabulated and graphical presentations, (multiplying by 100) to make interpretation easier. The transformed means and SDs from the ANOVAs and t-tests conducted on transformed data can be observed in Appendix 3.
8.3.3.1 Chimeric faces - Reaction time

The mean RTs and SDs to the happy and sad emotional expressions shown in each visual field by the chimeric stimuli are presented in Table 8.15 for each group separately, and in Table 8.16 for each sex of each group separately.

Table 8.15

Mean RTs (msec) and SDs to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the control and depressed groups - Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 31)</th>
<th>Depressed (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Happy</td>
<td>1221.81</td>
<td>396.52</td>
</tr>
<tr>
<td>LVF</td>
<td>1180.55</td>
<td>385.96</td>
</tr>
<tr>
<td>RVF</td>
<td>1263.07</td>
<td>454.38</td>
</tr>
<tr>
<td>Sad</td>
<td>1319.35</td>
<td>379.34</td>
</tr>
<tr>
<td>LVF</td>
<td>1228.00</td>
<td>357.51</td>
</tr>
<tr>
<td>RVF</td>
<td>1410.70</td>
<td>497.61</td>
</tr>
</tbody>
</table>

Overall

<table>
<thead>
<tr>
<th></th>
<th>LVF</th>
<th>RVF</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>1204.28</td>
<td>1336.88</td>
</tr>
<tr>
<td>SD</td>
<td>329.41</td>
<td>427.41</td>
</tr>
<tr>
<td>M</td>
<td>1589.99</td>
<td>1675.45</td>
</tr>
<tr>
<td>SD</td>
<td>478.14</td>
<td>550.99</td>
</tr>
</tbody>
</table>

Note: As there were eight missing values within the data set (five for the control group, and three for the depressed group), the ANOVA ran on control group n=31 and depressed group n=30 rather than control group n=36 and depressed group n=33. Therefore the means of the sample sizes ran by the ANOVA are reported.

Note: Mean RTs in rows labelled “Happy” and “Sad” are of overall RTs for these emotions.
Table 8.16

Mean RTs (msec) and SDs to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the males and females of the control and depressed groups - Experiment Two

<table>
<thead>
<tr>
<th></th>
<th>Control Males (n=15)</th>
<th>Control Females (n=16)</th>
<th>Depressed Males (n=12)</th>
<th>Depressed Females (n=18)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Happy</td>
<td>1244.50</td>
<td>367.37</td>
<td>1200.53</td>
<td>433.01</td>
</tr>
<tr>
<td>LVF</td>
<td>1160.04</td>
<td>296.31</td>
<td>1199.76</td>
<td>463.86</td>
</tr>
<tr>
<td>RVF</td>
<td>1328.96</td>
<td>465.40</td>
<td>1201.29</td>
<td>449.82</td>
</tr>
<tr>
<td>Sad</td>
<td>1308.29</td>
<td>273.72</td>
<td>1329.72</td>
<td>466.52</td>
</tr>
<tr>
<td>LVF</td>
<td>1168.66</td>
<td>237.27</td>
<td>1283.63</td>
<td>443.02</td>
</tr>
<tr>
<td>RVF</td>
<td>1447.92</td>
<td>458.45</td>
<td>1375.81</td>
<td>544.42</td>
</tr>
</tbody>
</table>

Overall

<table>
<thead>
<tr>
<th></th>
<th>LVF</th>
<th>R VF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1164.35</td>
<td>1388.44</td>
</tr>
<tr>
<td></td>
<td>211.51</td>
<td>431.66</td>
</tr>
<tr>
<td></td>
<td>1241.71</td>
<td>1288.55</td>
</tr>
<tr>
<td></td>
<td>414.94</td>
<td>431.62</td>
</tr>
<tr>
<td></td>
<td>1718.01</td>
<td>1968.46</td>
</tr>
<tr>
<td></td>
<td>400.50</td>
<td>705.90</td>
</tr>
<tr>
<td></td>
<td>1504.65</td>
<td>1480.11</td>
</tr>
<tr>
<td></td>
<td>516.64</td>
<td>307.35</td>
</tr>
</tbody>
</table>

Note: As there were eight missing values within the data set (three for the control males, two for the depressed males, two for the control females and one for a depressed female), the ANOVA ran of control males n=15, control females n=16, depressed males n=12, and depressed females n=18 rather than control males n=18, control females n=18, depressed males n=14, and depressed females n=19. Therefore the means of the sample sizes ran by the ANOVA are reported.

Note: Mean RTs in rows labelled “Happy” and “Sad” are of overall RTs for these emotions.

To investigate whether there were significant group and sex differences in RT for hemispheric processing of the happy and sad emotional expressions, a 2 (emotion: happy, sad) x 2 (visual field: LVF, RVF) x 2 (group: control, depressed) x 2 (sex: male, female) mixed-design ANOVA, with group and sex as between-subject factors, and visual field and emotion as within-subject factors, was calculated on the participants mean RT data (log_{10} transformed) for the chimeric face stimuli. The main effects and interactions of this analysis are presented in Table 8.17.
Table 8.17

Main effects and interactions from the 2 (emotion) x 2 (visual field) x 2 (group) x 2 (sex) mixed-design ANOVA for the chimeric faces task RT data (log_{10} transformed) – Experiment Two.

<table>
<thead>
<tr>
<th>Main effects &amp; interactions</th>
<th>F (1, 57)</th>
<th>p</th>
<th>partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotion</td>
<td>0.21</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Visual field</td>
<td>9.77</td>
<td>&lt;0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>Group</td>
<td>14.47</td>
<td>&lt;0.001</td>
<td>0.20</td>
</tr>
<tr>
<td>Sex</td>
<td>3.04</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Visual field x group</td>
<td>0.43</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Visual field x sex</td>
<td>4.73</td>
<td>&lt;0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Visual field x emotion</td>
<td>3.32</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Emotion x Group</td>
<td>2.74</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Emotion x Sex</td>
<td>0.22</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td>Group x Sex</td>
<td>1.62</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>Visual field x group x sex</td>
<td>0.07</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x group</td>
<td>0.05</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x sex</td>
<td>0.34</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Emotion x group x sex</td>
<td>0.04</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x group x sex</td>
<td>0.06</td>
<td>0.81</td>
<td></td>
</tr>
</tbody>
</table>

As shown in Table 8.17, there was a significant main effect for visual field, with RTs being significantly faster to expressions presented in the LVF ($M = 1393.97$ msec, $SD = 450.06$) than in the RVF ($M = 1503.39$ msec, $SD = 516.92$). There was also a significant main effect for group, with the control group ($M = 1270.58$ msec, $SD = 356.98$) responding significantly faster overall to the chimeric faces than the depressed group ($M = 1632.72$ msec, $SD = 470.19$). There was no significant main effect for emotion (sad: $M = 1437.67$ msec, $SD = 398.27$; happy: $M = 1459.69$ msec, $SD = 607.81$), or for sex (males: $M = 1528.32$ msec, $SD = 499.40$; females: $M = 1385.44$ msec, $SD = 406.09$). The only significant interaction observed between the variables visual field, emotion, group, and sex was between visual field and sex, which can be observed in Figure 8.3.
Figure 8.3. Mean RTs and SEM to the visual field presentations of the chimeric face stimuli for the males and females - Experiment Two.

Post-hoc t-tests were used to further assess the significant visual field by sex interaction. Post-hoc paired t-tests comparing RTs (log_{10} transformed) between each visual field for each sex showed that the males responded significantly faster (t (26) = 3.41, p<0.01) to expressions shown in the LVF (M = 1410.42 msec, SD = 412.98) than in the RVF (M = 1646.23 msec, SD = 630.41). For the females, there was no significant difference (t (33) = 0.78, p=0.44) in RTs to the emotional expressions shown in the LVF (M = 1380.91 msec, SD = 483.23) and in the RVF (M = 1389.96 msec, SD = 377.84). Post-hoc independent t-tests comparing RTs (log_{10} transformed) to each visual field between the sexes showed that there were no significant differences between the sexes in response to expressions shown in the RVF (t (59) = 1.81, p=0.08) or in the LVF (t (59) = 0.48, p=0.63).
The mean RTs to the happy and sad expressions shown in each visual field are presented in Figure 8.4 for each group.

![Graph showing mean RTs for different conditions and visual fields](image)

*Figure 8.4.* Mean RTs and SEM to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the control and depressed groups - Experiment Two.

Although there were no significant interactions between visual field, emotion, and group, visual inspection of Figure 8.4 shows that for both groups, the difference in RT between visual field presentations of sad expressions was greater than the RT difference between visual field presentations of happy expressions. Table 8.17 shows that the interaction between visual field and emotion approached significance. Further, the interaction between visual field and emotion had a weak to moderate observed power (0.43),
suggesting that the statistical power in the four-way ANOVA may not have been strong enough to detect a significant interaction. The interaction between visual field and emotion is presented in Figure 8.5.

Figure 8.5. Mean RTs and SEM to the happy and sad expressions shown in each visual field by the chimeric face stimuli - Experiment Two.

Paired t-tests were calculated on the RTs (log_{10} transformed) to the happy and sad emotional expressions shown in each visual field to further assess the visual field by emotion interaction. The paired t-tests indicated that there was no significant difference in RT between visual field presentations of happy expressions ($t (60) = 1.12, p=0.27$; LVF: $M = 1439.25$, $SD = 659.19$; RVF: $M = 1480.14$, $SD = 640.16$), however, sad expressions were recognized significantly faster ($t (60) = 3.40, p=0.001$) when shown in the LVF ($M = 1348.69$, $SD = 363.74$) than in the RVF ($M = 1526.64$, $SD = 521.59$). There was no significant
difference in RTs to happy and sad expressions shown in the LVF ($t(60) = 0.37, p=0.72$) or in the RVF ($t(60) = -1.32, p=0.19$).

In addition to the RT differences in visual field presentations of happy and sad expressions, Figure 8.4 shows a group difference in RTs to happy and sad expressions. Similarly, Table 8.17 shows that the interaction between group and emotion approached significance. The interaction between group and emotion also had a weak to moderate observed power (0.37), suggesting that the statistical power in the four-way ANOVA was not strong enough to detect a significant interaction. The interaction between group and emotion is presented in Figure 8.6.

![Figure 8.6](image_url)

Figure 8.6. Mean RTs and SEM to the happy and sad expressions shown by the chimeric face stimuli by the control and depressed groups - Experiment Two.
Paired and independent t-tests were calculated on the RTs to happy and sad emotional expressions by the control and depressed groups, to further assess the interaction between group and emotion. Despite a trend showing that the depressed group responded faster to sad than happy expressions, paired t-tests showed that RTs did not significantly differ for the recognition of happy and sad expressions ($t (29) = 1.31$, $p=0.20$) for the depressed group (Table 8.15). Similarly, despite a trend showing that the control group responded faster to happy than sad expressions, a paired t-test showed that RTs did not significantly differ for the recognition of happy and sad expressions ($t (30) = -1.79$, $p=0.08$) for the control group (Table 8.15). As can be observed in Figure 8.6, the SEM for the RTs produced by the depressed and control groups to the happy and sad expressions were large, thus potentially inhibiting the finding of a significant difference in RT to the happy and sad expressions. As would be expected from the significant group main effect observed in Table 8.17, the control group was significant faster than the depressed group when responding to happy ($t (45.89) = 3.34$, $p<0.01$) and sad ($t (59) = 2.46$, $p<0.05$) expressions.

Table 8.17 showed that there were no further significant interactions between visual field, emotion, group, and sex, or further non-significant interactions that approached significance.
8.3.3.2 Chimeric faces - Accuracy

The mean percentage correct and SDs for the recognition of happy and sad emotional expressions shown in each visual field by the chimeric face stimuli are presented in Table 8.18 for each group separately, and in Table 8.19 for each sex of each group separately.

Table 8.18

Mean recognition accuracy (percentage correct) and SDs to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the control and depressed groups - Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 36)</th>
<th>Depressed (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Happy</td>
<td>61.11%</td>
<td>22.94%</td>
</tr>
<tr>
<td>LVF</td>
<td>66.88%</td>
<td>29.64%</td>
</tr>
<tr>
<td>RVF</td>
<td>55.34%</td>
<td>27.33%</td>
</tr>
<tr>
<td>Sad</td>
<td>51.04%</td>
<td>16.38%</td>
</tr>
<tr>
<td>LVF</td>
<td>52.31%</td>
<td>16.62%</td>
</tr>
<tr>
<td>RVF</td>
<td>49.77%</td>
<td>21.78%</td>
</tr>
</tbody>
</table>

Overall

<table>
<thead>
<tr>
<th></th>
<th>LVF</th>
<th>RVF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happy</td>
<td>59.60%</td>
<td>52.56%</td>
</tr>
<tr>
<td>Sad</td>
<td>55.65%</td>
<td>55.73%</td>
</tr>
</tbody>
</table>

Note: the total number of possible correct responses was thirteen for happy expressions and twelve for sad emotions in each visual field.
Note: Mean accuracy in rows labelled “Happy” and “Sad” is of overall accuracy for these emotions.
Table 8.19

Mean recognition accuracy (percentage correct) and SDs to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the males and females of the control and depressed groups - Experiment Two.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th></th>
<th></th>
<th>Depressed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n = 18)</td>
<td>Females (n = 18)</td>
<td>Males (n=14)</td>
<td>Females (n=19)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Happy</td>
<td>60.04%</td>
<td>23.01</td>
<td>62.18%</td>
<td>23.50</td>
<td>56.32%</td>
</tr>
<tr>
<td>LVF</td>
<td>62.39%</td>
<td>29.95</td>
<td>71.37%</td>
<td>29.48</td>
<td>57.69%</td>
</tr>
<tr>
<td>RVF</td>
<td>57.69%</td>
<td>26.15</td>
<td>52.99%</td>
<td>29.10</td>
<td>54.95%</td>
</tr>
<tr>
<td>Sad</td>
<td>46.53%</td>
<td>15.80</td>
<td>55.56%</td>
<td>16.11</td>
<td>50.00%</td>
</tr>
<tr>
<td>LVF</td>
<td>49.07%</td>
<td>15.10</td>
<td>55.56%</td>
<td>17.85</td>
<td>48.21%</td>
</tr>
<tr>
<td>RVF</td>
<td>43.98%</td>
<td>20.77</td>
<td>55.56%</td>
<td>21.77</td>
<td>51.79%</td>
</tr>
</tbody>
</table>

Overall

<table>
<thead>
<tr>
<th></th>
<th>LVF</th>
<th>RVF</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>55.73%</td>
<td>50.84%</td>
</tr>
<tr>
<td>SD</td>
<td>18.85</td>
<td>17.50</td>
</tr>
<tr>
<td>M</td>
<td>63.46%</td>
<td>54.27%</td>
</tr>
<tr>
<td>SD</td>
<td>19.13</td>
<td>17.73</td>
</tr>
<tr>
<td>M</td>
<td>52.95%</td>
<td>53.37%</td>
</tr>
<tr>
<td>SD</td>
<td>16.07</td>
<td>12.10</td>
</tr>
<tr>
<td>M</td>
<td>57.64%</td>
<td>57.47%</td>
</tr>
<tr>
<td>SD</td>
<td>19.82</td>
<td>14.51</td>
</tr>
</tbody>
</table>

Note: the total number of possible correct responses was thirteen for happy expressions and twelve for sad emotions in each visual field.

Note: Mean accuracy in rows labelled “Happy” and “Sad” is of overall accuracy for these emotions.

To investigate whether there were significant group and sex differences in accuracy for hemispheric processing of the happy and sad emotional expressions, a 2 (emotion: happy, sad) x 2 (visual field: LVF, RVF) x 2 (group: control, depressed) x 2 (sex: males, females) mixed-design ANOVA, with group and sex as between-subject factors, and visual field and emotion as within-subject factors, was calculated on the participants mean accuracy rates for the chimeric face stimuli. The main effects and interactions from this analysis are presented in Table 8.20.
Table 8.20

Main effects and interactions from the 2 (emotion) x 2 (visual field) x 2 (group) x 2 (sex) mixed-design ANOVA for the chimeric faces task accuracy rate data – Experiment Two.

<table>
<thead>
<tr>
<th>Main effects &amp; interactions</th>
<th>F (1, 65)</th>
<th>p</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotion</td>
<td>10.51</td>
<td>&lt;0.01</td>
<td>0.14</td>
</tr>
<tr>
<td>Visual field</td>
<td>2.15</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>0.04</td>
<td>0.84</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>2.07</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Visual field x group</td>
<td>2.30</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>Visual field x sex</td>
<td>0.27</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion</td>
<td>0.94</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>Emotion x Group</td>
<td>0.05</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Emotion x Sex</td>
<td>0.08</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Group x Sex</td>
<td>0.03</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>Visual field x group x sex</td>
<td>0.15</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x group</td>
<td>1.51</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x sex</td>
<td>0.06</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>Emotion x group x sex</td>
<td>1.70</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Visual field x emotion x group x sex</td>
<td>4.20</td>
<td>0.05</td>
<td>0.06</td>
</tr>
</tbody>
</table>

As shown in Table 8.20, there was a significant main effect for emotion, with responses being significantly more accurate to happy expressions ($M = 61.48\%$, $SD = 21.99\%$) than to sad expressions ($M = 50.30\%$, $SD = 17.16\%$). No significant main effects were observed for visual field (RVF: $M = 54.07\%$, $SD = 15.65\%$; LVF: $M = 57.71\%$, $SD = 18.66\%$); group (control: $M = 56.08\%$, $SD = 14.61\%$; depressed: $M = 55.69\%$, $SD = 14.01\%$); or for sex (males: $M = 53.23\%$, $SD = 13.91\%$; females: $M = 58.19\%$, $SD = 14.26\%$). No significant interactions were observed between the variables, however the interaction between visual field, emotion, group, and sex approached significance.
The mean accuracy rates to the happy and sad expressions shown in each visual field are presented in Figure 8.7 for each sex of each group.

