CEREBRAL ASYMMETRY IN FACIAL AFFECT PERCEPTION OF WOMEN: NEUROPSYCHOLOGICAL EFFECTS OF DEPRESSION

by

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(ABSTRACT)

Forty right-handed women, half who had been classified as depressed, the other half nondepressed, participated in a tachistoscopic study of the influence of depression on the cerebral hemispheric processing of Ekman and Friesen's (1976) happy, sad, and neutral emotional faces. A dynamometer was also used as a standardized measure of hemispheric motor functioning such as hand grip strength, perseveration, and fatigue. Results indicated that the depressed women were characterized by elevated levels of both depression and anxiety, suggestive of an agitated, depressive state with heightened arousal. Further, depressed as compared to nondepressed women displayed significantly faster reaction times to sad faces presented their right visual fields and happy faces presented their left visual fields. For the dynamometer data, primary findings indicated that depressed women displayed significantly less perseveration at the left hand as compared to nondepressed women. There was also a trend for depressed as opposed to nondepressed women to show less perseveration at the right hand. These findings from both the tachistoscope and dynamometer data are suggestive of differential arousal of both the left and right cerebral hemispheres and are discussed in light of arousal theory.

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INTRODUCTION AND LITERATURE REVIEW

In recent years affective asymmetries of the cerebral hemispheres have received increasing attention (Davidson, 1984). A diversity of methodological procedures have been employed to examine these emotional processes. Likewise the study of cerebral asymmetry in facial affect perception has become increasingly popular for the neuropsychological investigation of emotion and depression. A review of the major findings of these affective asymmetry studies follows.

Consistent differences have been observed in the affective behavior of subjects with unilateral brain lesions (Coffey, 1987). In 1939, Goldstein reported a high incidence of a "catastrophic reaction" in patients with lesions to the left hemisphere (Goldstein, 1939). This "catastrophic reaction" is characterized by negative affect, fear, pessimism, and crying (Davidson, 1984). Two studies by Gainotti (1969, 1972) supported this idea of a catastrophic reaction. After examining hundreds of cases of unilateral cerebral lesions, Gainotti (1969, 1972) concluded that behaviors denoting a catastrophic reaction occurred significantly more frequently among left brain-damaged patients whereas an opposite reaction characterized by indifference, anosognosia, and euphoria were found to be associated more with right-sided lesions. These observations have been supported by Sackheim et al. (1982)

in his study of 119 cases of pathological laughing and crying. Laughing was predominantly associated (three times more likely) with right-sided brain damage whereas crying was linked with left-sided lesions (Sackheim et al., 1982). Further, a study of Vietnam veterans with penetrating brain injuries has shown that left hemispheric lesioned patients are prone to abnormally increased anger and hostility (Grafman, Vance, Weingartner, Salazar, & Amin, 1986). Administration of the MMPI to patients with unilateral hemispheric lesions has shown that many left-hemisphere diseased patients displayed marked elevations on the inventory's depression scale whereas patients with right hemisphere disease did not (Gasparrini, Satz, Heilman, & Coolidge, 1978). Almost 50% of the left hemisphere group and 0% of the right hemisphere group had depression scores of T >70 on the MMPI (Gasparrini et al., 1978). These data lend credence to the hypothesis that left hemispheric lesions are associated with more depression than right hemispheric lesions and that differences cannot be entirely attributed to difficulties in perceiving or expressing affective stimuli (Gasparrini et al., 1978). Several studies have found that patients with left anterior lesions have significantly more severe depressions as compared to any other lesion locations (Robinson & Benson, 1981; Robinson & Szetda, 1981; Robinson, Kubos, Starr, Rao, & Price, 1984). These findings indicate damage to the left frontal region is most likely associated with the most severe depression whereas posterior left damage is less likely to result in depression (Davidson, 1984).

Catastrophic and indifference reactions have been theorized to occur as a result of the breakdown (due to hemispheric damage) of the reciprocal interaction between the controlling systems of the left and right hemispheres leading to disinhibition of the undamaged hemisphere (Flor-Henry, 1979; Swartzburg, 1983; Otto, Yeo, & Dougher, 1987). For example, when the right hemisphere is no longer "under" left hemisphere control due to damage to the left side, the emotional catastrophic reaction is released (Flor-Henry, 1979; Swartzburg et al., 1983).

Other clinical studies have examined the expression and perception of emotion in brain-damaged individuals. In a study which tested the emotional processing of right-hemisphere damaged patients across visual and auditory modalities results indicated these subjects were deficient in emotional comprehension (Heilman, Scholes, & Watson, 1975). Likewise, Borod, Koff, Lorch, and Nicholas (1986) studied the expression and perception of facial emotion in patients with unilateral cerebrovascular pathology. Right brain-damaged patients were significantly impaired relative to left brain-damaged persons and normal controls in expressing and perceiving facial emotion (Borod et al., 1986). These results support the notion of right cerebral dominance for expressing and perceiving emotion (Borod et al., 1986).