Figure 8.7. Mean accuracy percentages and SEM to the happy and sad expressions shown in each visual field by the chimeric face stimuli for the males and females of the control and depressed groups - Experiment Two.
To further assess the significant four-way interaction and to determine where the differences in recognition accuracy to the happy and sad visual field presentations lay between the groups and the sexes, the means in Table 8.18 and Table 8.19, and the interactions in Table 8.20 were further examined. As indicated in Table 8.20, the interaction between visual field and group approached significance. Further, a trend can be seen showing a LVF advantage for emotional processing for the control group that was not observed for the depressed group. The interaction between visual field and group had a weak to moderate observed power (0.32), suggesting that the statistical power in the four-way interaction was not strong enough to detect a significant interaction. The interaction between visual field and group is presented in Figure 8.8.

![Figure 8.8](image_url)

**Figure 8.8.** Mean accuracy percentages and SEM to the visual field presentations of the chimeric face stimuli for the control and depressed groups - Experiment Two.
Paired and independent t-tests were calculated on the accuracy rates of each group to visual field presentations to further assess the visual field by group interaction. Post-hoc paired t-tests showed that there was no significant difference in recognition accuracy between presentations shown in the LVF and in the RVF for the control group ($t (35) = -1.92, p=0.06$) or for the depressed group ($t (32) = 0.03, p=0.98$) (Table 8.18). Post-hoc independent t-tests comparing recognition accuracy to each visual field between the groups showed that there were no significant group differences in recognition accuracy to expressions shown in the LVF ($t (67) = -0.88, p=0.38$) or in the RVF ($t (65.22) = 0.85, p=0.40$).

### 8.3.4 Effects of significant demographic differences between the depressed males and females

As indicated in demographics Table 8.2, mean age differed significantly between the depressed males and females. It is therefore possible that the significant main effect for sex observed on the phonemic and semantic verbal fluency task, and the significant visual field by sex interaction observed for the RT analyses on the chimeric faces task, were confounded by the significant difference in age between the depressed males and females. Further analysis indicated that after the exclusion of three depressed patients from the analyses on the chimeric faces task (for obtaining <25% accuracy on the whole face expressions), age no longer differed significantly between the depressed males and females. Therefore, the only result possibly confounded by the significant sex difference in age, was the significant main effect for sex observed for phonemic and semantic verbal fluency.

To assess whether the significant difference in age between the depressed males and females confounded the main effect for sex observed for phonemic and semantic verbal fluency, age was assessed for suitability as a covariate. This was achieved by firstly examining whether age was related to the dependent variable of phonemic and semantic verbal fluency for each sex of the depressed group. Using Pearson’s $r$ and scatterplots, no significant linear relationships were observed between age and phonemic verbal fluency for either sex of the depressed group. This suggests that phonemic verbal fluency for the depressed males and females was not influenced by age, and thus further treatment of age as a covariate was not necessary. A significant linear relationship between age and semantic verbal
fluency was observed for the depressed males ($r$ (15) = -0.53, $p<0.05$). Therefore, age may have influenced the semantic verbal fluency performance of the depressed males, and thus age, as a covariate for semantic verbal fluency, was further examined for use in ANCOVA.

An assumption of ANCOVA is that the covariate (age) is unrelated to the independent variable (sex). A correlation analysis using Kendell’s Tau-b indicated a weak, yet significant relationship between the independent variable and covariate for the verbal fluency task ($\zeta$ (36) = -0.32, $p<0.05$). Therefore, the assumption of ANCOVA that there be no relationship between the covariate and independent variable was violated. An additional assumption of ANCOVA is that there is a linear relationship between the dependent variable and the covariate for both sexes. As previously mentioned, Pearson’s $r$ and scatterplots showed a significant linear relationship between age and semantic verbal fluency for the depressed males only. A linear relationship between age and semantic verbal fluency was not observed for the depressed females ($r$ (21) = 0.12, $p=0.61$), thus violating the assumption that a linear relationship would be observed between the dependent variable and covariate for both sexes. An additional assumption of ANCOVA is that there is homogeneity of regression slopes, in which the relationship of the dependent variable to the covariate is the same for each sex. Inspection of the scatterplot showing the relationship between age and semantic verbal fluency for each sex of the depressed group indicated a violation of the homogeneity of regression slopes assumption of ANCOVA. Therefore, age was considered inappropriate for use as a covariate in ANCOVA. An alternative to ANCOVA is to categorise the covariate (age) into a categorical variable, to use as an additional independent variable in a factorial ANOVA. In the factorial ANOVAs, the interaction between the categorised variable (covariate) and sex is the only interaction of interest. An interaction would indicate that the significant difference in age between the depressed males and females had an impact on the performance of each sex, and that further analysis would be required.

Frequency tables were used to determine the categories for age. Age was categorised into three categories, which was the best attempt to make the categories as balanced as possible between the
depressed and control males and females. The three categories were: <=44, 45-50, >=51. The sample size for each group and each sex of each group is depicted in Table 8.21.

Table 8.21
Sample sizes for categorised age by sex of the participant for the depressed and control groups – Experiment Two.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age (yrs)</th>
<th>&lt;=44</th>
<th>45-50</th>
<th>&gt;=51</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depressed</td>
<td></td>
<td>16</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>4</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>12</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>18</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>11</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

In the factorial ANOVA, the interaction between the categorised variable (age) and sex is the only effect of interest. An interaction would indicate that the significant difference in age between the depressed males and females had an impact on semantic verbal fluency performance for each sex and that further analysis would be required. A 2 (group) x 2 (sex) x 3 (age category) factorial ANOVA was calculated on the number of words generated for semantic verbal fluency by each group and each sex. No significant interaction was found between sex and age for semantic verbal fluency ($F$ (2, 60) = 1.76, $p=0.18$). Therefore, the significant difference in age between the depressed males and females did not confound the significant main effect for sex observed on the semantic verbal fluency task.

8.3.4.1 Missing cases and demographics

As indicated in the MRT analyses and RT analyses of the chimeric faces task, there were missing cases within these datasets that were not replaced. The ANOVA analyses excluded the participants with a missing cases from the dataset, thus reducing the sample sizes from those reported in demographic Tables 9.1 and 9.2. It is possible that the significant group and sex differences in the demographics
reported in Tables 8.1 and 8.2 changed with the reduced sample sizes of the MRT analyses and RT analyses of the chimeric faces task. If so, there may be an additional demographic that differs significantly between the groups or sexes that needs to be considered as a covariate.

One-way ANOVAs were recalculated, comparing the demographics between the groups and sexes of the smaller sample sizes of the MRT (depressed group \( n=34 \), control group \( n=36 \)), and RT analyses of the chimeric faces task (depressed group \( n=30 \), control group \( n=31 \)). For the reduced sample sizes of the MRT, there were no additional significant group or sex differences than those reported in Tables 8.1 and 8.2.

For the reduced sample sizes of the RT analyses of the chimeric faces task, there were no significant group differences in the demographics. The reduced sample size of the depressed group however, resulted in a significant difference in age (\( F(1, 28) = 4.50, p<0.05 \), partial \( \eta^2 = 0.14 \)) and handedness (\( F(1, 28) = 4.74, p<0.05 \), partial \( \eta^2 = 0.15 \)) between the depressed males and females.

The relationship between age and handedness with the dependent variable of RT for the chimeric faces task, was assessed to determine whether they may have confounded the significant sex by visual field interaction observed for the RT analyses. For each sex of the depressed group, Pearson’s \( r \) indicated no significant linear relationships between age and RTs for each visual field / emotion condition of the chimeric faces task. Therefore, the significant interaction between sex and visual field was not confounded by the significant difference in age between the depressed males and females. A significant linear relationship between handedness and RTs to LVF sad faces of the chimeric faces task was observed for the depressed males (\( r(12) = 0.59, p<0.05 \)). Therefore, handedness may have influenced the RTs to the chimeric faces for the depressed males, and thus handedness, as a covariate for the RTs on the chimeric faces task, was further examined for use in ANCOVA.

The assumption of ANCOVA that the covariate (handedness) is unrelated to the independent variable (sex) was firstly examined. A correlation analysis using Kendell’s Tau-b indicated that there was no
significant relationship between the independent variable and covariate for the chimeric faces task ($\zeta(30) = 0.31, p=0.053$), thus not violating the assumption. The assumption of ANCOVA that the covariate is linearly related to the dependent variable for both the depressed males and females was then investigated for the RTs to each visual field / emotion condition of the chimeric faces task. As previously mentioned, a significant linear relationship between handedness and RTs to the LVF sad faces was observed for the depressed males only. A significant linear relationship between handedness and RTs to any chimeric face condition was not observed for the depressed females, thus violating the assumption that a linear relationship would be observed between the dependent variable and covariate for both sexes. The assumption of ANCOVA that there is homogeneity of regression slopes, in which the relationship of the dependent variable to the covariate is the same for each sex of the depressed group, was violated for the RTs of the chimeric faces task. Due to the violations of the assumptions of ANCOVA, handedness was considered inappropriate for use as a covariate in ANCOVA, and was subsequently converted into a categorical independent variable for use in a factorial ANOVA.

Frequency tables were used to determine the categories for handedness. Handedness was categorised into three categories, which was the best attempt to make the categories as balanced as possible between the depressed and control males and females. The three categories were: <=60, 61-90, >=91. The sample size for each group and each sex of each group is depicted in Table 8.23.
Table 8.22

Sample sizes for categorised handedness by sex of the participant for the depressed and control groups, with missing cases from the chimeric faces task RT (log₁₀ transformed) analyses – Experiment Two.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Handedness</th>
<th>&lt;=60</th>
<th>61-90</th>
<th>&gt;=91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depressed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>5</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>5</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td>2</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

A 2 (visual field) x 2 (emotion) x 2 (group) x 2 (sex) x 3 (handedness category) mixed-factorial ANOVA calculated on the RTs of the chimeric faces task (log₁₀ transformed) showed no significant interaction between sex and handedness ($F(2, 49) = 2.56$, $p=0.09$). The non-significant interaction between handedness and sex suggests that the significant sex by visual field interaction, observed from the RTs on the chimeric faces task, was not confounded by the significant difference in handedness between the depressed males and females.

8.4 Discussion

The aim of Experiment Two was to investigate brain lateralized spatial, verbal and emotional functioning in a clinically depressed group, to determine whether clinical depression is associated with impaired RH functioning. It was also the aim of Experiment Two to examine how clinical depression affects brain lateralized spatial, verbal and emotional functioning for each sex.
8.4.1 Group differences in brain lateralization for spatial, verbal and emotional functioning

8.4.1.1 Brain lateralization for spatial and verbal functioning in a clinically depressed group

The hypothesis that clinical depression would be associated with impaired RH functioning was partially supported by the results of Experiment Two. The clinically depressed group performed significantly poorer than the control group on the RH task (the MRT), and also on the LH task (the semantic verbal fluency task). Therefore, an impairment in both RH and LH functioning was observed for the clinical depressed group in Experiment Two.

For the MRT, a positive linear relationship between RT and angle of rotation was observed for each group, indicating that both the depressed and control groups were mentally rotating the PMA stimuli (Cooper, 1976; Cooper & Shepard, 1975; Shepard & Metzler, 1971). Despite the faster RTs of the control group to each angle of rotation, the rate of mental rotation did not differ significantly between the depressed and control groups. Therefore, the hypothesis that the depressed group would mentally rotate the PMA stimuli significantly slower than the control group was not supported. The significant group difference in performance on the MRT was found in overall RT, and on the mental rotation intercept, thus suggesting that the control group encoded the PMA stimuli significantly faster than the depressed group. The significant group difference on the mental rotation intercept but not on the mental rotation slope, indicates that the RH impairment with clinical depression lies at the encoding and comparison stages of cognitive functioning. It also suggests that following a delay in the time taken to encode cognitive information, performance (mental rotation) by the depressed group is relatively unimpaired.

In the only other known study to examine mental rotation performance by a depressed group, Rogers, et al. (2002) also found a depressed group capable of performing mental rotation. The mental rotation of the depression group however, slowed progressively in comparison to the control group, for each increasing angle of rotation. Rogers, et al. attributed their finding to slowed motor planning in patients with depression. Similarly, Ladavas, Nicoletti, Rizzolatti, and Umiltà (1984) found that participants who induced
sad emotional feelings responded significantly slower to RH cues in a simple RT task. Ladavas, et al. (1984) proposed that depression influences RH processing at a late stage of pre-motor organization, by occupying the centres involved in the programming of RH motor responses. Such interference thus impairs RT performance and delays responses.

Depressed patients typically perform worse than control non-depressed groups on a range of tasks, showing a generalised performance deficit. The poorer performance by the depressed group, than a control group, has more often been reported to be significant on tasks involving RH functioning and not LH functioning (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Liotti, et al., 1991; Miller, et al., 1995; Rogers, et al., 2002). The performance of the depressed group in Experiment Two was expected to be poorer than the performance of the control group on each of the tasks, however, not significantly so on the semantic fluency task. Semantic fluency is a measure of left temporal lobe functioning (Fedio, et al., 1997; Pihlajamaki, et al., 2000; Troyer, et al., 1998), which is an area of the brain not implicated by electrophysiological research as being impaired with depression. As such, a significant impairment in LH functioning was not expected for the depressed group, and thus verbal fluency was not predicted to differ significantly between the groups.

The failure to detect an exclusive RH impairment with depression is not consistent with the majority of past research that has investigated brain lateralization with depression. It is possible that a generalised performance deficit for the depressed group in Experiment Two, was displayed in the form of significant group differences on both the MRT, and semantic verbal fluency, and that the findings are not representative of impaired brain lateral functioning with clinical depression. If the results are reflective of a generalised performance deficit, rather than of impaired brain lateral functioning with clinical depression, it may be argued that a significant group difference in performance on the phonemic verbal fluency task would have also been observed. Inspection of the results from the verbal fluency task, show that the difference between the depressed and control groups in the number of words generated, was larger for phonemic verbal fluency than semantic verbal fluency. It is also evident that the SDs of each group for phonemic fluency were large, thus potentially inhibiting the finding of a significant group difference.
In summary, the group comparisons in brain lateralization for spatial and verbal functioning showed an impairment of both RH and LH functioning for the clinically depressed group. The results may be representative of a generalised performance deficit with clinical depression, rather than of impaired brain lateral functioning with clinical depression. The performance deficit observed for the depressed group on the MRT suggests that the cognitive dysfunction observed with clinical depression lies at the encoding stage of information processing. There may also be an interfering effect at a late stage of pre-motor organization with depression, thus delaying motor responses and RTs. The results from the MRT also showed that once the depressed patients had encoded the information, performance was relatively unimpaired.

8.4.1.2 Brain lateralization for emotional processing in a clinically depressed group

The results from the chimeric faces task in Experiment Two failed to clearly show a RH impairment with clinical depression. A RH impairment with clinical depression was hypothesised to be evident on the chimeric faces task, through significantly slower and less accurate responses to emotional expressions presented in the LVF. More specifically, the responses of the depressed group were predicted to be significantly slower and less accurate to emotional expressions shown in the LVF than the RVF, and also significantly slower and less accurate than the control group to expressions shown in the LVF.

In contrast to the hypotheses, the RT analyses of the chimeric faces task did not show a RH deficit in emotional processing for the depressed group. Rather, there was no evidence that brain lateralization for emotional processing differed between the control and depressed groups. Regardless of group, responses were significantly faster to expressions shown in the LVF than the RVF, a finding consistent with the RH hypothesis of brain lateralization for emotional processing. As found in Experiment One, the LVF advantage in RT was markedly stronger to the sad expressions than the happy expressions. A non-significant mood congruency effect was observed, where; the depressed group responded faster to the sad expressions than the happy expressions, and the control group responded faster to the happy expressions than the sad expressions. Such mood congruency however, had no impact on brain
lateralization for emotional processing. A similar observation was made by David (1989), who found that
induced elation and induced depression increased the number of happy and sad choices respectively, but
did not influence the magnitude of visual field bias to those emotions. Similar to the observations on MRT,
the control group responded significantly faster than the depressed group in overall RT on the chimeric
faces task, again suggesting slowed RT with clinical depression. Whilst there was a delay in responses to
the chimeric stimuli for the depressed group, once the stimuli had been encoded, performance (brain
lateralization) by the depressed group was similar to the control group.

In contrast to the RT analyses, a group difference in brain lateralization for emotional processing was
implicated by the accuracy analyses of the chimeric faces task. For the control group, a strong non-
significant trend toward a LVF advantage in recognition accuracy to the emotional expressions was
observed. Conversely, the recognition accuracy of the depressed group to the emotional expressions was
comparable across visual field presentations. In contrast to the hypotheses, the recognition accuracy of
the depressed group, to LVF presentations of emotional expressions, was not significantly poorer than
their recognition accuracy to RVF presentations, or significantly poorer than the recognition accuracy of
the control group to LVF presentations of emotional stimuli. Further, no significant group differences in
recognition accuracy to expressions shown in the RVF were observed, along with no significant group
difference in overall accuracy. Therefore, the hypothesis that the depressed group would display
impairment in RH functioning on the chimeric faces task was not supported.

It is difficult to determine whether the findings from the accuracy analyses of the chimeric faces task are
suggestive of impaired RH functioning with clinical depression, to the point where LH and RH emotional
processing is comparable, or whether indicative of bilateralization of emotional processing for clinically
depressed patients. If the results were indicative of bilateralization for emotional processing with clinical
depression, the RH advantage in RT to the chimeric faces would not have been expected for the
depressed group. Similarly, if the results were indicative of RH impairment with clinical depression, the
RH advantage in RT to the chimeric faces would not have been expected for the depressed group, and
the results may have been supported by a significant group difference in performance on the MRT only.
The difference in brain lateralization for the depressed group, across the dependent variables of the chimeric faces task, suggests that there is a difference between the dependent variables RT and accuracy in their measurement of brain lateralization for emotional processing. The findings also suggest that the process of emotional processing that is measured by accuracy is impaired by clinical depression. The finding that the control group was significantly faster than the depressed group in overall RT, yet overall recognition accuracy was non-significantly different between the groups, replicates the delayed RT for the depressed group observed on the MRT, and is supportive of the proposal of Ladavas, et al. (1984). Ladavas, et al. proposed that there is impairment in pre-motor organization with depression, which is more likely to impair RT than accuracy, because of its requirement of motor functioning.

Although the pattern of brain lateralization for emotional processing for the depressed group differed across dependent variables, both the RT and accuracy results failed to show significantly poorer RH functioning for the depressed group in emotional processing. This finding is not consistent with the findings of previous research that examined the effects of depression on brain lateralization for emotional processing (Jaeger, et al., 1987; Lior, & Nachson, 1999; Moretti, et al., 1996). In the past, where a RH dysfunction in emotional processing has been reported for a depressed group, performance was significantly impaired for responses to LVF presentations of emotional stimuli, than to RVF presentations of emotional stimuli. Factors that may have contributed to the differing findings between Experiment Two and past research are outlined in proceeding Section 8.4.3 of this chapter.

In summary, impaired RH processing of emotional stimuli with clinical depression can not be concluded from the results of Experiment Two. In contrast to previous research, brain lateralization for emotional processing was similar between the control and depressed groups for the RT analyses, with the RH being more specialized than the LH for emotional processing. Unlike the RT findings, a difference between the control and depressed groups was observed for the recognition accuracy of the chimeric faces. A RH dominance in recognition accuracy to the emotional expressions was observed for the control group, yet no hemispheric differences in recognition accuracy to the emotional expressions were observed for the
depressed group. It could not be determined whether the accuracy analyses were indicative of bilateralization for emotional processing with clinical depression, or whether there was reduced RH functioning with depression to result in a non-significant difference in recognition accuracy across visual field presentations.

8.4.2 Sex differences in brain lateralization for spatial, verbal and emotional functioning in a clinically depressed group

8.4.2.1 Sex differences in brain lateralization for spatial and verbal functioning in a clinically depressed group

Sex differences in brain lateralization for spatial and verbal functioning have often resulted in differing responses between males and females to hemispheric dysfunction, such as unilateral brain lesions (Inglis & Lawson, 1981, 1982; Lewis & Kamptner, 1987; McGlone, 1977). The stronger brain lateralization for spatial and verbal functioning of males, compared to females, has often resulted in a more detrimental effect in cognitive performance with hemispheric dysfunction (Inglis & Lawson, 1981, 1982; Lewis & Kamptner; McGlone). As males are more brain lateralized for verbal and spatial abilities than females, assistance by the unimpaired hemisphere to support the impaired hemisphere is believed to be limited (Kimura, 1969; Lansdell; McGlone, 1977, 1980; Springer & Deutsch). In contrast, the less lateralization, or bilateralization of verbal and spatial abilities for females allows a greater degree of assistance from the unimpaired hemisphere to perform the task at hand, and results in a relatively better performance by the females than males.

For Experiment Two, it was hypothesised that clinical depression would be associated with impaired RH functioning. The impaired RH functioning of the depressed group was expected to result in a significant group difference in performance on the MRT, and a non-significant group difference in performance on the verbal fluency task. It was hypothesised that the depressed males would perform significantly poorer than the depressed females, on the tasks measuring functions lateralized to the hemisphere impaired with
clinical depression. As such, it was anticipated that a RH impairment with clinical depression would result in a significantly poorer performance by the depressed males on the MRT than the depressed females. Whereas performance on the verbal fluency task would be relatively unimpaired, and the typical female advantage in performance on the verbal fluency task would be observed.

In contrast to expectations, the results from Experiment Two showed that the depressed group performed significantly poorer than the control group on both the MRT and semantic verbal fluency task. That is, a significant impairment for both RH and LH functioning was observed for the clinically depressed group of Experiment Two. Therefore, in regards to the hypothesis of sex differences in brain lateralization with depression, it was expected that a RH impairment with clinical depression would result in a significantly poorer performance by the depressed males than the depressed females on the MRT. In addition, it was expected that LH impairment with clinical depression would significantly impair the verbal fluency performance of the depressed males, to result in a stronger female advantage in verbal fluency performance. These hypotheses however, were not supported by the results of Experiment Two.

For the MRT, a positive linear relationship between RT and angle of rotation was observed for each sex of each group. Therefore, the males and females of both the depressed and control groups were mentally rotating the PMA stimuli (Cooper, 1976; Cooper & Shepard, 1975; Shepard & Metzler, 1971). There was no significant sex difference in the rate of mental rotation, or in the time taken to encode the PMA stimuli, for either group. The significant group difference in overall RT, and on the mental rotation intercept, indicates that the delay in encoding the stimuli observed with clinical depression was similar for the depressed males and females. If clinical depression was to have a greater impact on the brain lateralized performance of males, a significantly greater delay in encoding time would have been observed for the depressed males in comparison to the depressed females. A greater delay in encoding time for the depressed males, than the depressed females, would have produced a significant group by sex interaction on the MRT intercept. There was no evidence to suggest that a difference in brain lateralization between the males and females resulted in a different impairment in spatial functioning with clinical depression.
For both phonemic and semantic verbal fluency, a significant main effect for sex was observed, showing a female advantage in verbal processing regardless of group. As observed for the MRT, the impact of clinical depression on verbal fluency performance appeared similar between the depressed males and females. If clinical depression was to have a greater impact on the brain lateralized performance of males than females, a significantly greater sex difference in verbal fluency performance would have been observed for the depressed group than the control group. There was no evidence to suggest that the depressed males performed significantly poorer on the verbal fluency task, than the depressed females. There were no significant group by sex interactions to suggest a greater sex difference in verbal fluency performance for the depressed group.

For phonemic verbal fluency, the females generated significantly more words than the males, regardless of group. That is, clinical depression had no effect on phonemic fluency for either sex, and the sex difference in performance observed for the control group was also observed for the depressed group. Although a significant group by sex interaction was not observed for phonemic verbal fluency, inspection of the mean number of words produced by each sex of each group did indicate that the female advantage in phonemic verbal fluency performance was not consistent across the two groups. The female advantage in phonemic verbal fluency was larger for the control group than the depressed group, with the words generated for phonemic verbal fluency being negligible between the depressed males and females. Comparison between the same sex of each group shows that the phonemic verbal fluency performance of the depressed males was comparable to that of the control males. The phonemic verbal fluency performance of the depressed females, however, was poorer than that of the control females. These findings are opposite to the hypothesis that clinical depression would have a greater impairment on the brain lateralized performance of males than females.

Similar to phonemic verbal fluency, the females produced significantly more words than the males for semantic verbal fluency, regardless of group. Further, a significant main effect for group indicated that the control group generated significantly more words than the depressed group, regardless of sex. As the female advantage in semantic fluency was relatively consistent between the groups, the significant group
main effect indicated that the effect of clinical depression, on the performance of the semantic verbal fluency task, was similar across males and females. As with the MRT, there was no evidence to suggest that a difference in brain lateralization between the males and females resulted in a different impairment in verbal functioning with clinical depression.

In summary, the sex difference results from the MRT and verbal fluency task suggest that clinical depression did not have a greater effect on the brain lateralized performance of males than females. In contrast, the similar sex difference findings between the control and depressed groups suggest that clinical depression had a similar impact on the spatial and verbal functioning of males and females, regardless of brain laterality differences.

8.4.2.2 Sex differences in brain lateralization for emotional processing in a clinically depressed group

There was also no evidence from the results of the chimeric faces task that clinical depression resulted in a greater impairment to the brain lateralized functioning of males than females.

The RT analyses of the chimeric faces task showed that there was a significant sex difference in RTs to the LVF and RVF presentations of emotional expressions, a difference which was regardless of group. More specifically, males responded significantly faster to emotional expressions shown in the LVF than in the RVF. In contrast, there was no significant visual field difference in RTs to the emotional expressions for the females. The finding of a sex difference in brain lateralization for emotional processing, as measured by RT, replicates the findings of Experiment One. The sex difference finding also suggests that the effect of clinical depression on brain lateralization for emotional processing was similar between males and females. If clinical depression were to have a greater impairment on the brain lateral functioning of males than females, the sex difference in RTs to visual field presentations would not have been similar between the control and depressed groups. Rather, a significant interaction between group, sex, and visual field would have been evident, which was not the case.
Similarly, there was no evidence from the accuracy analyses of the chimeric faces task that clinical depression resulted in a greater impairment to the brain lateralized emotional processing of males than females. There were no significant interactions or trends involving sex, suggesting that the group differences observed in recognition accuracy, to emotional expressions shown across visual fields, was consistent across sex. For the control males and females, there was a LVF advantage in recognition accuracy to emotional expressions. For the depressed males and females however, there was no visual field advantage in recognition accuracy to emotional expressions. As previously discussed for the group comparisons, it is difficult to determine whether the findings for the depressed group are due to impaired RH functioning, or to the depressed group being bilateralized for emotional processing. Either a RH impairment in emotional processing, or bilateral emotional processing with clinical depression would have been expected to be supported by the findings from the RT analyses. If clinical depression was to result in a greater impairment in lateral brain function for males than females, a significant group, sex, by visual field interaction would have been observed.

The similar sex difference findings between the control and depressed males and females on the chimeric faces task, suggests that clinical depression had a similar impact on the performance of males and females. There was no evidence to suggest that the brain lateralized emotional processing of depressed males was more impaired than that of depressed females.

8.4.2.3 Summary of findings

The results of Experiment Two implicate impairment in both RH and LH lateralized spatial and verbal functioning with clinical depression. Variance in brain lateralization for emotional processing between the control and depressed groups was observed by the accuracy analyses of the chimeric faces task, however whether the group difference was the result of impaired RH functioning with depression, or bilateralization for clinically depressed patients, could not be determined. The group differences in task performance in Experiment Two could be implicative of impaired brain lateral functioning with clinical depression.
Alternatively, the results could be representative of a generalised performance deficit with clinical depression, which was presented in the form of significant group differences.

The results of Experiment Two also indicated that clinical depression is associated with significantly slowed RT. The results from the MRT suggest that the delay in RT for clinically depressed patients is due to impairment at the encoding stage of information processing. Further, there may be impairment in pre-motor organization with depression which delays motor movement in responding to stimuli.

In regards to sex differences, the findings from Experiment Two showed that clinical depression did not result in greater dysfunction in task performance for one sex over the other, but rather that the impact of clinical depression on task performance was similar across sex. Therefore, there was no evidence to suggest that a sex difference in brain lateralization resulted in a different impairment in spatial, verbal, and emotional functioning between the males and females with clinical depression.

The findings from Experiment Two reject the hypothesis that clinical depression would have a greater impact on the brain lateralized functioning of males than females, which was based on evidence derived from brain lesion research (Inglis & Lawson, 1981, 1982; Lewis & Kamptner, 1987; McGlone, 1977). In contrast to brain lesion research, Heller (1993) proposed that the distribution of asymmetric activation may be identical in depressed males and females. Similarly, Silberman, et al. (1983) suggested that people with depression may be less lateralized to begin with. Heller, and Silberman, et al. did not empirically test their proposals, however, the findings from Experiment Two suggest that similar and less brain lateralization for the depressed males and females is not the case. If brain lateralization was similar and less lateralized for the depressed males and females, significant sex differences in task performance in Experiment Two would not have been evident on the semantic verbal fluency task, or in the RT analyses of the chimeric faces task. Rather, the depressed males and females would have performed similarly on the semantic verbal fluency task, and in RT on the chimeric faces task, and significant group by sex interactions would have been observed. Further, sex difference findings between the depressed males and females were similar to those reported for the control group, suggesting that brain lateralization across
sex did not differ with clinical depression. If brain lateralization was to be similar and less lateralized for the depressed males and females, similar sex differences in task performance would not be expected between the control and depressed groups.

The results of Experiment Two may be reflective of a generalised performance deficit associated with clinical depression, rather than of impaired brain lateralized functioning with clinical depression. If this is the case, it may explain why any effects of clinical depression on the brain lateralization of each sex were not observed in Experiment Two. The results may simply indicate that the symptoms of clinical depression led to a generalised performance deficit, which was experienced equally across sex.

8.4.3 Consistency with prior research

General performance deficits for depressed groups have been reported in past literature, however, the performance deficit has typically been significantly larger on the tasks measuring RH than LH functioning. Where a RH dysfunction was observed, the depressed and control groups were found to perform significantly different on tasks measuring RH functioning, although performance between groups on the tasks measuring LH functioning did not differ significantly. The failure to observe a greater deficit in RH functioning for the depressed group in Experiment Two is not consistent with the majority of past literature (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Jaeger, et al., 1987; Kucharska-Pietura & David, 2003; Liotti, et al., 1991; Miller, et al., 1995; Moretti, et al., 1996; Rogers, et al., 2002).

There are a number of potential factors that may have contributed to the differing results of Experiment Two compared to the results of past research. Such factors include: the definition of “depressed” in each study, the severity and state of the patients’ depression, varying patient medication and thus varying side effects, and the measurement of anxiety in depressed groups.

Past research has varied in their definition of “depressed”, with depressed groups varying from clinically depressed patients, to non-depressed participants (usually students) who have received a self-rated score on a depression rating inventory which was indicative of having depressive symptoms (Ladavas, et al.,
1984; Moretti, et al., 1996). Such variation in classifying depressed groups could lead to mistakenly classifying non-depressed participants as depressed based on their non-professional self-rating. Furthermore, the severity of the depressive symptoms may differ between clinically diagnosed and self-rated “depression” groups. Given the difficulty associated with recruiting non-medicated depressed patients, medication types and strengths would also differ within depressed populations, and between studies. At the time of testing, depressed patients may experience differing associated side effects of the differing medications and possibly varying levels of depression. The prescribed medications to the patients of Experiment Two were vastly different to the point where groups by medication type were too small, and too mixed, to perform post-hoc analyses to examine any differences in performance across medication type. Each of these potential factors may result in testing depressed groups who differ in the severity of their depression and thus potentially differ in the severity of hemispheric disturbance associated with depression. The severity of depression has been found to have an effect on brain lateral indices, with Bruder, Sutton, Berger-Gross, Quitkin, and Davies (1981) observing an association between increasing severity of depression and reduced symmetry regardless of the distinction of asymmetry.

In addition, depression is often co-morbid with anxiety, which has been associated with a diverging pattern of hemispheric dysfunction. In contrast to depression, anxiety has been related to a decrement in LH functioning (Tucker, Antes, Stenslie, & Barnhardt, 1978). It is possible that these opposing hemispheric dysfunctions with depression and anxiety, may suppress each other in populations where depression and anxiety are co-morbid. For example, if a level of anxiety in a sample of depressed participants is high, the tendency toward lower RH functioning associated with depression might be cancelled out or diminished by the tendency toward lower LH functioning with anxiety. Such opposing tendencies between depression and anxiety may result in variability between findings of the degree of hemispheric dysfunction observed within depressed groups. Therefore, screening for anxiety in future research examining brain lateralization in depressed samples is important, especially given the high frequency to which anxiety and depression co-occur.
CHAPTER NINE

THESIS SUMMARY AND CONCLUSIONS

9.1 Chapter Nine overview

Two experiments were reported in this dissertation, each based around the central topic of brain lateralization. In brief, Experiment One sought to replicate the sex differences in brain lateralization for spatial and verbal processing. Experiment One also investigated brain lateralization for processing happy and sad emotional stimuli by a non-depressed sample, in an attempt to differentiate between two competing hypotheses on brain lateralization for emotional processing and also to examine sex differences in brain lateralization for emotional processing. Experiment Two examined the effect of clinical depression on brain lateralization for spatial, verbal, and emotional functioning, with the aim of investigating how clinical depression affects brain lateralization for each sex separately.