A variety of hemispheric lateralization studies have examined the expression and production of emotion in normal subjects. In her study of emotional expression, Campbell (1978) found a greater intensity of posed emotion expressions on the left side of the face as opposed to the right indicating greater right hemisphere involvement. This finding was supported in later studies which examined both spontaneous and posed facial asymmetries (Borod, Koff, White, 1983; Dopson, Beckwith, Tucker, & Bullard-Bates, 1984; Borod, Kent, Koff, Martin, & Alpert, 1988). For example, Dopson et al. (1984) examined facial asymmetry as subjects remembered happy and sad experiences and contrasted these with subjects' posed expressions of happiness and sadness. Both procedures resulted in more intense expressions on the left side of the face regardless of the emotion indicating right hemispheric involvement in emotion (Dopson et al., 1984). Likewise, Borod (1988) found that posed expressions of both positive and negative emotions were produced significantly more intensely on the left side of the face suggesting right cerebral dominance for the overall expression of facial emotion.

Examination of lateral eye movements during affective tasks have also implicated the right hemispheric role in emotional expression. Results of these studies have shown subjects tend to look more to the left while responding to emotion-laden statements suggesting greater right hemispheric involvement in emotional processes (Schwartz, Davidson, & Maer, 1975; Borod, Vingiano, & Cytryn, 1988). No directional bias was seen with nonemotional instruction (Borod et al., 1988).

Investigations with normal subjects into the recognition and perception of emotion have also implicated the right hemisphere's involvement in affective processes. A number of visual perception studies have examined reaction times to identify emotional faces (happy and sad or angry) presented tachistoscopically to the left and right visual fields. Results of these experiments have generally shown faster reaction times to emotional faces presented the left visual field for both men and women indicating a right superiority for visual emotional perception (Buchtel, Campari, DeRisio, & Rota, 1978; McKeever & Dixon, 1981; Harrison, Gorelczenko, & Cook, 1990). In the McKeever and Dixon (1981) study, women in an affective imagery group showed a left visual field superiority over women in a neutral imagery group. The authors state this suggests the possible importance of "cognitive style" in studies of hemispheric asymmetry of function (McKeever & Dixon, 1981). Left visual field superiorities have also been found for recognition of emotionally expressive facial drawings (Ley & Bryden, 1979; Hugdahl, Iversen, Ness, & Flaten, 1989).

These studies also suggest a right hemispheric superiority for processing emotional stimuli (Ley & Bryden, 1979; Hugdahl et al., 1989). Further, Ley and Bryden (1979) found that the left visual field superiority for emotion remained after the effects of face recognition had been factored out. In a study designed to investigate affective asymmetries while minimizing factors favoring right hemispheric processes, subjects were presented pairs of faces (one emotional, one neutral) one to each visual field and instructed to respond to the one which made them feel better or worse (McLaren & Bryson, 1987). Performances were superior for both men and women when the emotional faces were presented to their left visual field, suggesting an overall right hemispheric superiority for emotion (McLaren & Bryson, 1987). Likewise, in their study of tachistoscopically presented emotional faces, Crews and Harrison (1992) found cerebral asymmetry as a function of affective valence with a right hemisphere advantage for the identification of angry faces while symmetry was found for happy face identification. This finding lends support to the hypothesis of cerebral asymmetry in emotion rather than simply visuospatial processing (Crews & Harrison, 1992).

Other studies have examined the auditory perception of affectively intoned stimuli. These experiments have presented emotionally intoned words or sounds to normal subjects via a dichotic listening test (Haggard &

Parkinson, 1971; Saxby & Bryden, 1984). Subjects were found to display a left-ear advantage for the perception of affectively intoned stimuli which supports the role of the right hemisphere in emotion (Haggard & Parkinson, 1971; Saxby & Bryden, 1984). Ley and Bryden (1982) have found similar left ear advantages for emotionally intoned sentences while a right ear advantage was found for recognizing the verbal content of the sentences. These results also indicate a right hemisphere superiority for emotion (Ley & Bryden, 1982). In a related clinical study, Heilman et al. (1975) found that patients with right temporoparietal infarctions performed significantly worse in the identification of the emotional tone of a speaker reading semantically neutral sentences than patients with left temporoparietal infarctions. This study further suggests the right hemisphere's involvement in processing the affective intonation of speech (Heilman et al., 1975).

A diversity of studies has examined the differential lateralization of recruited emotions in normal subjects. In an examination of subjects' emotional ratings of films presented their left or right visual fields, the right hemisphere was found to judge films significantly more unpleasant than the left brain (Dimond, Farrington, & Johnson, 1976). Two additional investigations which looked at reaction times to tachistoscopically presented emotional faces (happy, sad, and neutral) have found similar results

(Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, Givis, & Moscovitch, 1983). Faster reaction times were seen when happy faces were presented to the right visual field (left hemisphere) and a left visual field (right hemisphere) advantage was found for sad faces (Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz et al., 1983). These findings support the hypothesis for differential hemispheric specialization for positive (left hemisphere) and negative (right hemisphere) emotion (Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz et al., 1983).

Electroencephalogram (EEG) studies support the differential lateralization of recruited emotions hypothesis. In an investigation of electroencephalogram changes during induced emotional states, the right frontal cortex displayed an increase in activation (superiority) during negative affect while a similar activation (superiority) was found in the left frontal cortex during positive affective states (Davidson, Schwartz, Saron, Bennett, & Goleman, 1979). Right parietal zone activation was seen for both positive and negative affect (Davidson et al., 1979). The authors suggest that differential lateralization of positive and negative emotions is a characteristic of the frontal zones (Davidson et al., 1979). Similarly, Ahern and Schwartz (1985) examined EEG spectral analysis in subjects who were asked emotion-laden questions. Results indicated left hemispheric activation in the frontal zones for positive emotions and right hemispheric frontal activation for negative emotions (Ahern & Schwartz, 1985). These findings bolster the earlier differential lateralization hypothesis. Likewise, the study found marginally significant results for the right parietal region's specialization in emotion regardless of valence (Ahern & Schwartz, 1985). Davidson and Fox (1988) have postulated that the posterior regions of the hemispheres actively participate in perception tasks whereas it is in the anterior regions (which participate in emotional expression) that differential asymmetries as a function of affective valence are observed.

A relationship has been suggested between the differential processing of emotions and approach and avoidance behaviors. It is hypothesized that positive emotions which may accompany approach behaviors should reflect left frontal activation whereas negative emotions that correspond to withdrawal should be associated with right hemispheric activation (Fox & Davidson, 1984; Davidson & Fox, 1988). A recent EEG study lends support for this relationship. Subjects watched films to promote happiness (approach) or disgust (withdrawal) while EEG and facial expression were concurrently recorded (Davidson, Ekman, Saron, Senulis, & Friesen, 1990). Disgust was found to be associated with right-sided activation in the frontal and anterior temporal regions whereas happiness was accompanied by left-sided anterior temporal activation (Davidson et al., 1990). Results underscore the importance of anterior cerebral asymmetry for emotions associated with approach and withdrawal (Davidson et al., 1990).

There have been repeated reports of sex differences in hemispheric asymmetries and lateralization of emotional processes. In general, men outperform women on measures of spatial abilities and mathematics while women excel over men on verbal and language tasks (Bryden, 1982; see also Kolb & Whishaw, 1990). Overall men have shown more extensive lateralization of spatial functions in the right hemisphere and verbal abilities in the left hemisphere (Harrison & Gorelczenko, 1990; Bryden, 1982; Kolb & Whishaw, 1990). Women have been suggested to have more diffuse anatomical representation of functions and to be less lateralized than men (Bigler, 1988; Bryden, 1982; Kolb & Whishaw, 1990). Swartzburg (1983) suggests that as women tend to be more verbally expressive of emotion than men their language function may have a heightened emotional component (right hemisphere) than do the language functions of men. A possible explanation for women having a greater degree of right hemispheric input into language may be that women tend to have a lesser degree of lateralization as opposed to men (Swartzburg, 1983). Regarding the affective asymmetries, two studies examining the identification of tachistoscopically presented emotional faces found men were significantly faster than women in processing affective facial stimuli presented to their left visual fields (Harrison & Gorelczenko, 1990; Harrison, Gorelczenko, & Cook, 1990). These findings suggested a right hemisphere superiority for face identification or for a combination of emotion and visuospatial features in men as opposed to women. Further, these results are consistent with earlier findings of more diffuse and bilateral representation of spatial and verbal functions in women (Bradshaw & Nettleton, 1983; McGlone, 1980; Springer & Deutsch, 1989).

Neuropsychological studies have also found sex differences related to depression. Based on evidence from clinics, prevalence studies indicate depression is two times more common among women than men (Flor-Henry, 1978; Weissman & Klerman, 1977; American Psychiatric Association, 1987). Studies have indicated that these prevalence differences cannot be fully explained by sex biases in precipitating situational factors, symptoms-reporting or help-seeking behaviors (Weissman & Klerman, 1977; Radloff & Rae, 1979).