To examine each of these research areas, sixty non-depressed participants and thirty-nine clinically depressed patients completed neuropsychological tasks that measure brain lateralized spatial, verbal, and emotional functioning. The neuropsychological tasks that were selected also measure the brain regions found to be involved with depression (frontal lobe and right parietal lobe). The respective neuropsychological tasks were: the MRT as a measure of right hemisphere (RH) functioning; the verbal fluency task (phonemic and semantic fluency) as a measure of left hemisphere (LH) functioning; and the chimeric faces task as a measure of frontal lobe functioning. Participants also completed the Vocabulary subtest of the WASI, which served as a measure of premorbid IQ for the clinically depressed group in Experiment Two. Chapter Nine will outline the key findings of each experiment, along with the implications of such findings. The limitations of this research and ideas for future research will also be presented in Chapter Nine, as well as the thesis conclusions.
9.2 Experiment One: Sex differences in brain lateralization for spatial, verbal and emotional processing in a non-depressed group

*Why sex differences in brain lateralization were investigated*

Sex differences in spatial and verbal functioning are well documented. Males are typically reported to perform better than females on tasks of spatial ability, whereas females are typically reported to perform better than males on tasks involving verbal ability (Flor-Henry, 1978; Harshman, et al., 1983; Maccoby & Jacklin, 1974). Such sex differences in spatial and verbal functioning have been attributed to sex differences in brain lateralization for these functions. Males are proposed to be more lateralized for spatial abilities in the RH and for verbal abilities in the LH, whereas females are proposed to be less lateralized, in which spatial and verbal abilities are shared between the hemispheres (Kimura, 1969; Lansdell, 1961; McGlone, 1977, 1980; Springer & Deutsch, 1993). The sex difference findings on spatial and verbal tasks suggest that bilateral representation of spatial abilities in females is less efficient than the unilateral representation of spatial abilities in males (Crucian & Berenbaum, 1998). In contrast, bilateral representation of verbal abilities in females appears more efficient than the unilateral representation of verbal abilities in males. It was the aim of Experiment One to illustrate that there are sex differences in brain lateralization for spatial and verbal functioning in a non-depressed sample by replicating the male advantage in spatial processing on the MRT (Blough & Slavin, 1987; Bryden, et al., 1990; Delgrado & Prieto, 1996; Dollinger, 1995; Kail, et al., 1979; Maccoby & Jacklin), and the female advantage in verbal processing on the verbal fluency task (Acevado, et al., 2000; Herlitz, et al., 1997, 1999; Monsch, et al., 1992).

In comparison to past research on brain lateralization for verbal and spatial processing, evidence of brain lateralization for emotional processing has been unclear. Findings have varied from supporting either the RH hypothesis or valence hypothesis, or offering partial to no support to either. Such inconsistency in the literature in regards to brain lateralization for emotional processing inspired its further investigation in this
thesis. Further, unlike spatial and verbal functioning, sex differences in brain lateralization for emotional processing have not been established, with findings in the literature being mixed and inconsistent.

It therefore was the aim of Experiment One to further investigate brain lateralization for emotional processing and differentiate between the competing RH and valence hypotheses, and also to determine whether there is a sex difference in brain lateralization for emotional processing.

_How sex differences in brain lateralization were investigated_

To examine sex differences in brain lateralization for spatial, verbal, and emotional processing, the performance of the thirty males and thirty females of the non-depressed group was compared on the MRT, verbal fluency task, and chimeric faces task respectively.

_Hypotheses_

Based on the sex difference findings of past neuropsychological research, it was hypothesised that:

- \( H_1 \): The male participants will mentally rotate the stimuli in the MRT significantly faster than the female participants.

- \( H_2 \): The female participants will generate significantly more words for both phonemic and semantic verbal fluency than the male participants.

The majority of past research that has used chimeric faces to investigate brain lateralization for emotional processing has generally reported findings in support of the RH hypothesis (Campbell, 1978; Christman & Hackworth, 1993; David, 1989; Drebing, et al., 1997; Moreno, et al., 1990). Despite the changes in methodology to improve the chimeric faces task used in this dissertation, it was expected that the RH
hypothesis would also be supported by the results of Experiment One. Therefore, in terms of the results from the chimeric faces task, it was hypothesised that:

H3: Responses will be significantly faster and significantly more accurate to happy and sad emotional expressions shown in the LVF than in the RVF.

Due to the inconsistent findings in the literature in regards to sex differences in brain lateralization for emotional processing, a directional hypothesis predicting a sex difference in performance on the chimeric faces task could not be justified. The investigation of sex differences in brain lateralization for emotional processing remained a research aim for Experiment One.

Key findings

No significant sex differences in performance were observed on the MRT, with performance being similar between the males and females on the mental rotation slope, intercept, and overall RT. For the verbal fluency task, the females generated significantly more words than the males for both phonemic and semantic verbal fluency.

As hypothesised, responses were faster and more accurate to happy and sad emotional expressions shown in the LVF than in the RVF. That is, the RH was more specialized than the LH for emotional processing, regardless of valence. The degree to which the RH was lateralized for processing the happy and sad emotional stimuli was found to vary across RT and accuracy. For the RT analyses, a stronger LVF advantage for the processing of sad than happy expressions was observed. In contrast, the LVF advantage in recognition accuracy was relatively consistent across happy and sad expressions. No consistent sex differences in performance were observed between the RT and accuracy rate analyses on the chimeric faces task. For the RT analyses of the chimeric faces task, a LVF advantage in RT for emotional processing was observed for the males, and no hemispheric bias for emotional processing was observed for the females. In contrast, the accuracy rate analyses of the chimeric faces task showed a
LVF advantage in emotional processing for both the males and the females. Therefore, while a sex
difference in emotional processing was implicated by the RT analyses of the chimeric faces task, the
accuracy analyses implied no sex difference in brain lateralization for emotional processing.

Implications from findings

The hypothesis that the males would mentally rotate the MRT stimuli significantly faster than the females
was not supported by the results of Experiment One. The failure to observe a significant sex difference in
performance on the MRT implicates no sex difference in brain lateralization for spatial functioning. Given
the relative consistency to which a male advantage has been reported in past mental rotation research
(Blough & Slavin, 1987; Bryden, et al., 1990; Delgrado & Prieto, 1996; Dollinger, 1995; Kail, et al., 1979;
Maccoby & Jacklin, 1974), it was argued that the finding did not necessarily mean that there is no sex
difference in brain lateralization for spatial functioning. Stimulus type, number of trials, and sample size
were ruled out as contributing to the non-significant sex difference finding on the MRT, given that previous
research has reported a significant male advantage in mental rotation performance using the same stimuli
(Blough & Slavin; Kail, et al., 1979), the same or less number of trials (Blough & Slavin; Kail, et al.), and
comparable or smaller sample sizes (Blough & Slavin; Bryden, et al.; Dollinger). Although it was expected
that the sample size was large enough to detect a significant sex difference in performance on the MRT, it
is possible that it was not. It is possible that any sex difference in mental rotation performance (male
advantage in overall RT and mental rotation slope) was just too weak to reach statistical significance.

The hypothesis that the female participants would generate significantly more words for both phonemic
and semantic verbal fluency than the male participants was supported by the results of Experiment One.
The female advantage in verbal fluency is consistent with past literature that has reported a female
advantage on the verbal fluency task (Acevado, et al., 2000; Herlitz, et al., 1997, 1999; Monsch, et al.,
1992). The finding supports the proposal that the bilateralization of verbal processing for females is more
efficient than the unilateral processing of verbal skills for males.
Consistent with the RH hypothesis, the results from Experiment One imply that emotional processing is a RH lateralized function. The support for the RH hypothesis in Experiment One validates the findings from earlier chimeric face research, in which the methodology may have contributed to a RH advantage by stimulating facial processing, a function of the RH (Geffen, et al., 1971; Kolb, et al., 1983). In contrast, the findings of Experiment One conflict with past research that has supported the valence hypothesis of brain lateralization for emotional processing. The main source of support for the valence hypothesis has been the research of Reuter-Lorenz and Davidson (1981) and Reuter-Lorenz, et al. (1983). Past research has failed to replicate the valence effect observed by Reuter-Lorenz, et al. (1981, 1983) (McLaren & Bryson, 1987; Moretti, et al., 1996), which has subsequently raised questions about the reliability of a valence effect for brain laterality for emotional processing.

In regards to sex differences in brain lateralization for emotional processing, the findings from the RT analyses of the chimeric faces task implicate a sex difference in brain lateralization for emotional processing. More specifically, that emotional processing is lateralized to the RH for males, whereas females are bilateralized for emotional processing. In contrast, the findings from the accuracy rate analyses of the chimeric faces task implicates RH lateralization for emotional processing for both males and females. The contrasting sex difference findings in brain lateralization for emotional processing between the RT and accuracy rate analyses of the chimeric faces task in Experiment One, and also in the literature, suggests that a strong sex difference in brain lateralization for emotional processing does not exist. If a strong sex difference, or even a similarity between the sexes, in brain lateralization for emotional processing exists, it would be expected to be observed across various methodologies and differing dependent variables, and not result in such inconsistent findings.
9.3 Experiment Two: Brain lateralization in clinical depression and sex differences in brain lateralization for a clinically depressed group

Why brain lateralization in a clinically depressed group, and sex differences in brain lateralization for a clinically depressed group was investigated

The majority of past research that has investigated disturbed lateral brain function in depressed patients has found depression to be associated with poorer performance in functions lateralized to the RH (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Liotti, et al., 1991; Miller, et al., 1995; Rogers, et al., 2002). While past research has been conducted to investigate how disturbed hemispheric functioning from unilateral brain lesions has affected brain lateralized functioning for each sex, research investigating how disturbed hemispheric functioning from mental illness, like clinical depression, affects brain lateralization for each sex separately is lacking.

Experiment Two sought to add to the literature on clinical depression and brain lateralization, by providing more specific findings on the effect of clinical depression on the brain lateralization of each sex separately. In addition to extending the knowledge of this area, the findings from Experiment Two on the affect of clinical depression on brain lateralization for each sex could potentially further the understanding of why there is a sex difference in the prevalence of clinical depression.

How brain lateralization in a clinically depressed group, and sex differences in brain lateralization in a clinically depressed group was investigated

To examine the affect that clinical depression has on brain lateralized spatial, verbal, and emotional functioning, the performance of thirty-six (fifteen males, twenty-one females) clinically depressed patients and thirty-six (eighteen males, eighteen females) non-depressed control participants was compared on the MRT, verbal fluency task, and chimeric faces task.
Hypotheses

Based on the findings of past neuropsychological research, it was hypothesised that clinical depression would be associated with a significantly poorer RH than LH functioning. Therefore, in terms of task performance between the control and depressed groups, it was hypothesised that:

Hₐ: The depressed group will perform significantly poorer than the non-depressed control group on the task measuring RH functioning, the MRT, by mentally rotating the stimuli significantly slower than the control group.

Hₐ: Performance between the groups on the task measuring LH functioning, the verbal fluency task, will not significantly differ, with the number of words generated for phonemic and semantic verbal fluency being non-significantly different between the depressed and control groups.

Hₐ: For the chimeric faces task, the depressed group will respond significantly slower and be significantly less accurate than the control group when identifying the sad and happy expressions shown in the LVF.

Hₐ: For the chimeric faces task, the depressed group will respond significantly slower and be significantly less accurate when identifying happy and sad emotional expressions shown in the LVF than in the RVF.

The findings from past unilateral brain lesion research (Inglis & Lawson, 1981, 1982; Lewis & Kamptner, 1987; McGlone, 1977), suggest that hemispheric dysfunction is likely to result in greater impairment to the brain lateralized functioning of males than females. The greater brain lateralization of males is presumed to restrict assistance of the unimpaired hemisphere to perform the task of the impaired hemisphere. In contrast, the bilateralization of females is presumed to allow the unimpaired hemisphere to perform the
task at hand. Therefore in regards to the effect that clinical depression may have on brain lateralization for each sex, it was hypothesised that:

H₀: The depressed males will perform significantly poorer than the depressed females on the tasks measuring functions lateralized to the cerebral hemisphere that is impaired during clinical depression

Key findings

In regards to group differences in task performance, a significant group difference was found on the MRT, with the clinically depressed group performing significantly slower than the control group on the mental rotation intercept and in overall RT. A significant group difference was also observed for semantic verbal fluency, with the depressed group generating significantly fewer words than the control group. No further significant group differences in performance were observed on the MRT or verbal fluency task. For the chimeric faces task, responses were significantly faster to expressions shown in the LVF than in the RVF, regardless of group and emotion. The LVF advantage in RT was found to be markedly stronger to sad than happy expressions. In contrast to the RT analyses, the accuracy rate analyses of the chimeric faces task showed a LVF advantage in emotional processing for the control group, yet no hemispheric bias for emotional processing for the depressed group. The control group was found to respond significantly faster overall to the chimeric faces than the depressed group, yet accuracy was comparable between the groups.

In regards to sex differences in task performance, no significant sex differences in performance on the MRT were observed for either group. For the verbal fluency task, with the females generated significantly more words than the males for both phonemic and semantic fluency, regardless of group. Regardless of group and emotion, the RT analyses of the chimeric faces task showed that the males responded significantly faster to emotional expressions shown in the LVF than in the RVF, yet for the females, there was no significant hemispheric bias in RT for emotional processing. The accuracy rate analyses of the chimeric faces task showed no sex differences in performance for either group.
Implications from findings

The hypothesis that clinical depression would be associated with impaired RH functioning was partially supported by the findings of Experiment Two. The significantly poorer performance of the depressed group on both the MRT and verbal fluency task, implicates both RH and LH impairment with clinical depression. Further, although brain lateralization for emotional processing differed for the depressed group between the RT and accuracy rate analyses of the chimeric faces task, the results still failed to show significantly poorer RH functioning for the depressed group in the recognition of emotional expressions. These findings are inconsistent with the majority of past research that has investigated brain lateralization for depressed groups (Bruder, et al., 1989; Cassens, et al., 1998; Henriques & Davidson, 1997; Jaeger, et al., 1987; Lior, & Nachson, 1999; Liotti, et al., 1991; Miller, et al., 1995; Moretti, et al., 1996; Rogers, et al., 2002). It was suggested that the findings of Experiment Two may be reflective of a generalised performance deficit associated with depression, rather than to a disturbance in brain lateralized functioning with clinical depression.

The group difference in performance on the MRT was found to be due to an increase on the intercept and not a difference on the slope. This finding implicates impairment at the encoding stage of information processing for clinically depressed patients. It was also suggested that the slowed responses of the depressed group on the MRT and the chimeric faces task may relate to impairment in pre-motor organization with depression, thus resulting in delayed motor responses (Ladavas, et al., 1984; Rogers, et al. (2002).

The hypothesis that the depressed males would perform significantly poorer than the depressed females, on the tasks measuring the functions lateralized to the cerebral hemisphere that is impaired during depression, was not supported by the findings of Experiment Two. The sex difference findings of the depressed group in Experiment Two largely resembled those observed for the control group. This implies that clinical depression had a similar impact on males and females, regardless of sex differences in brain lateralization. If the depressed males were to perform significantly poorer than the depressed females due
to sex differences in brain lateralization, diverging sex difference results between the depressed and control groups in task performance would have been observed. In contrast, if brain lateralization was similar between the depressed males and females, the sex difference in performance on the semantic verbal fluency task, and in RTs to the chimeric faces, would not have been evident. If the group differences in task performance were representative of a generalised performance deficit with clinical depression, not of impaired brain lateralized functioning with clinical depression, this may explain why a sex difference in the effects of clinical depression on brain lateralization was not observed in Experiment Two.

9.4 Limitations of this research

The following limitations were recognised from the research conducted in this dissertation.

9.4.1 Mixed depression subtypes

Due to recruiting difficulties for the research on clinical depression in this dissertation, the clinically depressed sample in Experiment Two comprised patients diagnosed with Major Depression, Bipolar Depression, Post-natal Depression, and depression co-morbid with PTSD. It may be possible that the impairment of RH lateralized functions with depression, that have commonly been reported in the literature, vary across depression subtype. Such differing impacts on brain lateralization with depression subtype may have made it difficult to detect impairment in RH functioning with depression in the results of Experiment Two.

9.4.2 Sample size

It is recognised that the sample size of the clinically depressed and non-depressed control groups in Experiment Two may not have produced sufficient statistical power needed for the larger analyses, such as the four-way repeated measure ANOVAs of the chimeric faces task. While this is noted as a limitation,
it should be acknowledged that the sample size of the clinically depressed group in Experiment Two is large for a clinical study, and is also larger than some of the past research that has investigated brain lateralization in depressed groups (e.g. Lior & Nachson, 1999; Liotti, et al., 1991).

9.4.3 Screening for anxiety

Another limitation of the research conducted in Experiment Two was the failure to screen for anxiety experienced by the depressed patients. As mentioned in Chapter Nine, Experiment Two, depression is often co-morbid with anxiety, which in contrast to depression, has been found to be associated with impaired LH functioning (Tucker, et al., 1978). Therefore, it is possible that the opposing hemispheric dysfunctions with depression and anxiety may have suppressed each other, so that an impairment in RH functioning with depression could not be observed. As such, it is advised that future research aiming to investigate brain lateralization in depressed groups screen for anxiety.

9.4.4 Chimeric faces task confounding asymmetries in facial expression with asymmetries in the perception of emotion

While the chimeric faces task is considered an effective method of investigating brain lateralization for emotional processing, the chimeric faces task used in this thesis did not account for asymmetries in facial expressions. As mentioned in Chapter Seven, Experiment One, there is evidence suggesting that the left hemiface is more emotionally expressive than the right hemiface, inferring RH superiority for the generation of emotional facial expressions. It is possible therefore that the observations of asymmetry for emotional processing in this thesis were confounded by asymmetries of facial expression. Future research using facial emotional stimuli to investigate brain lateralization for emotional processing is advised to include mirror-imaged orientations of each facial expression, so that asymmetries of facial expressions can be balanced out. Using faces both in their normal and mirror-imaged orientations would result in more reliable interpretations of brain laterality for emotional processing.
9.4.5 MRT and chimeric faces task exclusion criteria

For both the chimeric faces task and the MRT, participant recognition accuracy percentiles were screened to examine whether there were any participants with extremely low accuracy to indicate problems with understanding and performing the task. Participants with recognition accuracies lower than the set criterion, were removed from analysis. The recognition accuracy exclusion criterion set for each task was based on the number of available button choices. For the chimeric faces task, in which there were four button choices, the exclusion criterion was set at less than 25%. For the MRT, in which there was two button choices, the exclusion criterion was set at less than 50%. Future research is advised to set an exclusion criterion at a level which is significantly better than chance, as there it is possible that participants may not respond randomly across each category.

9.4.6 Visual angle of chimeric faces stimuli

While it is generally accepted that images shown in the LVF project to the RH, and images shown in the RVF project to the LH, there is debate about how stimuli presented against the central strip of the visual fields (the fovea region) is projected to the hemispheres (Lavidor, 2003; Lindell & Nicholls, 2003). The bilateral projection theory proposes that the representation of foveal stimuli is projected to both hemispheres (Lavidor & Walsh, 2004), with 0.5° (Wyatt, 1978) to 3° (Bunt & Minckler, 1977) of the fovea believed to project bilaterally. Conversely, the split fovea theory suggests that the foveal representation could be split between the two hemispheres (Lavidor & Walsh, 2004). To prevent the possible bilateral presentation of stimuli presented in the foveal region, researchers investigating brain laterality often present stimuli beyond the boundary of bilateral foveal projection, at least 2° to the left or right of central fixation (Lavidor & Walsh, 2004; Lindell & Nicholls, 2003).

The chimeric face stimuli of the chimeric faces task used in this thesis were presented centrally, thus presenting the stimuli both within the central foveal strip to possible bilateral presentation, and > 2° left and right of central fixation for lateral presentation (6.43° left and right of central fixation). The presentation of
some of the chimeric face stimuli within the bilateral presentation region is a limitation of the chimeric faces task in this thesis.

It could be argued, however, that the chimeric face stimuli used in the chimeric faces task were essentially being presented unilaterally. The vast majority of each hemiface was shown outside the possible bilateral presentation region. Further, it might be argued that the outer regions of the facial expression are more revealing and useful for recognising the emotional expression (upward or downward turning mouth) than the information shown in the narrow central strip of the face. This being said, future research would still benefit from not presenting any stimulus information in the central strip of central fixation. The results from such research would be more reliable as there would be more confidence that the stimuli were presented only to the lateral fields.

9.5 Future research

The findings from the two experiments of this dissertation have highlighted a number of areas that could be addressed by future research.

9.5.1 Replication

Given that the results of Experiment Two did not clearly determine the effect of clinical depression on brain lateralization, in particular for each sex, future research is directed towards re-examining this topic with improved methodology. One such change could be to administer differing neuropsychological tasks to measure brain lateralized function. This is not to say that the tasks administered in this dissertation are considered problematic, but different tasks may provide additional information that may provide more clarity in this area. It would be advantageous for future research to determine whether the deficit in brain lateralized function associated with depression is the same across differing depression subtypes, and how differing diagnoses of depression affect the brain lateralization of each sex.
9.5.2 Brain lateralization in recovered depressed patients

Whether the disruption to RH lateralized functions with depression is a state or trait characteristic has been a research topic of the past. There is some argument that the RH dysfunction associated with depression is evident during the depressed state only (Brumback, 1985; Kronfol, et al., 1978; Moscovitch, Strauss, & Olds, 1981; Wexler & Heninger, 1979). In contrast, others have argued that the RH dysfunction with depression is a pre-existing condition that does not improve with recovery (Allen, Iacono, Depue, & Arbisi, 1993; Henriques & Davidson, 1990; 1991; Silberman, et al., 1983). This topic has not been clearly answered from past research indicating that there is a need for further investigation. Future research is directed towards improving patient selection when comparing the performance of patients during their depressed state and again during their recovered state. Patients may be interpreted as “recovered” when the visible symptoms of depression have been treated with medication, however the patients may still be therapy reliant (de Groot, Nolen, Huijsman, & Bouvy, 1996). Examination of brain lateralized functioning with the recovered state was attempted for a follow-up experiment in this dissertation, in which brain lateralized functioning of “recovered” depressed males and females was to be examined. Recruiting patients who were recovered from their depression was extremely difficult, due to the patients relapsing or not being in a “well enough” condition. Therefore, a follow-up experiment could not be conducted.

9.6 Conclusions

The evidence from the results of Experiment One, and from prior research, that the RH is more specialized than the LH for emotional processing, regardless of emotional valence. Factors such as stimulus type, method of stimulus presentation, task demand, and dependent variable may affect the degree to which the RH advantage for emotional processing is observed. In any case, the RH advantage for emotional processing is a consistent finding.

Sex differences in brain lateralization for spatial and verbal functioning can be observed through sex differences in performance on spatial and verbal cognitive tasks. The replication of a male advantage for
spatial functioning, and thus the advantage of unilateral representation of spatial abilities than bilateral representation, may be hampered by factors that have a mediating effect of hemispheric performance, such as level of spatial ability. Unlike spatial and verbal functioning, there is no consistent evidence in the literature, or from the results of Experiment One, to suggest that there is a strong sex difference in brain lateralization for emotional processing.

Determining the effect of clinical depression on brain lateralization is difficult given that the symptoms of depression (fatigue and lack of concentration) can result in a generalised performance deficit and subsequent significant group differences on both RH and LH tasks. A generalised performance deficit that results in significant group differences on both RH and LH tasks camouflages any effect of hemispheric dysfunction in cognitive performance that results from clinical depression. A generalised performance deficit also makes it difficult to determine the effect that clinical depression has on brain lateralization of each sex separately. A greater effect on the brain lateralized performance of one sex over the other with clinical depression would have resulted in diverging sex difference results between the depressed and control groups in task performance, yet this was not observed. Conversely, similar brain lateralization between the depressed males and females would have resulted in no significant sex differences in the performance on the semantic verbal fluency task, and in RTs to the chimeric faces. Therefore, the sex difference results of Experiment Two are more likely showing that a generalised performance deficit with depression was experienced equally across sex.

Clinical depression was associated with delayed responses, arising from impairment at the encoding stage of information processing, or from impairment in pre-motor organization and motor planning. Following the delay however, performance from the clinically depressed group appears to be relatively unimpaired.

Future research observing a RH impairment with clinical depression is encouraged to further examine the effect of clinical depression on brain lateralization for each sex separately. Future research is encouraged to recruit patients with the same diagnosis of depression, and to screen for the level of anxiety experienced by each patient.
REFERENCE LIST


App. 1. Pearson’s R Correlation Checks for Speed-Accuracy Trade-Offs (MRT and Chimeric faces task)

A.1.1. Experiment One

MRT

Pearson’s r correlations from untruncated data

<table>
<thead>
<tr>
<th>Angle</th>
<th>Males</th>
<th>Females</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>( r(30) = -0.42, p&lt;0.05 )</td>
<td>( r(30) = -0.28, p=0.13 )</td>
<td>( r(60) = -0.36, p&lt;0.01 )</td>
</tr>
<tr>
<td>30°</td>
<td>( r(30) = -0.15, p=0.82 )</td>
<td>( r(30) = -0.08, p=0.68 )</td>
<td>( r(60) = -0.09, p=0.48 )</td>
</tr>
<tr>
<td>60°</td>
<td>( r(29) = -0.03, p=0.87 )</td>
<td>( r(30)= -0.08, p=0.68 )</td>
<td>( r(59) = -0.05, p=0.70 )</td>
</tr>
<tr>
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<td>( r(30) = -0.07, p=0.72 )</td>
<td>( r(30) = -0.08, p=0.66 )</td>
<td>( r(60) = -0.01, p=0.93 )</td>
</tr>
<tr>
<td>120°</td>
<td>( r(30) = -0.36, p=0.05 )</td>
<td>( r(30) = -0.19, p=0.32 )</td>
<td>( r(60) = -0.28, p=0.05 )</td>
</tr>
<tr>
<td>150°</td>
<td>( r(29) = 0.08, p=0.69 )</td>
<td>( r(30) = -0.20, p=0.29 )</td>
<td>( r(59) = -0.04, p=0.77 )</td>
</tr>
<tr>
<td>Overall</td>
<td>( r(178) = -0.21, p&lt;0.01 )</td>
<td>( r(180) = -0.21, p&lt;0.01 )</td>
<td>( r(358) = -0.21, p&lt;0.001 )</td>
</tr>
</tbody>
</table>

Pearson’s r correlations from truncated data

<table>
<thead>
<tr>
<th>Angle</th>
<th>Males</th>
<th>Females</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>( r(30) = -0.46, p&lt;0.05 )</td>
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<td>( r(60) = -0.50, p&lt;0.001 )</td>
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<tr>
<td>30°</td>
<td>( r(30) = -0.12, p=0.82 )</td>
<td>( r(30) = -0.08, p=0.68 )</td>
<td>( r(60) = -0.09, p=0.52 )</td>
</tr>
<tr>
<td>60°</td>
<td>( r(29) = -0.03, p=0.87 )</td>
<td>( r(30)= -0.08, p=0.68 )</td>
<td>( r(59) = -0.05, p=0.70 )</td>
</tr>
<tr>
<td>90°</td>
<td>( r(30) = -0.13, p=0.50 )</td>
<td>( r(30) = 0.06, p=0.75 )</td>
<td>( r(60) = -0.03, p=0.85 )</td>
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<tr>
<td>120°</td>
<td>( r(30) = -0.36, p=0.05 )</td>
<td>( r(30) = -0.25, p=0.19 )</td>
<td>( r(60) = -0.32, p&lt;0.05 )</td>
</tr>
<tr>
<td>150°</td>
<td>( r(29) = 0.05, p=0.87 )</td>
<td>( r(30) = -0.20, p=0.29 )</td>
<td>( r(59) = -0.06, p=0.63 )</td>
</tr>
<tr>
<td>Overall</td>
<td>( r(178) = -0.18, p&lt;0.05 )</td>
<td>( r(180) = -0.26, p&lt;0.001 )</td>
<td>( r(358) = -0.24, p&lt;0.001 )</td>
</tr>
</tbody>
</table>

Chimeric faces task

Pearson’s r correlations from untruncated data

<table>
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<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVHappy</td>
<td>( r(28) = -0.31, p=0.11 )</td>
<td>( r(30) = -0.31, p=0.10 )</td>
<td>( r(58) = -0.28, p&lt;0.05 )</td>
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<tr>
<td>RVSad</td>
<td>( r(27) = 0.18, p=0.38 )</td>
<td>( r(29) = 0.01, p=0.98 )</td>
<td>( r(56) = 0.06, p=0.68 )</td>
</tr>
<tr>
<td>LVHappy</td>
<td>( r(28) = -0.36, p=0.06 )</td>
<td>( r(29) = -0.31, p=0.10 )</td>
<td>( r(57) = -0.35, p=0.01 )</td>
</tr>
<tr>
<td>LVSad</td>
<td>( r(29) = -0.09, p=0.65 )</td>
<td>( r(30) = -0.24, p=0.20 )</td>
<td>( r(59) = -0.15, p=0.27 )</td>
</tr>
<tr>
<td>Overall</td>
<td>( r(112) = -0.16, p=0.08 )</td>
<td>( r(118) = -0.23, p&lt;0.05 )</td>
<td>( r(230) = -0.21, p&lt;0.01 )</td>
</tr>
</tbody>
</table>
### A. 1.1  Experiment One continued

#### Pearson’s r correlations from truncated data

<table>
<thead>
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<th></th>
<th>Males</th>
<th>Females</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVFhappy</td>
<td>$r (28) = -0.31$, $p=0.11$</td>
<td>$r (30) = -0.31$, $p=0.10$</td>
<td>$r (58) = -0.29$, $p&lt;0.05$</td>
</tr>
<tr>
<td>RVFsad</td>
<td>$r (27) = 0.18$, $p=0.38$</td>
<td>$r (29) = 0.03$, $p=0.87$</td>
<td>$r (56) = 0.07$, $p=0.62$</td>
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<tr>
<td>LVFhappy</td>
<td>$r (28) = -0.36$, $p=0.06$</td>
<td>$r (29) = -0.31$, $p=0.10$</td>
<td>$r (57) = -0.35$, $p&lt;0.01$</td>
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<tr>
<td>LVFsad</td>
<td>$r (29) = -0.15$, $p=0.45$</td>
<td>$r (30) = -0.24$, $p=0.20$</td>
<td>$r (59) = -0.16$, $p=0.24$</td>
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<tr>
<td>Overall</td>
<td>$r (112) = -0.17$, $p=0.08$</td>
<td>$r (118) = -0.23$, $p&lt;0.05$</td>
<td>$r (230) = -0.21$, $p&lt;0.01$</td>
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</table>
### A.1.2 Experiment Two

**MRT**

#### Pearson's r correlation from untruncated data

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<th>Angle</th>
<th>Control Group</th>
<th>Control males</th>
<th>Control females</th>
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<tbody>
<tr>
<td>0°</td>
<td>r (36) = -0.26, p=0.13</td>
<td>r (18) = -0.33, p=0.18</td>
<td>r (18) = -0.21, p=0.40</td>
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<td>30°</td>
<td>r (36) = 0.001, p=0.10</td>
<td>r (18) = 0.04, p=0.87</td>
<td>r (18) = 0.01, p=0.98</td>
</tr>
<tr>
<td>60°</td>
<td>r (36) = -0.09, p=0.60</td>
<td>r (18) = -0.12, p=0.63</td>
<td>r (18) = -0.09, p=0.73</td>
</tr>
<tr>
<td>90°</td>
<td>r (36) = -0.20, p=0.24</td>
<td>r (18) = -0.33, p=0.18</td>
<td>r (18) = -0.13, p=0.61</td>
</tr>
<tr>
<td>120°</td>
<td>r (36) = -0.22, p=0.19</td>
<td>r (18) = -0.30, p=0.22</td>
<td>r (18) = -0.16, p=0.52</td>
</tr>
<tr>
<td>150°</td>
<td>r (35) = -0.03, p=0.85</td>
<td>r (18) = 0.16, p=0.54</td>
<td>r (18) = -0.36, p=0.14</td>
</tr>
<tr>
<td>Overall</td>
<td>r (215) = -0.20, p&lt;0.01</td>
<td>r (107) = -0.18, p=0.07</td>
<td>r (108) = -0.23, p&lt;0.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angle</th>
<th>Depressed Group</th>
<th>Depressed males</th>
<th>Depressed females</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>r (34) = -0.29, p=0.09</td>
<td>r (15) = 0.12, p=0.67</td>
<td>r (19) = -0.58, p=0.01</td>
</tr>
<tr>
<td>30°</td>
<td>r (34) = -0.44, p&lt;0.01</td>
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<td>r (19) = -0.50, p&lt;0.05</td>
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<tr>
<td>60°</td>
<td>r (34) = -0.37, p&lt;0.05</td>
<td>r (15) = -0.68, p&lt;0.01</td>
<td>r (19) = -0.23, p=0.33</td>
</tr>
<tr>
<td>90°</td>
<td>r (34) = -0.12, p=0.49</td>
<td>r (15) = -0.09, p=0.75</td>
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<tr>
<td>120°</td>
<td>r (34) = -0.13, p=0.48</td>
<td>r (15) = -0.30, p=0.27</td>
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<tr>
<td>150°</td>
<td>r (34) = -0.21, p=0.25</td>
<td>r (15) = -0.06, p=0.05</td>
<td>r (19) = 0.37, p=0.12</td>
</tr>
<tr>
<td>Overall</td>
<td>r (204) = -0.29, p&lt;0.001</td>
<td>r (90) = -0.37, p&lt;0.001</td>
<td>r (114) = -0.24, p&lt;0.05</td>
</tr>
</tbody>
</table>

#### Pearson's r correlation from truncated data

<table>
<thead>
<tr>
<th>Angle</th>
<th>Control Group</th>
<th>Control males</th>
<th>Control females</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>r (36) = -0.41, p&lt;0.05</td>
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<td>r (18) = 0.54, p&lt;0.05</td>
</tr>
<tr>
<td>30°</td>
<td>r (36) = 0.07, p=0.67</td>
<td>r (18) = 0.04, p=0.87</td>
<td>r (18) = 0.01, p=0.70</td>
</tr>
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<td>60°</td>
<td>r (36) = -0.09, p=0.61</td>
<td>r (18) = -0.12, p=0.65</td>
<td>r (18) = -0.09, p=0.73</td>
</tr>
<tr>
<td>90°</td>
<td>r (36) = -0.30, p=0.08</td>
<td>r (18) = -0.33, p=0.19</td>
<td>r (18) = -0.34, p=0.17</td>
</tr>
<tr>
<td>120°</td>
<td>r (36) = -0.22, p=0.19</td>
<td>r (18) = -0.30, p=0.22</td>
<td>r (18) = -0.16, p=0.52</td>
</tr>
<tr>
<td>150°</td>
<td>r (35) = -0.08, p=0.67</td>
<td>r (18) = 0.09, p=0.73</td>
<td>r (18) = 0.40, p=0.11</td>
</tr>
<tr>
<td>Overall</td>
<td>r (215) = -0.23, p=0.001</td>
<td>r (107) = -0.21, p&lt;0.05</td>
<td>r (108) = -0.29, p=0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Angle</th>
<th>Depressed Group</th>
<th>Depressed males</th>
<th>Depressed females</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>r (34) = -0.19, p=0.30</td>
<td>r (15) = -0.04, p=0.90</td>
<td>r (19) = -0.33, p=0.17</td>
</tr>
<tr>
<td>30°</td>
<td>r (34) = -0.44, p&lt;0.01</td>
<td>r (15) = -0.31, p=0.26</td>
<td>r (19) = -0.50, p&lt;0.05</td>
</tr>
<tr>
<td>60°</td>
<td>r (34) = -0.39, p&lt;0.05</td>
<td>r (15) = -0.68, p&lt;0.01</td>
<td>r (19) = -0.25, p=0.29</td>
</tr>
<tr>
<td>90°</td>
<td>r (34) = -0.12, p=0.49</td>
<td>r (15) = -0.09, p=0.75</td>
<td>r (19) = -0.15, p=0.54</td>
</tr>
<tr>
<td>120°</td>
<td>r (34) = -0.13, p=0.48</td>
<td>r (15) = -0.30, p=0.27</td>
<td>r (19) = -0.02, p=0.92</td>
</tr>
<tr>
<td>150°</td>
<td>r (34) = -0.21, p=0.25</td>
<td>r (15) = -0.06, p=0.05</td>
<td>r (19) = 0.37, p=0.12</td>
</tr>
<tr>
<td>Overall</td>
<td>r (204) = -0.30, p&lt;0.001</td>
<td>r (90) = -0.44, p&lt;0.001</td>
<td>r (114) = -0.20, p&lt;0.05</td>
</tr>
</tbody>
</table>
A. 1.2 Experiment Two continued