Radloff and Rae (1979) argue that there are likely some biological sex differences in susceptibility to depression. An EEG study of induced affective states has found evidence of greater right hemispheric activation in women during affective states versus nonemotional states whereas men showed no task-dependent shifts (Davidson, Schwartz, Pugash, & Bromfield, 1976). Gur et al. (1982) examined the relationship between cerebral blood flow, level of activity and subject's sex. Results indicate higher blood flow rates in women over men and that right-handed women had heightened right hemisphere blood flow during spatial task performance as opposed to men (Gur et al., 1982). Women were also found to have a greater percentage of fast blood perfusing tissue (Gur et al., 1982). These results suggest that the lesser degree of hemispheric asymmetry reported in women may be compensated for by greater activation of the hemisphere specialized for a particular task (Gur et al., 1982). Additionally, Otto, Yeo, and Dougher (1987) have stated that this heightened right hemispheric activation in women may predispose them to the "depressive tone" characterizing this hemisphere.

A diversity of studies have found hemispheric asymmetries in depressed subjects. Differences between depressives and normals have been found in their perception of chimeric faces (David, 1989). David (1989) tested subjects' responses to happy versus sad chimeric face drawings of affective expression during induced elation and depression. Lower mood was found to increase the sad bias to the left hemiface and thus a right hemispheric advantage for sad facial processing. David argues that these findings may reflect the intrinsically lower mood of the right hemisphere or a tendency to rate expressions more negatively overall. Alternatively, Jaeger, Borod, and Peselow (1987) in their study of chimeric face perception in depressed men found depressives were significantly less lateralized than controls in perceiving emotional faces. This result may indicate impairment of subcortical systems and not necessarily localized involvement of the right hemisphere (Jaeger et al., 1987).

In a study of the relationship between sad mood induction in women and hemispheric processing of visual stimuli a lengthening in reaction time was found for stimuli presented to the right hemisphere following sad mood induction (Ladavas, Nicoletti, Umilta, & Rizzolatti, 1984). No lengthening was found for stimuli presented the left hemisphere (Ladavas et al., 1984). This provides evidence supporting a right hemisphere activation during sadness (Ladavas et al., 1984). Silberman, Weingartner, Stillman, Chen, and Post (1983) investigated the processing of tachistoscopically presented verbal stimuli. Depressed women were found to display a trend toward right hemisphere superiority for the task as opposed to a left hemisphere advantage seen in normal subjects (Silberman et al., 1983). Depressed subjects also had slower reaction times than nondepressives (Silberman et al., 1983). It was suggested that in depression the right hemisphere may share functions performed exclusively by the left hemisphere and that the right brain may be compensating for the deactivation of the left brain (Silberman et al., 1983).

A recent tachistoscopic study supports the above findings. Crews and Harrison (1992) investigated the influence of depression, as defined by the Beck Depression Inventory, on the hemispheric processing of emotional faces. Faster facial emotional processing was found in depressed as opposed to nondepressed men, whereas diametrically opposite effects were seen in women. In this study, depressed women displayed significantly slower reaction times than did nondepressed women. These findings may indicate that emotional processing in women requires a greater verbal component. The slower reaction times to affective stimuli seen in depressed women reflect increased processing time due to a decrease in activation of the left hemisphere language areas (Crews & Harrison, 1992). Additionally, depressed women more often identified neutral faces as angry than did nondepressed women. This response bias may reflect a relative increase in right hemispheric activation and a tendency to perceive neutral stimuli as negative.

Auditory asymmetries have also been found in depressed individuals. A dichotic listening study of subjects with affective disorders found that their performances resembled patients with right temporal lobe lesions (Yosawitz et al., 1979). Results provide support for a hypothesis of right hemispheric dysfunction. Other dichotic listening studies have likewise found evidence of right hemispheric dysfunction in depressed subjects (Tucker, Stenslie, Roth,

& Shearer, 1981; Johnson & Crockett, 1982; Bruder et al., 1989). For example, Bruder et al. (1989) found that melancholic patients demonstrate an abnormally large right ear advantage for CV syllables (due to poor left ear performance) and a right ear advantage for complex tones, which is opposite to the ear asymmetry seen in normal subjects.