Chimeric faces task

Pearson’s r correlations from untruncated data

<table>
<thead>
<tr>
<th></th>
<th>Control group</th>
<th>Control males</th>
<th>Control females</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVFhappy</td>
<td>$\tau (35) = -0.36, p&lt;0.05$</td>
<td>$\tau (17) = -0.37, p=0.14$</td>
<td>$\tau (18) = -0.42, p=0.08$</td>
</tr>
<tr>
<td>RVFsad</td>
<td>$\tau (34) = 0.06, p=0.74$</td>
<td>$\tau (17) = 0.20, p=0.43$</td>
<td>$\tau (17) = -0.05, p=0.86$</td>
</tr>
<tr>
<td>LVFhappy</td>
<td>$\tau (34) = -0.44, p=0.01$</td>
<td>$\tau (17) = -0.51, p&lt;0.05$</td>
<td>$\tau (17) = -0.40, p=0.12$</td>
</tr>
<tr>
<td>LVFsad</td>
<td>$\tau (36) = -0.09, p=0.62$</td>
<td>$\tau (18) = 0.13, p=0.60$</td>
<td>$\tau (18) = -0.30, p=0.23$</td>
</tr>
<tr>
<td>Overall</td>
<td>$\tau (139) = -0.26, p&lt;0.01$</td>
<td>$\tau (72) = -0.21, p=0.08$</td>
<td>$\tau (70) = -0.30, p=0.05$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Depressed group</th>
<th>Depressed males</th>
<th>Depressed females</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVFhappy</td>
<td>$\tau (32) = -0.66, p&lt;0.001$</td>
<td>$\tau (13) = -0.79, p=0.001$</td>
<td>$\tau (19) = -0.54, p&lt;0.05$</td>
</tr>
<tr>
<td>RVFsad</td>
<td>$\tau (31) = -0.09, p=0.62$</td>
<td>$\tau (13) = -0.34, p=0.25$</td>
<td>$\tau (18) = -0.11, p=0.67$</td>
</tr>
<tr>
<td>LVFhappy</td>
<td>$\tau (33) = -0.45, p=0.01$</td>
<td>$\tau (14) = -0.76, p&lt;0.01$</td>
<td>$\tau (19) = -0.19, p=0.43$</td>
</tr>
<tr>
<td>LVFsad</td>
<td>$\tau (33) = -0.01, p=0.98$</td>
<td>$\tau (14) = 0.04, p=0.89$</td>
<td>$\tau (19) = -0.01, p=0.99$</td>
</tr>
<tr>
<td>Overall</td>
<td>$\tau (129) = -0.32, p&lt;0.001$</td>
<td>$\tau (54) = -0.51, p&lt;0.001$</td>
<td>$\tau (75) = -0.16, p=0.17$</td>
</tr>
</tbody>
</table>

Pearson’s r correlations from truncated data

<table>
<thead>
<tr>
<th></th>
<th>Control group</th>
<th>Control males</th>
<th>Control females</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVFhappy</td>
<td>$\tau (35) = -0.41, p&lt;0.05$</td>
<td>$\tau (17) = -0.43, p=0.08$</td>
<td>$\tau (18) = -0.42, p=0.08$</td>
</tr>
<tr>
<td>RVFsad</td>
<td>$\tau (34) = 0.06, p=0.74$</td>
<td>$\tau (17) = 0.20, p=0.43$</td>
<td>$\tau (17) = -0.05, p=0.86$</td>
</tr>
<tr>
<td>LVFhappy</td>
<td>$\tau (34) = -0.39, p&lt;0.05$</td>
<td>$\tau (17) = -0.46, p=0.06$</td>
<td>$\tau (17) = -0.40, p=0.12$</td>
</tr>
<tr>
<td>LVFsad</td>
<td>$\tau (36) = -0.06, p=0.75$</td>
<td>$\tau (18) = 0.23, p=0.36$</td>
<td>$\tau (18) = -0.25, p=0.31$</td>
</tr>
<tr>
<td>Overall</td>
<td>$\tau (139) = -0.25, p&lt;0.01$</td>
<td>$\tau (72) = -0.21, p=0.09$</td>
<td>$\tau (70) = -0.30, p=0.05$</td>
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<td>RVFsad</td>
<td>$\tau (31) = -0.09, p=0.62$</td>
<td>$\tau (13) = -0.34, p=0.25$</td>
<td>$\tau (18) = -0.11, p=0.67$</td>
</tr>
<tr>
<td>LVFhappy</td>
<td>$\tau (33) = -0.45, p=0.01$</td>
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<td>$\tau (19) = -0.19, p=0.43$</td>
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<tr>
<td>LVFsad</td>
<td>$\tau (33) = -0.01, p=0.98$</td>
<td>$\tau (14) = 0.04, p=0.89$</td>
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<tr>
<td>Overall</td>
<td>$\tau (129) = -0.32, p&lt;0.001$</td>
<td>$\tau (54) = -0.51, p&lt;0.001$</td>
<td>$\tau (75) = -0.16, p=0.17$</td>
</tr>
</tbody>
</table>
APPENDIX 2. STATISTICAL ASSUMPTIONS CHECK

A.2.1 Experiment One

**Demographic analyses between the sexes**

**Applied statistics:**
- One-way ANOVAs comparing each demographic between the males and females

**Normality**
The normality assumption of ANOVA was examined for each demographic of each sex, to which the demographics were found to be normal or close to normal according to skewness and kurtosis statistics.

**Homogeneity of variance**
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. Levene’s test for equality of variance examined any significant differences in variance between the sexes for each demographic. For each one-way ANOVA comparing a demographic variable between the sexes, Levene’s statistic was non-significant at $p<0.05$. Therefore, homogeneity of variance for each demographic analysis had not been violated. There was the exception however, of the variance between the sexes for the MADRS scores ($p<0.01$) and handedness ($p=0.001$). Although this is indicative of an assumption violation, the ratios of largest cell variance to smallest cell variance ($F_{\text{max}}$) for the MADRS scores and the handedness scores of each sex did not exceed three. With sample sizes that were equal between the males and females, such $F_{\text{max}}$ values indicate that the homogeneity of variance assumption of ANOVA had not been violated (Tabachnick & Fidell, 2001).
A. 2.1 Experiment One continued

MRT
Applied statistics:
- RT and accuracy rate analyses (separate): 6 (angle of rotation) x 2 (sex) mixed-design ANOVA
- Post-hoc paired t-tests: to further assess the significant main effect of angle from the mixed-design RT and accuracy rate ANOVAs

Normality
Prior to calculating the ANOVAs on the RT and accuracy rate data, normality was examined using skewness and kurtosis. For each sex, the distributions of RT and accuracy rates to each individual angle of rotation were normal or close to normal after screening the data as outlined in section 8.2.3.

Prior to calculating the post-hoc paired t-tests, which were used to further examine the significant main effect of angle from the RT and accuracy rate data, the distributions of RT and accuracy rates to each individual angle (regardless of sex) were examined. The normality for each angle of rotation was initially examined for each sex separately prior to the ANOVA analyses, however when combined regardless of sex, some outlying RTs and accuracy rates were observed (values that fell three SDs from the group mean). For the post-hoc paired t-tests, the outliers were truncated to the next most extreme value that fell within three SDs of the group mean. Truncating the outliers had minimal affect on the group mean and rendered skewness and kurtosis to be normal or close to normal for each individual angle of rotation.

Sphericity
For the mixed-design ANOVAs calculated on the RT and accuracy rate data, the sphericity assumption of ANOVA was examined using Mauchly’s test of sphericity. For both the RT and accuracy rate ANOVAs, Mauchly’s test of sphericity indicated a violation of the sphericity assumption of ANOVA. Therefore for both the RT and accuracy rate ANOVAs, the Huynh-Feldt statistic was reported with adjusted degrees of freedom.

Homogeneity of variance
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. Levene’s test for equality of variance examined any significant differences in variance between the sexes for RTs and accuracy rates to each angle of rotation. Prior to the statistical analyses, $F_{\text{max}}$ (the ratio of largest cell variance to smallest cell variance) was also calculated between each angle of rotation for each sex separately.

For the MRT mixed-design ANOVA calculated on the participants’ mean RTs, Levene’s statistic indicated no significant difference ($p>0.05$) in variance between the sexes for any angle of rotation. Also for the RT data, $F_{\text{max}}$ comparing the variance between each angle of rotation for each sex separately, did not exceed ten for either sex. With the cell sizes being equal for the females and almost equal for the males (one missing case for 150°), $F_{\text{max}}$ values less than ten are acceptable and indicate that the assumption of homogeneity of variance was not violated (Tabachnick & Fidell, 2001).

For the MRT mixed-design ANOVA calculated on the participants’ accuracy rates, Levene’s statistic indicated a significant difference ($p<0.05$) in variance between the sexes for the angles 0°, 30°, and 150°. Although this is indicative of an assumption violation, $F_{\text{max}}$ between the sexes for these angles was less than ten, indicating that there was no violation in the homogeneity of variance assumption. Also for the accuracy rate data, $F_{\text{max}}$ comparing the variance between each angle of rotation for each sex separately, showed that $F_{\text{max}}$ exceeded ten for the males between the angles 90° and 150°, and for the females between the angles 0° and 120°, and 0° and 150°. Transformation of the data did not improve these variances for the males and females. Therefore analyses were conducted on the original accuracy rate data. An $F_{\text{max}}$ value greater than ten suggests that the MRT mixed-design ANOVA analysis on the accuracy rates should be tested at a conservative $p$ value. The significant main effect for angle from this analysis was significant at $p<0.001$ suggesting that the effect was real.
A. 2.1 Experiment One continued

MRT Homogeneity of variance continued

For the post-hoc paired t-tests examining the significant main effect of angle, $F_{\text{max}}$ was calculated comparing the variance between each angle for both the RT and accuracy rate data. For the RT data, $F_{\text{max}}$ did not exceed ten, indicating that the homogeneity assumption of ANOVA would not be violated. For the accuracy rate data, $F_{\text{max}}$ exceeded ten between the angles $0^\circ$ and $120^\circ$, and $0^\circ$ and $150^\circ$. Transforming the data did not improve these variances or reduce $F_{\text{max}}$, therefore the post-hoc analyses were conducted on the original accuracy rate data. An $F_{\text{max}}$ value greater than ten suggests that the post-hoc paired t-tests on the accuracy rates should be tested at a conservative $p$ value. Each of the significant findings were significant at $p<0.01$ suggesting that the effects were real.

Homogeneity of Intercorrelations

The homogeneity of intercorrelations assumption of mixed-design ANOVA was examined using the Box’s $M$ statistic. Tabachnick and Fidell (2001) report that Box’s $M$ statistic is too sensitive for use at routine alpha levels, and should be rejected at highly significant levels. Therefore, for the mixed-design ANOVAs in this dissertation, Box’s $M$ was considered significant if $p<0.001$.

For the MRT mixed-design ANOVA calculated on the participants’ RTs, Box’s $M$ was not significant at $p>0.001$. Therefore there was no violation of the homogeneity of intercorrelations assumption for this analysis. For the MRT mixed-design ANOVA calculated on the participants’ accuracy rates, Box’s $M$ was significant at $p<0.001$. Transformation ($\log_{10}$, SQRT) of the accuracy rate data did not render Box’s $M$ to be non-significant. Therefore, with the violation of the homogeneity of intercorrelations assumption, the mixed-design ANOVA for the accuracy rate data had to be tested at a conservative $p$ value. The significant main effect of angle from the mixed-design ANOVA on the accuracy rates was significant at $p<0.001$ suggesting that the effect was real.

Applied statistics:
- MRT Slope and Intercept (separate): One-way between groups ANOVAs

Normality

The normality assumption of ANOVA was examined using skewness and kurtosis statistics and was assessed prior to the statistical analyses. For each sex, distribution statistics indicated that there was an outlier greater than three SDs from the group mean for both the slope and the intercept. Despite the presence of the outliers, the distributions of the intercept of both the males and females was close to normal, and the distribution of the slope of the females was also close to normal. The kurtosis value for the control males on the slope however, was indicative of a violation in normality. The outlier values for the slopes and intercepts of both sexes were not truncated for reasons explained in section 8.2.3. As the outliers were not truncated, the validity of the one-way ANOVAs comparing the MRT slopes and intercepts between the sexes was confirmed with the Mann-Whitney non-parametric test.

Homogeneity of variance

The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. Levene’s test for equality of variances examined any significant differences in variance between the sexes on the MRT slope and the MRT intercept. For both the one-way ANOVAs comparing the MRT slope and intercept between the sexes, Levene’s statistic was not significant at $p>0.05$. Therefore, homogeneity of variance for the slope and intercept had not been violated for these analyses.
A. 2.1  Experiment One continued

The verbal fluency task

Applied statistics:

- Phonemic and semantic verbal fluency (separate): One-way between groups ANOVAs

Normality
The normality assumption of ANOVA was examined using skewness and kurtosis statistics and was examined prior to statistical analyses. Normality was found to be normal or close to normal for the phonemic and semantic fluency distributions of each sex.

Homogeneity of variance
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. Levene’s test for equality of variances examined any significant differences in variance between the sexes for phonemic and semantic verbal fluency. For both the one-way ANOVAs comparing phonemic and semantic verbal fluency between the sexes, Levene’s statistic was significant (p<0.05). Although this is indicative of an assumption violation, F_{max} between the phonemic fluency scores (variance) of each sex, and between the semantic fluency scores (variance) of each sex did not exceed three. With sample sizes that were equal between the males and females, such F_{max} values indicate that the homogeneity of variance assumption of ANOVA had not been violated (Tabachnick & Fidell, 2001).
A. 2.1 Experiment One continued

Chimeric faces task

Applied statistics:
- Chimeric faces task RT and accuracy rate analyses (separate): 2 (visual field) x 2 (emotion) x 2 (sex) mixed-design ANOVA
- Post-hoc paired and independent t-tests: to further assess the significant visual field by sex interaction from the mixed-design RT ANOVA
- Post-hoc paired t-tests: to further assess the visual field by emotion interaction of each sex from the RT and accuracy rate mixed-design ANOVAs

Normality
Prior to calculating the ANOVAs on the chimeric faces task RT and accuracy rate data, normality was examined using skewness and kurtosis statistics. For each sex, the distributions of RT and accuracy rates to each visual field / emotion condition of the chimeric faces were normal or close to normal after screening the data as outlined in section 8.2.3.

Prior to calculating the post-hoc paired and independent t-tests used to further examine the significant visual field by sex interaction of the RT analyses, the distributions of RTs to each visual field (regardless of emotion) by each sex were examined. The normality for each visual field / emotion chimeric face condition was initially examined for each sex separately for the ANOVA analyses, however when responses to each visual field were collapsed over emotion, an outlier RT was observed for the females to LVF presentations (RT value that fell three SDs from the female LVF group mean). Therefore for the post-hoc t-tests examining the visual field by sex interaction, the outlier was truncated to the next most extreme value that fell within three SDs of the group mean. Truncating the outlier had minimal affect on the group mean and rendered skewness and kurtosis statistics to be normal or close to normal.

Prior to calculating the post-hoc paired t-tests used to further examine the visual field by emotion interactions for each sex, the distributions of RT to each visual field / emotion condition of each sex was examined. Whilst the distributions of RTs to each visual field / emotion condition of each sex were examined prior to the ANOVA analyses, they were re-examined for the RT post-hoc t-tests as the ANOVA removed participants with missing values from the sample, thus altering the data set. Despite the smaller sample sizes for each sex, the distributions of RT to each visual field / emotion condition for each sex was normal or close to normal, and there were no outliers that fell outside three SDs from the group mean. The distributions of accuracy rates to each visual field / emotion condition of each sex did not have to be re-examined for the post-hoc paired t-tests as they were the same as those examined for the ANOVA on accuracy rates.

Sphericity
For the mixed-design ANOVAs calculated on the RT and accuracy rate responses to the chimeric faces, there was no more than one degree of freedom as there were only two dependent variables. Therefore a test of sphericity was not required (Tabachnick & Fidell, 2001) and was not provided.