Electroencephalogram studies have generally found a relative right hemisphere activation in depressed subjects (Flor-Henry, 1978; Tucker et al., 1981; Schaffer, Davidson, & Saron, 1983). Tucker (1981) induced depressive and euphoric moods in subjects and observed greater alpha dysynchrony (activation) over the frontal lobe of the right hemisphere in the depressed group. Likewise Schaffer et al. (1983) compared high versus low Beck Depression Inventory scores on measures of resting EEG activity from frontal and parietal regions. Depressed subjects displayed greater relative right frontal activation as opposed to nondepressed subjects (Schaffer et al., 1983). Parietal activity did not distinguish groups (Schaffer et al., 1983). Other researchers have concluded that in depressives the most robust right hemisphere activation tends to be in the frontal areas (Otto et al., 1987; Davidson & Fox, 1988). Otto et al. (1987) states this relative right hemisphere activation can occur in two ways: by an increase in the activity of the right hemisphere or by a decrease in left hemisphere activity. This contention has been proposed by other investigators as well (Swartzburg, 1983; Davidson & Fox, 1988). Davidson and Fox (1988) conclude that the relative right frontal activation predisposes subjects to experience negative affect.

Depression has also been associated with impaired neuropsychological test performance. Kronfol, Hamsher, Digre, and Waziri (1978) administered a series of neuropsychological tests to depressed patients prior to undergoing electroconvulsive therapy. Results indicated more defective performances on tests purported to be sensitive to right hemispheric functions than for left hemisphere function tests (Kronfol et al., 1978). This finding supports the theory that depression is associated with dysfunction of the right hemisphere (Kronfol et al., 1978). Likewise other studies have found impaired right hemispheric test performances in depressed subjects who were given either the Luria-Nebraska Neuropsychological Battery or the San Diego Neuropsychological Battery (Silverstein, McDonald, & Meltzer, 1988; Richards & Ruff, 1989). Depressives were especially impaired on tactile-stereognostic and visuospatial memory and learning (Silverstein et al., 1988; Richards & Ruff, 1989). These results appear to further support right hemispheric dysfunction in depression.

As a final note it must be cautioned that the preceding literature review may represent an oversimplification of the importance (role) of the level (cortical, subcortical) and type of brain pathology in depression. For example, Gilley (1990) found differences in the severity of depressive symptomatology across three neurodegenerative disorders. Specifically, depression was most severe in Parkinson's disease, intermediate in subcortical vascular disease, and least severe in Alzheimer's disease. Thus depression may also be a function of the anatomical level and type of brain involvement.

There has been a relative lack of research on facial affect perception in depressed women. The purpose of this research was to provide data on depressed versus nondepressed women in the hemispheric processing of affective stimuli and motor behaviors sensitive to cerebral asymmetries (dynamometer grip strength, perseveration, and fatigue performance). Ekman and Friesen's (1976) pictures of happy, sad, and neutral faces were presented within the left and right visual half fields, while subjects identified the emotional tone displayed as being either "happy" or "sad." No "neutral" response alternative was available nor were subjects instructed that faces might depict neutral affect. Thus, a forced-choice reaction-time paradigm was used.

Additionally, Heilman and associates (Heilman & Van Den Abell, 1979, 1980; Heilman, Bowers, & Valenstein, 1985) have suggested that both the anterior and posterior regions of the brain play important roles in mediating arousal and attentional/intentional processes. Further, they have postulated that, while each cerebral hemisphere can mediate its own arousal, the right hemisphere appears to be dominant for such activation processes. Hence, subjects were also tested with a dynamometer, a device used to measure anterior cerebral motor functioning such as hand grip strength, hand grip perseveration, and hand grip fatigue (Dodrill, 1978; Huntzinger, 1989). This instrument was used to obtain additional information on the cerebral asymmetries (especially the frontal lobes) in depressed versus nondepressed women.

Since prior research (Crews & Harrison, 1992) has demonstrated slower reaction times in depressives, it was hypothesized that depressed women would display significantly slower overall reaction times to affective facial stimuli, presented tachistoscopically, than their nondepressed counterparts. As negative affect has been shown to be processed faster in the left visual field (right hemisphere) it was also predicted that sad faces would be identified faster within the left than within the right visual fields.

For the affectively neutral stimuli, based on the previous findings of Crews and Harrison (1992), it was expected that depressed women would identify neutral slides as sad more often than nondepressed women.

For the dynamometer tests of motor functioning, based on the hypothesized relative left hemisphere deactivation (as opposed to the relative right hemisphere activation) seen in depression, it was predicted that depressed women would exhibit poorer left hemispheric governed motor performances of hand strength, perseveration, and fatigue with their contralaterally controlled right hand as opposed to their left hand (right hemisphere).

Method

Subjects

Group screening was conducted to identify undergraduate, right-handed, depressed and nondepressed women (N = 40) with good visual acuity and no history of neurological problems and/or learning disabilities. These women ranged in age from 18 to 23 years with a mean age of 19.15 years. Half the women were classified via the Beck Depression Inventory as depressed and the other half as nondepressed. As more nondepressed subjects met selection criteria than needed, these subjects were randomly assigned/not assigned to their respective group.