Homogeneity of variance
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. Levene’s test for equality of variance examined any significant differences in variance between the sexes in RT and accuracy rates to each visual field / emotion condition of the chimeric faces task. Prior to the statistical analyses, $F_{\text{max}}$ (the ratio of largest cell variance to smallest cell variance) was also calculated between each visual field / emotion chimeric faces condition for each sex separately.
A. 2.1 Experiment One continued

Chimeric faces task – Homogeneity of variance continued

For the mixed-design ANOVAs calculated on the participants’ RTs and accuracy rates, Levene’s statistic indicated no significant difference (p>0.05) in variance between the sexes for each visual field / emotion condition. There was the exception of the variance between the sexes in RTs to LVF sad faces however. Although this is indicative of an assumption violation, F_{max} for the RTs to LVF sad faces of each sex did not exceed three. With sample sizes that did not exceed a ratio of four to one, such an F_{max} value indicates that the homogeneity of variance assumption of ANOVA had not been violated (Tabachnick & Fidell, 2001). For both the RT and accuracy rate data, F_{max} comparing the variance between each visual field / emotion chimeric face condition for each sex separately, did not exceed ten for either sex. With the cell sizes being almost equal for both the males and females, F_{max} values less than ten are acceptable and indicate that the assumption of homogeneity of variance was not violated (Tabachnick & Fidell, 2001).

For the post-hoc independent t-tests examining the significant visual field by sex interaction from the mixed-design ANOVA on RTs, Levene’s statistic was not significant (p>0.05) between the sexes for RTs to RVF expressions, and for RTs to LVF expressions. Therefore, the homogeneity of variance assumption for independent t-tests was not violated. For the post-hoc paired t-tests examining the significant visual field by sex interaction, F_{max} was calculated between the RTs to LVF and RVF presentations for each sex separately. For each sex, the F_{max} values between visual field presentations were less than three, indicating that homogeneity of variance had not been violated.

For the post-hoc paired t-tests examining the visual field by emotion interaction for each sex separately, F_{max} was calculated comparing the variance between each visual field / emotion condition for the RTs of each sex. Whilst the F_{max} between each visual field / emotion chimeric face condition for each sex were calculated prior to the ANOVA on RTs, they were re-calculated for the RT post-hoc paired t-tests as the ANOVA removed participants with missing values from the sample, thus altering the data set. For each sex, the F_{max} between each visual field / emotion chimeric face condition did not exceed ten, indicating no violation in homogeneity of variances. F_{max} did not have to be calculated between the accuracy rates to each visual field / emotion chimeric face condition for each sex, as they were the same as those calculated for the ANOVA on accuracy rates.

Homogeneity of intercorrelations

The homogeneity of intercorrelations assumption of mixed-design ANOVA was examined using the Box’s M statistic. For both the mixed-design ANOVAs calculated on the participants’ RT and accuracy rate data, Box’s M statistic was not significant at p<0.001, therefore there was no violation of the homogeneity of intercorrelations assumption (Tabachnick & Fidell, 2001).
A. 2.1 Experiment One continued

Factorial ANOVAs for years of education, handedness and Vocabulary covariates

**Applied statistics:**
- Phonemic verbal fluency: 2 (sex) x 3 (years of education / Vocabulary t-score category) between groups ANOVA
- Semantic verbal fluency: 2 (sex) x 3 (Vocabulary t-score category) between groups ANOVA
- Chimeric faces task RT analysis: 2 (visual field) x 2 (emotion) x 2 (sex) x 3 (Vocabulary t-score category) mixed-design ANOVA
- Chimeric faces task accuracy rate analyses: 2 (sex) x 3 (years of education / handedness category) mixed-design ANOVA
- Post-hoc paired and independent t-tests: to further assess the significant visual field by sex interaction from the chimeric faces task 2(visual field) x 2 (emotion) mixed-design ANOVA conducted on the RTs of participants from the second category of Vocabulary t-scores

**Normality**
The normality assumption of ANOVA was examined using skewness and kurtosis statistics and was examined prior to statistical analysis. For each sex, the distributions of phonemic and semantic fluency scores and chimeric faces task RTs and accuracy rates to each visual field / emotion condition were normal or close to normal for the relevant categories of years of education, handedness, and Vocabulary. There was the exception of seven cases where kurtosis was slightly higher, ranging between four and seven (three cases for categorised years of education for the chimeric faces accuracy rate data (three males); four cases for categorised Vocabulary t-scores for the chimeric faces RT data (three males, one female)). Each of the distributions for each sex however, showed that there were no outliers that fell three SDs from the group mean. Transforming (log10, SQRT) the chimeric faces task accuracy rate data did not improve the kurtosis values but in fact made them worse. Similarly, transforming the chimeric faces task RT data did not improve the kurtosis values for the four cases mentioned. Therefore the factorial ANOVAs were conducted on the original non-transformed data and had to be examined at conservative p values. It should also be noted that where categories contained three cases, a kurtosis value could not be obtained and therefore could not be examined.

Prior to calculating the post-hoc paired and independent t-tests used to further examine the significant visual field by sex interaction of the chimeric faces task mixed-design ANOVA calculated on the RTs of participants from the second category of Vocabulary t-scores, the distributions of RTs to each visual field (regardless of emotion) of each sex were examined. For each sex, normality for each visual field / emotion chimeric face condition was initially examined for each Vocabulary category for the ANOVA analyses, however when responses to each visual field were collapsed over emotion, some outlying RTs were observed (values that fell three SDs from the group mean). For the post-hoc t-tests examining the visual field by sex interaction, the outliers were truncated to the next most extreme value that fell within three SDs of the group mean. Truncating the outliers had minimal affect on the group mean and rendered skewness and kurtosis statistics to be normal or close to normal for each visual field of each sex.

**Homogeneity of variance**
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. For the factorial ANOVA comparing semantic verbal fluency between the sexes across Vocabulary t-scores, Levene’s statistic was not significant (p>0.05). For the factorial ANOVAs comparing phonemic verbal fluency between the sexes across categorised years of education, and Vocabulary, Levene’s statistic was significant (p<0.05). Although this is indicative of an assumption violation, Fmax between phonemic fluency scores for each category of years of education, and Vocabulary of each sex was not greater than ten. Therefore, there was no violation in homogeneity of variance (Tabachnick & Fidell, 2001) for phonemic verbal fluency.
A. 2.1 Experiment One continued

Factorial ANOVAs for years of education, handedness and Vocabulary t-scores continued

For the chimeric faces task mixed-design ANOVAs comparing RTs to the chimeric face conditions between sex and categorised Vocabulary, Levene’s statistic was not significant between the sexes for each of the visual field / emotion chimeric face conditions. $F_{\text{max}}$ comparing the variance between each visual field / emotion chimeric face condition for each sex separately for each Vocabulary category did not exceed ten for the females. For the males however, $F_{\text{max}}$ exceeded ten between category three: RVF happy and LVF happy faces; RVF sad and LVF happy faces; and LVF happy and LVF sad faces. Transforming the data did not improve the $F_{\text{max}}$ between these conditions for the males. Therefore analyses were conducted on the original RT data. $F_{\text{max}}$ values greater than ten suggest that the RT analyses on the categorised chimeric faces task analyses should be tested at a conservative p value. The significant visual field by sex interaction found from these analyses was significant at $p<0.05$ suggesting that interpretation of this finding should be treated cautiously.

For the chimeric faces task mixed-design ANOVAs comparing accuracy rates to the chimeric face conditions between sex and categorised years of education, and handedness, Levene’s statistic was not significant between the sexes for each of the visual field / emotion chimeric face conditions. $F_{\text{max}}$ comparing the variance between each visual field / emotion chimeric face condition for each sex separately for each years of education category, and each handedness category did not exceed ten for either sex. Therefore, there was no violation in the homogeneity of variance assumptions for these analyses.

For the post-hoc independent t-tests examining the significant visual field by sex interaction from the chimeric faces task mixed-design ANOVA on RTs of participants from the second category of Vocabulary, Levene’s statistic was not significant ($p>0.05$) between the sexes for RTs to RVF or LVF expressions. Therefore, the homogeneity of variances assumption for independent t-tests was not violated. For the post-hoc paired t-tests examining the significant visual field by sex interaction, $F_{\text{max}}$ was calculated between the RTs to LVF and RVF presentations for each sex of the second category of Vocabulary. For each sex, the $F_{\text{max}}$ value between visual field presentations were less than ten, indicating that homogeneity of variance was not violated.

Homogeneity of Inter correlations
The homogeneity of intercorrelations assumption of mixed-design ANOVA was examined using the Box’s M statistic. For the chimeric faces task mixed-design ANOVAs calculated on the participants’ RTs, Box’s M statistic was not significant ($p>0.001$), for the ANOVA on categorised Vocabulary.

For the chimeric faces task mixed-design ANOVAs calculated on the participants’ accuracy rates, Box’s M statistic was not significant ($p>0.001$), for the ANOVA on categorised years of education or handedness.
A. 2.2  Experiment Two

Demographic analyses between the sexes

Applied statistics:
- One-way ANOVAs comparing each demographic between groups, between sexes within each group, and between the same sex of each group

Normality
The normality assumption of ANOVA was examined for each demographic of each group, and each sex of each group, to which the demographics were found to be normal or close to normal according to skewness and kurtosis statistics. There was the exception of years of education for the depressed group however, in which an outlier of a depressed male was greater than three SDs from the group mean, causing kurtosis to be higher. The outlier was truncated to the next extreme value that fell within three SDs of the group mean. Truncating the years of education outlier for the depressed group had a minimal affect on the group mean, and rendered kurtosis to be close to normal.

Homogeneity of variance
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic.

For the One-way ANOVAs comparing each demographic between the depressed and control groups, Levene’s statistic was not significant, with the exception of the MADRS scores (p<0.001), HAMD scores (p<0.001) and age (p<0.05). Although this is indicative of an assumption violation, the F_max values between the HAMD scores (variances) of each group, and between the age values (variances) of each group did not exceed ten. With sample sizes that were equal between the depressed and control groups, such F_max values indicate that the homogeneity of variance assumption of ANOVA had not been violated (Tabachnick & Fidell, 2001). The F_max between the MADRS scores of each group however, was slightly greater than ten. Therefore, as the homogeneity of variance assumption of ANOVA was violated for MADRS, the Mann-Whitney non-parametric test was used in addition to validate the ANOVA results.

For the One-way ANOVAs comparing each demographic between the sexes of each group, Levene’s statistic was not significant, indicating no violation of homogeneity of variance for these analyses. For the control group however, Levene’s statistic was significant (p<0.01) for handedness. Although this is indicative of an assumption violation, F_max for the handedness scores of each sex did not exceed ten. With equal sample sizes between the control males and females, this F_max value is considered acceptable and not in violation of the assumption (Tabachnick & Fidell, 2001).

For the One-way ANOVAs comparing each demographic between the same sex of each group, Levene’s statistic was not significant, indicating no violation of homogeneity of variance for these analyses. There was the exception of the MADRS scores (p<0.001), HAMD scores (p<0.01), and age (p<0.05) between the males of each group. Whilst this is indicative of an assumption violation, F_max between the HAMD scores (variances) of the males of each group, and between the age values (variances) of the males of each group did not exceed ten indicating no violation of homogeneity of variance for these demographics. The F_max for the MADRS scores (variances) of the males of each group however, was greater than ten. Therefore, as the homogeneity of variance assumption of ANOVA was violated for the comparison of MADRS scores between the males of each group, the Mann-Whitney non-parametric test was used in addition to validate the ANOVA results. Levene’s statistic was also significant for the MADRS scores (p<0.001), and handedness (p<0.05) between the females of each group. Similarly, F_max between the MADRS scores (variances) of the females of each group, and between the handedness scores (variances) of the females of each group did not exceed ten, indicating that there was no violation of homogeneity of variance for these demographics.
A. 2.2 Experiment Two continued

MRT

**Applied statistics:**
- RT and accuracy rate analyses (separate): 6 (angle of rotation) x 2 (group) x 2 (sex) mixed-design ANOVA
- Post-hoc paired t-tests: to further assess the significant main effect of angle from the mixed-design RT and accuracy rate ANOVAs

**Normality**
Prior to calculating the ANOVAs on the MRT RT and accuracy rate data, normality was examined using skewness and kurtosis statistics. For each group, and each sex of each group, the distributions of RT and accuracy rates to each individual angle of rotation were normal or close to normal after screening the data as outlined in section 9.2.3.

Prior to calculating the post-hoc paired t-tests, which were used to further examine the significant main effect of angle from the mixed-design RT and accuracy rate ANOVAs, the distributions of RT and accuracy rates to each individual angle (regardless of group and sex) were examined. The normality for each angle of rotation was initially examined for each group, and each sex of each group separately for the ANOVA analyses, however when collapsed over group and sex some outlying RTs and accuracy rates were observed (values that fell three SDs from the group mean). Truncating the outlier RTs was considered, however given that the ANOVA which produced the significant main effect of angle was conducted on log_{10} transformed data, normality for each individual angle from the log_{10} transformed data was examined. For the log_{10} transformed RTs to each individual angle, normality was close to normal and there were no outliers. Therefore, to examine the main effect of angle from the ANOVA conducted on participants’ RTs, the paired t-tests were conducted on the log_{10} transformed data.

Outliers from the accuracy rate data were truncated to the next most extreme value that fell within three SDs of the group mean. Truncating the accuracy rate outliers had minimal affect on the group mean and rendered skewness and kurtosis to be normal or close to normal for each individual angle of rotation.

**Sphericity**
For the mixed-design ANOVAs calculated on the RT and accuracy rate data, the sphericity assumption of ANOVA was examined using Mauchly’s test of sphericity. For both the RT and accuracy rate ANOVAs, Mauchly’s test of sphericity indicated a violation of the sphericity assumption of ANOVA. Therefore for both the RT and accuracy rate ANOVAs, the Huynh-Feldt statistic was reported with adjusted degrees of freedom.

**Homogeneity of variance**
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. Prior to the statistical analyses, F_{max} was also calculated between each angle of rotation for each group, and each sex of each group separately (the ratio of largest cell variance to smallest cell variance).

For the MRT mixed-design ANOVA calculated on the participants’ RTs, Levene’s statistic indicated no significant differences (p>0.05) in variance between the groups and sexes for any angle of rotation. Also for the RT data, F_{max} comparing the variance between each angle of rotation for each group separately, and each sex of each group separately, did not exceed ten. With the cell sizes being equal for the depressed males, depressed females, and the control females, and being not very discrepant for the control males (one missing case for 150°), F_{max} values less than ten are acceptable and indicate that the assumption of homogeneity of variance was not violated (Tabachnick & Fidell, 2001).
A. 2.2  Experiment Two continued

**MRT – Homogeneity of variance continued**

For the MRT mixed-design ANOVA calculated on the participants’ accuracy rates, Levene’s statistic indicated a significant difference (p<0.05) in variance between the groups and sexes for the angles $60^\circ$ and $90^\circ$. Although this is indicative of an assumption violation, $F_{\text{max}}$, between the accuracy rates (variance) to the angle $60^\circ$ of each group, each sex of each group, and the same sex of each group, and between the accuracy rates (variance) to the angle $90^\circ$ of each group, each sex of each group, and the same sex of each group did not exceed ten, indicating that there was no violation in the homogeneity of variance assumption. Also for the accuracy rate data, $F_{\text{max}}$ comparing the variance between each angle of rotation for each group separately, and each sex of each group separately, did not exceed ten for the depressed group or for the depressed males or females, indicating that there was no violation in the homogeneity of variance assumption (Tabachnick & Fidell, 2001). For the control group $F_{\text{max}}$ did not exceed ten between any of the angles. For the control males however, $F_{\text{max}}$ did exceed ten between the angles: $30^\circ$ and $150^\circ$, and $90^\circ$ and $150^\circ$. For the control females, $F_{\text{max}}$ exceeded ten between the angles: $0^\circ$ and $120^\circ$, $90^\circ$ and $120^\circ$, and $90^\circ$ and $150^\circ$. Transformation of the data did not improve these variances for the control males and females, and in fact increased $F_{\text{max}}$. Therefore analyses were conducted on the original accuracy rate data. The larger $F_{\text{max}}$ values for the control males and females suggest that the MRT mixed-design ANOVA analysis on the accuracy rate data should be tested at a conservative p value. The significant main effect of angle for this analysis was significant at $p<0.001$ suggesting that the effect was real.

Prior to calculating the post-hoc paired t-tests examining the significant main effect of angle, $F_{\text{max}}$ was calculated comparing the variance between each angle for both the RT and accuracy rate data. For the RT (log$_{10}$ transformed) data and the accuracy rate data, $F_{\text{max}}$ did not exceed ten, indicating that the homogeneity assumption of ANOVA would not be violated.

**Homogeneity of Intercorrelations**

The homogeneity of intercorrelations assumption of mixed-design ANOVA was examined using the Box’s M statistic. For the MRT mixed-design ANOVA calculated on the participants’ RTs, Box’s M was significant at $p<0.001$, indicating a violation of the homogeneity of intercorrelations assumption. The mean RT data of the MRT was log$_{10}$ transformed and the mixed-design ANOVA re-calculated. Transforming the RT data rendered Box’s M statistic non-significant, thus no longer violating the homogeneity of intercorrelations assumption of mixed-design ANOVA.