Group Classification and Measures

Handedness was determined using a validated self-report questionnaire (Coren, Porac, & Duncan, 1979) consisting of 13 items which inventories four types of lateral preference (hand, foot, eye, and ear) (See Appendix A). Average concordance between self-report and behavioral measures for the test is stated to be .90. Items were scored as +1 for "right-handed," -1 for "left-handed," or 0 for "both" (right or left) responses. The criterion for right-hand dominance and inclusion in the study was a score of +6 or more.

Depression was assessed using the validated self-report Beck Depression Inventory (Beck, 1972) (See Appendix B). Scores on this 21-question measure may range from 0 to 63. Subject scores of 0 - 5 (x = 2.0) were considered nondepressed while subjects who scored 15 - 29 (x = 18.5) were considered depressed.

Anxiety was assessed (at time of group screening) using the validated self-report State-Trait Anxiety Inventory (Spielberger, 1983) (See Appendix C). This is a 40-item questionnaire which inventories both state and trait anxiety. This inventory was not used as a criterion measure for inclusion in this study.

A history questionnaire (See Appendix D) was also administered during group screening to assess for both past and present neurological problems, learning disabilities, and/or vision difficulties. Those individuals with such problems or histories of such were excluded from this study.

Stimuli and Apparatus

Various apparatus and procedures are adapted from those previously used by Harrison, Gorelczenko and Cook (1990). Thirty emotional faces (10 happy, 10 neutral, and 10 sad) from Ekman and Friesen's (1976) validated pictures of facial affect were randomly selected. Pictures were reproduced onto slides (with permission of the publisher) with the stimulus appearing in either the right visual field (RVF) or left visual field (LVF). Stimuli were mounted with the inside edge of the picture 3 degrees from center and the outside edge 12 degrees from center. A total of 60 slides (10 RVF happy, 10 LVF happy, 10 RVF neutral, 10 LVF neutral, 10 RVF sad, 10 LVF sad) were used.

Subjects were tested in a sound-attenuated chamber. All time-based and event recording were performed in a separate room using automated programming equipment. Subjects were monitored from this separate room and prompted via an intercom. Stimuli was presented using a Constant Illumination Tachistoscope (Lafayette Model 42011) onto a white screen at a distance of 2.67 m and 1.35 m in front of the subject. The screen's center was marked with a black dot positioned 1.47 m above the floor. Luminance level was 4.5 candellas per m^2 reduced to 2.5 candellas per m^2 during stimuli presentation. Stimuli onset was signalled by a 2000 Hz, 55dB (A-scale, .002 dynes/cm) tone located behind the subjects. Manipulanda consisted of two "soft touch" trip switches mounted flush on the midline of a right-handed student desk, 58.5 cm from the chair's back. Switches were separately labeled "happy" and "sad."

A dynamometer was used as a standardized measure of hemispheric motor functioning such as hand strength, perseveration, and fatigue (Dodrill, 1978; Huntzinger, 1989; Harrison & Pauly, 1990). These measures have been associated with anterior (frontal lobe) brain functioning (Stuss & Benson, 1984). Poor performances may indicate anterior cerebral dysfunction contralateral to the hand tested as distal extremities are controlled by the contralateral anterior hemisphere (Dodrill, 1978; Kolb & Whishaw, 1990). Substandard performance by both hands may reflect bilateral cerebral dysfunction (Dodrill, 1978). The dynamometer records hand grip strength in kilograms (kg).

Procedures

Procedures were approved by the Institutional Review Board and Human Subjects Committee at Virginia Polytechnic Institute and State University. Informed Consent (Appendix E) was also obtained from each subject prior to testing.

Upon arrival for testing subjects were seated and received another prescreening with the Beck Depression Inventory. Only subjects who scored within their previous group screening ranges were tachistoscopically and dynametrically tested; others were debriefed and excused.

Subjects were next administered the following tachistoscopic task instructions:

In this part of the study, you will have to make decisions concerning faces which you will see on the screen. The presentation of the faces will be brief and either to the left or to the right of the black dot. The presentation of the face will be preceded by a tone (the tone is sounded). We ask that, upon hearing the tone, you focus on the black dot because the face will be presented about 3 seconds after the tone. We also ask that you use your right index finger to choose whether the face is happy or sad. Please keep your index finger raised above and between the two switches. After the presentation of the face, please make your selection by pressing the switch labeled "happy" or "sad." Please respond as quickly and as accurately as possible. To get you used to the procedure, practice trials will be provided. Also, we will inform you when the practice trials end and the study begins. There is an intercom located behind you if you need to contact us. We will remind you to fixate on the black dot during the testing. Any questions?

After reading the instructions, practice trials were initiated consisting of 10 happy and 10 sad slides (Appendix F). A one-second duration tone signaled the impending presentation of an affective face. Three seconds after the tone, a stimulus slide was shown for 200 ms. Subject identification of stimuli affective valence occurred using a forced-choice reaction time paradigm. Intertrial intervals were 15 s. Subjects were required to identify 8 consecutive slides correctly within the first three replications of practice slides for study inclusion.

The actual test phase consisted of 20 happy, 20 neutral, and 20 sad facial slides (See Appendix G). A restricted (3 effects, 2 response alternatives) forced-choice reaction time paradigm was used. Subjects were instructed to focus on the fixation point (black dot) at the screen's center after every 18 slides to improve integrity of stimulus presentation within visual fields. Location of response keys (happy, sad) were counterbalanced across subjects to eliminate position effects. Two randomized orders of slide presentation were also used to control order effects.

Test subjects were then administered the dynamometer tests to both the right and left hands (See Appendix H). Hand strength was assessed by asking subjects to squeeze the device as hard as possible with one hand. Subjects were then instructed to squeeze the dynamometer just half as hard to assess perseveration. This procedure was repeated with the opposite hand. Fatigue was then observed by having subjects squeeze the device as hard as they could five consecutive times with each hand. The dynamometer was reset after all trials and the device's scale was always turned away from subjects. Order of testing was counterbalanced across subjects.

Results

Tachistoscope

For the tachistoscopic data a three-factor mixed design analysis of variance (ANOVA) with the fixed factor of group (depressed/nondepressed) and with repeated measures of visual field (left and right) and slide affect (happy and sad only) was performed using the square root of the reaction time scores. As homogeneity of variance was violated for the reaction time scores, this transformation was selected on the basis of tests for homogeneity of variance and found to result in the most homogenous data set. Appendix I provides an overview of the means and standard deviations of all trials before and after the data transformation. To further increase homogeneity, the first trial for all combinations of affects and visual fields in the test phase was not included in any of the tachistoscope data analyses. This was based on the overall slower mean reaction time for trial one and the observation that only trial one differed significantly from any of the other nine trials. These findings are possibly the result of the initiation of the more ambiguous neutral slides in the test phase. Additionally, post hoc pairwise comparisons of means were made using Tukey's Studentized Range Test. Table 1

Table 1. Summary of Tachistoscope Results

TABLE 1

Summary of Tachistoscope Results

Source	dF	SS	MS	F	p
Happy/Sad Affects, ($\sqrt{rt}$)					
Group	(1,38)	.0391	.0391	.14	<.71
Visual Field	(1,38)	.0278	.0278	5.62	<.02 *
Group x VF	(1,38)	.0003	.0003	.06	<.81
Slide Affect	(1,38)	1.2162	1.2162	40.04	<.0001*
Group x SA	(1,38)	.0071	.0071	.24	<.63
VF x SA	(1,38)	.0010	.0010	.13	<.72
Group x VF x SA	(1,38)	.0311	.0311	3.94	<.05 *
Neutral Affects, ($\sqrt{rt}$)					
Group	(1,38)	.0268	.0268	.09	<.76
Visual Field	(1,38)	.1175	.1175	8.79	<.005 *
Group x VF	(1,38)	.0181	.0181	1.35	<.25
Reported Affect					
Group	(1,38)	1.1680	1.1680	2.28	<.14
Visual Field	(1,38)	1.9014	1.9014	15.17	<.0004 *
Group x VF	(1,38)	.1681	.1681	1.34	<.25

* = significant

provides an overview of all significant and nonsignificant tachistoscopic data results.

The Group x Visual Field x Slide Affect interaction was significant, F (1,38) = 3.94, $p < .05$ (see Figure 1). Specifically, post hoc analyses revealed depressed women's reaction times were significantly faster to sad faces presented their right visual field (RVF) as compared to nondepressed women's RVF reaction times for sad faces. Further, depressed women identified happy faces reliably quicker than did nondepressed women when presented in their LVFs. Depressed women also identified happy faces reliably quicker in their LVF as compared to the RVF. However, there was a relative lack of asymmetry across visual fields for nondepressed women in their reaction times to happy versus sad faces. Additionally, nondepressed women displayed significantly faster reaction times to sad faces presented to their LVF as opposed to their RVF. In contrast, depressed women displayed a relative lack of asymmetry in reaction times for sad faces across the left and right visual fields.