For the MRT mixed-design ANOVA calculated on the participants’ accuracy rates, Box’s M was not significant ($p>0.001$), therefore there was no violation of the homogeneity of intercorrelations assumption for this analysis.
A. 2.2 Experiment Two continued

**MRT – slope and intercept analyses**

**Applied statistics:**
- MRT Slope and Intercept (separate): 2 (group) x 2 (sex) between group ANOVAs

**Normality**
The normality assumption of ANOVA was examined using skewness and kurtosis statistics and was assessed prior to the statistical analyses. For each group, and each sex of each group, the distribution of the MRT slope and intercept was found to be normal or close to normal. It was noted however, that the kurtosis value of the MRT slope for the control males was slightly higher, due to an outlier that was greater than three SDs from the group mean. The outlier value was not truncated as explained in section 9.2.3.

**Homogeneity of variance**
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. For the between groups ANOVA comparing the MRT slope between the groups and sexes, Levene’s statistic was not significant. Therefore, there was no violation in the homogeneity of variance assumption of ANOVA.

For the between groups ANOVA comparing the MRT intercept between the groups and sexes, Levene’s statistic was significant (p=0.001). Although this is indicative of an assumption violation, F_{max} comparing the variance of the intercept values between the groups, between the sexes of each group, and between the same sex of each group, did not exceed ten. With sample sizes that were not very discrepant, and not larger than a ratio of four to one, F_{max} values less than ten are acceptable and indicate that there was no violation in the assumption of homogeneity of variance (Tabachnick & Fidell, 2001).
A. 2.2 Experiment Two continued

The verbal fluency task

**Applied statistics:**
- Phonemic and semantic verbal fluency (separate): 2 (group) x 2 (sex) between groups ANOVAs
- Post-hoc independent t-tests: to further assess the group by sex interaction for phonemic fluency

**Normality**
The normality assumption of ANOVA and t-tests was examined using skewness and kurtosis statistics and was examined prior to the statistical analyses. Normality was found to be normal or close to normal for the phonemic and semantic fluency distributions of each group, and each sex of each group after screening the data as outlined in section 9.2.3.

**Homogeneity of variance**
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic.

For the between groups ANOVA comparing phonemic verbal fluency between the groups and sexes, Levene’s statistic was significant (p<0.05). Although this is indicative of an assumption violation, $F_{\text{max}}$ between phonemic fluency scores (variance) of each group, of each sex of each group, and of the same sex of each group did not exceed three. With sample sizes that were not very discrepant, and not larger than a ratio of four to one, $F_{\text{max}}$ values less than ten are acceptable and indicate that there was no violation in the assumption of homogeneity of variance (Tabachnick & Fidell, 2001).

For the between groups ANOVA comparing semantic verbal fluency between the groups and sexes, Levene’s statistic was not significant, indicating that there was no violation of the homogeneity of variance assumption for this analysis.
A. 2.2 Experiment Two continued

Chimeric faces task

**Applied statistics:**
- Chimeric faces task RT and accuracy rate analyses (separate): 2 (visual field) x 2 (emotion) x 2 (group) x 2 (sex) mixed-design ANOVA
- Post-hoc paired and independent t-tests: to further assess the significant visual field by sex interaction, and group by emotion interaction from the mixed-design RT ANOVA
- Post-hoc paired t-tests: to further assess the visual field by emotion interaction from the mixed-design RT ANOVA
- Post-hoc paired and independent t-tests: to further assess the visual field by group interaction from the accuracy rate mixed-design ANOVA

**Normality**

Prior to calculating the ANOVAs on the chimeric faces task RT and accuracy rate data, normality was examined using skewness and kurtosis statistics. For each group, and each sex of each group, the distributions of RT and accuracy rates to each visual field / emotion chimeric face condition were normal or close to normal after screening the data as outlined in section 9.2.3.

Prior to calculating the post-hoc t-tests used to further examine the significant visual field by sex interaction, the group by emotion interaction, and the visual field by emotion interaction from the RT ANOVA, the distributions of RTs to each variable were examined. Normality for each visual field / emotion chimeric face condition was initially examined for each group, and each sex of each group separately for the ANOVA analyses, however when responses were collapsed to examine the variable involved in the respective t-tests, some outlying RTs were observed (values that fell three SDs from the group mean). Truncating the outlier RTs was considered, however given that the ANOVA which produced the interactions of interest was conducted on log10 transformed data, the variables involved in the interactions were log10 transformed and normality re-examined. For the log10 transformed RTs to each variable involved in each of the interactions, normality was close to normal and there were no outliers. Therefore, to examine the interactions between visual field and sex, and visual field and emotion from the ANOVA conducted on participants’ RTs, the t-tests were conducted on the log10 transformed data. Normality was close to normal for RTs to each emotion for each group, and no outliers were observed. Therefore, for the post-hoc t-tests examining the group by emotion interaction the data did not have to be log10 transformed and the post-hoc t-tests assessing the group by emotion interaction were conducted on the non-transformed RTs.

Prior to calculating the post-hoc paired and independent t-tests used to further examine the visual field by group interaction from the accuracy rate ANOVA, the distributions of accuracy rates to each visual field (regardless of emotion) of each group was examined. The distributions of accuracy rates to each visual field of each group was normal or close to normal, and there were no outliers that fell outside three SDs from the group mean.

**Sphericity**

For the mixed-design ANOVAs calculated on the RT and accuracy rate responses to the chimeric faces, there was no more than one degree of freedom as there were only two dependent variables. Therefore a test of sphericity was not required (Tabachnick & Fidell, 2001) and was not provided.
A. 2.2  Experiment Two continued

Chimeric faces task continued

Homogeneity of variance
The homogeneity of variance assumption of ANOVA was assessed using Levene’s statistic. Levene’s test for equality of variance examined any significant differences in variance between the groups and sexes in RT and accuracy rates to each visual field / emotion chimeric face condition. Prior to the statistical analyses, F_{max} (the ratio of largest cell variance to smallest cell variance) was also calculated between visual field / emotion chimeric face condition for each group, and each sex of each group separately.

For the mixed-design ANOVAs calculated on the participants’ RT and accuracy rate data, Levene’s statistic indicated no significant differences (p>0.05) in the variance between the groups and the sexes for each visual field / emotion chimeric face condition. For both the RT and accuracy rate data, F_{max} comparing the variance between each visual field / emotion chimeric face condition for each group separately, and for each sex of each group separately, did not exceed ten. With the cell sizes being almost equal for each group, and each sex of each group, F_{max} values less than ten are acceptable and indicate that there was no violation in the assumption of homogeneity of variance (Tabachnick & Fidell, 2001).

For the post-hoc independent t-tests examining the significant visual field by sex interaction from the mixed-design ANOVA on RTs (log_{10} transformed), Levene’s statistic was not significant (p>0.05) between the sexes for RTs to LVF or RVF presentations, indicating that the homogeneity of variance assumption was not violated. For the post-hoc paired t-tests examining the significant visual field by sex interaction, F_{max} was calculated between the RTs (log_{10} transformed) to LVF and RVF presentations for each sex separately. For each sex, the F_{max} values between visual field presentations were less than three, indicating that homogeneity of variance had not been violated.

For the post-hoc paired t-tests examining the visual field by emotion interaction from the mixed-design ANOVA on RTs (log_{10} transformed), F_{max} was calculated between RTs (log_{10} transformed) of each visual field / emotion chimeric face condition. F_{max} did not exceed three for any of the visual field / emotion condition comparisons, indicating that homogeneity of variance had not been violated.

For the post-hoc independent t-tests examining the group by emotion interaction from the mixed-design ANOVA on RTs (log_{10} transformed), Levene’s statistic was significantly different (p<0.05) between the groups for RTs to happy expressions. Therefore the degrees of freedom and t statistic from the equal variances not assumed column was reported. Levene’s statistic was not significantly different between the groups for RTs to sad expressions, indicating that the homogeneity of variance assumption was not violated. For the post-hoc paired t-tests examining the significant group by emotion interaction, F_{max} was also calculated between the RTs to happy and sad presentations for each group separately. For each group, the F_{max} values between happy and sad presentations were less than three, indicating that homogeneity of variance had not been violated.

For the post-hoc independent t-tests examining the visual field by group interaction from the mixed-design ANOVA on accuracy rates, Levene’s statistic was not significantly different between the groups for recognition accuracy to LVF presentations. Levene’s statistic however, was significant (p<0.05) between the groups for recognition accuracy to RVF presentations, therefore the degrees of freedom and t-statistic from the equal variances not assumed column was reported. For the post-hoc paired t-tests examining the significant visual field by group interaction, F_{max} was calculated between the accuracy rates to LVF and RVF presentations for each group separately. For each group, the F_{max} values between visual field presentations were less than three, indicating that homogeneity of variance had not been violated.
A. 2.2   Experiment Two continued

Chimeric faces task continued

*Homogeneity of Intercorrelations*

The homogeneity of intercorrelations assumption of mixed-design ANOVA was examined using the Box’s M statistic. For the mixed-design ANOVA conducted on RTs, Box’s M was significant at $p<0.001$, indicating a violation of the homogeneity of intercorrelations assumption. The mean RT data of the chimeric faces task was $\log_{10}$ transformed and the mixed-design ANOVA re-conducted. Transforming the RT data rendered Box’s M statistic non-significant, thus no longer violating the homogeneity of intercorrelations assumption of mixed-design ANOVA. For the mixed-design ANOVA conducted on accuracy rates, Box’s M was not significant ($p>0.001$) therefore there was no violation of the homogeneity of intercorrelations assumption.
A. 2.2 Experiment Two continued

Factorial ANOVAs for age and handedness as covariates between the depressed males and females

Applied statistics:
- Semantic verbal fluency: 2 (sex) x 2 (group) x 3 (age category) between sexes ANOVA on depressed group
- Chimeric face RT analyses (log_{10} transformed): 2 (visual field) x 2 (emotion) x 2 (group) x 2 (sex) x 3 (handedness category) mixed-design ANOVA on depressed group

Normality
The normality assumption of ANOVA was examined using skewness and kurtosis statistics and was examined prior to statistical analyses. For each group and each sex of each group, the distributions of semantic fluency scores were normal or close to normal for each category of age. Similarly, for each group and each sex of each group, the distributions of chimeric faces task RTs to each visual field / emotion condition were normal or close to normal for each category of handedness. There were some cases however, where kurtosis was slightly higher, and there were no outliers that fell outside three SDs from the group mean. Transforming (log_{10}) the RT data for the RTs to the chimeric faces improved kurtosis for these conditions. It should be noted that where categories contained three cases, a kurtosis value could not be obtained and therefore could not be examined.

Homogeneity of variance
The homogeneity of variance assumption of ANOVA was assessed through Levene’s statistic.

For the factorial ANOVA comparing semantic verbal fluency between the groups and the sexes of the across categorised age, the Levene’s statistic was not significant. Therefore homogeneity of variance for the semantic verbal fluency factorial ANOVA was not violated.

For the chimeric faces mixed-design ANOVA comparing RTs (log_{10} transformed) to the chimeric face conditions between each group, sex and categorised handedness, Levene’s statistic was significant for the LVF and RVF presentations of sad expressions (p<0.05), and also for LVF presentations of happy expressions (p<0.05). Whilst this is indicative of an assumption violation, F_{max} between the LVF sad presentations, between the RVF sad presentations, and between the RVF happy presentations (variances) of each group and sex for each category of handedness was less than ten. Therefore, there was no violation in homogeneity of variance between the groups and sexes for the LVF and RVF presentations of sad expressions, and the RVF presentations of happy expressions. There was the exception of the F_{max} value for the RTs (log_{10} transformed) between the control males and females in category one to RVF presentations of sad expressions, and LVF presentations to sad expressions, which was greater than ten. Further, the F_{max} value for the RTs (log_{10} transformed) between the males of each group in category one to RVF sad expressions, and between the females of each group in category one to RVF sad expressions were greater than ten. This would suggest that the analysis be tested at a conservative p value. The p value for this analysis however, was not significant.
A. 2.2  Experiment Two continued

Factorial ANOVAs for age and handedness as covariates continued

$F_{\text{max}}$ comparing the variance between each visual field / emotion chimeric face condition for each group and each sex separately for each handedness category exceeded ten for the depressed males between: category one RVF happy and LVF sad faces; category one RVF sad and LVF sad faces; category one LVF happy and LVF sad faces; category three RVF sad and LVF happy faces; and for the control males between category two RVF sad and LVF sad faces. $F_{\text{max}}$ values greater than ten suggest that the RT analyses on the categorised chimeric faces task analyses should be tested at a conservative $p$ value. No significant interaction was found for this analysis however.

Homogeneity of Intercorrelations

The homogeneity of intercorrelations assumption of mixed-design ANOVA was examined using the Box’s $M$ statistic. For the mixed-design ANOVA conducted on RTs of the chimeric faces task, Box’s $M$ was significant at $p<0.001$, indicating a violation of the homogeneity of intercorrelations assumption. The mean RT data of the chimeric faces task was $\log_{10}$ transformed and the mixed-design ANOVA re-conducted. Transforming the RT data rendered Box’s $M$ statistic non-significant, thus no longer violating the homogeneity of intercorrelations assumption of mixed-design ANOVA.
APPENDIX 3. TRANSFORMED MEANS AND SDS FROM THE STATISTICS CONDUCTED ON TRANSFORMED RTS IN EXPERIMENT TWO

Experiment Two

MRT

6 (angle) x 2 (group) x 2 (sex) mixed-design ANOVA log₁₀ means and SDs

Mean log₁₀ transformed RTs and SDs as a function of angle of rotation in the MRT for both the control and depressed groups for Experiment Two

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>Control (n = 35)</th>
<th>Depressed (n = 34)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>0</td>
<td>3.21</td>
<td>0.22</td>
</tr>
<tr>
<td>30</td>
<td>3.34</td>
<td>0.23</td>
</tr>
<tr>
<td>60</td>
<td>3.38</td>
<td>0.18</td>
</tr>
<tr>
<td>90</td>
<td>3.42</td>
<td>0.21</td>
</tr>
<tr>
<td>120</td>
<td>3.46</td>
<td>0.23</td>
</tr>
<tr>
<td>150</td>
<td>3.52</td>
<td>0.22</td>
</tr>
<tr>
<td>Overall</td>
<td>3.41</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Mean log₁₀ RT (msec) and SDs as a function of angle of rotation in the MRT for both males and females of the control and depressed groups for Experiment Two

<table>
<thead>
<tr>
<th>Degree of rotation</th>
<th>Control</th>
<th>Depressed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n=17)</td>
<td>Females (n=18)</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>0</td>
<td>3.21</td>
<td>0.23</td>
</tr>
<tr>
<td>30</td>
<td>3.31</td>
<td>0.21</td>
</tr>
<tr>
<td>60</td>
<td>3.34</td>
<td>0.16</td>
</tr>
<tr>
<td>90</td>
<td>3.39</td>
<td>0.21</td>
</tr>
<tr>
<td>120</td>
<td>3.42</td>
<td>0.23</td>
</tr>
<tr>
<td>150</td>
<td>3.46</td>
<td>0.21</td>
</tr>
<tr>
<td>Overall</td>
<td>3.37</td>
<td>0.19</td>
</tr>
</tbody>
</table>
MRT transformed means continued

Log_{10} means and SDs from post-hoc paired t-tests examining main effect for angle from mixed-design ANOVA on RT data

Overall mean log_{10} RTs and SDs for each angle of rotation - Experiment Two

<table>
<thead>
<tr>
<th>Angle</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>3.32</td>
<td>0.27</td>
</tr>
<tr>
<td>30°</td>
<td>3.44</td>
<td>0.27</td>
</tr>
<tr>
<td>60°</td>
<td>3.49</td>
<td>0.23</td>
</tr>
<tr>
<td>90°</td>
<td>3.51</td>
<td>0.25</td>
</tr>
<tr>
<td>120°</td>
<td>3.54</td>
<td>0.24</td>
</tr>
<tr>
<td>150°</td>
<td>3.59</td>
<td>0.23</td>
</tr>
</tbody>
</table>

N=69

Chimeric faces task

2 (visual field) x 2 (emotion) x 2 (group) x 2 (sex) mixed-design ANOVA

Mean log_{10} RTs and SDs to the happy and sad affect on the chimeric face stimuli for each visual field of the control and depressed males - Experiment Two

<table>
<thead>
<tr>
<th></th>
<th>Control (n = 31)</th>
<th>Depressed (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Happy</td>
<td>3.07</td>
<td>0.13</td>
</tr>
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Overall

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Chimeric faces task transformed means continued

Mean \log_{10} RTs and SDs to the happy and sad affect on the chimeric face stimuli for each visual field for both males and females of the control and depressed group - Experiment Two

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Log_{10} means and SDs from post-hoc paired and independent t-tests examining the sex by visual field interaction from mixed-design ANOVA on RT data

Mean \log_{10} RTs and SDs to each visual field for both males and females of the depressed group - Experiment Two

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Log_{10} means and SDs from post-hoc paired t-tests examining the visual field by emotion interaction from mixed-design ANOVA on RT data

Mean \log_{10} RTs and SDs to each happy and sad expressions shown in each visual field - Experiment Two

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**Log$_{10}$ means and SDs from the 2 (visual field) x 2 (emotion) x 2 (sex) x 3 (handedness block) mixed-design ANOVA – depressed group**

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### Log_{10} means and SDs from the 2 (visual field) x 2 (emotion) x 2 (group) x 2 (sex) x 3 (handedness block) mixed-design ANOVA – control group

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