The main effect of Visual Field was significant, F (1,38) = 5.62, $p < .02$ (see Figure 2). Reaction times were significantly faster in the left as opposed to the right visual field irrespective of the facial affect depicted. Also, the main effect of Slide Affect was significant, F (1,38) = 40.04, $p < .0001$ (see Figure 3). Happy faces were

Figure 1. Group by Visual Field by Slide Affect Interaction for the Reaction Times to Affective Facial Stimuli Presented Tachistoscopically

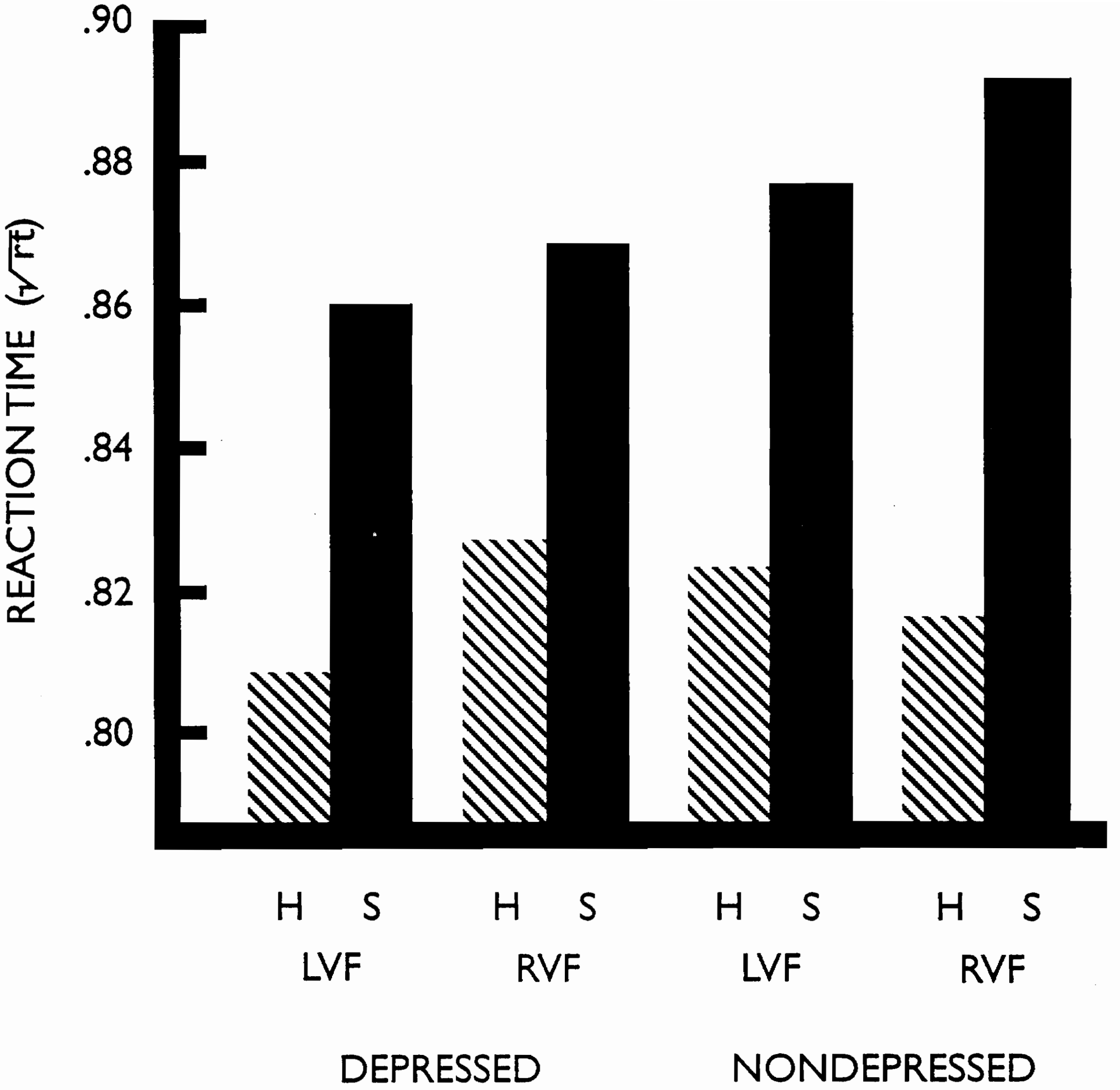

Figure 1. Group by Visual Field by Slide Affect Interaction for the Reaction Times to Affective Facial Stimuli Presented Tachistoscopically

Figure 2. Main Effect of Visual Field for the Reaction Times to Affective Facial Stimuli Presented Tachistoscopically

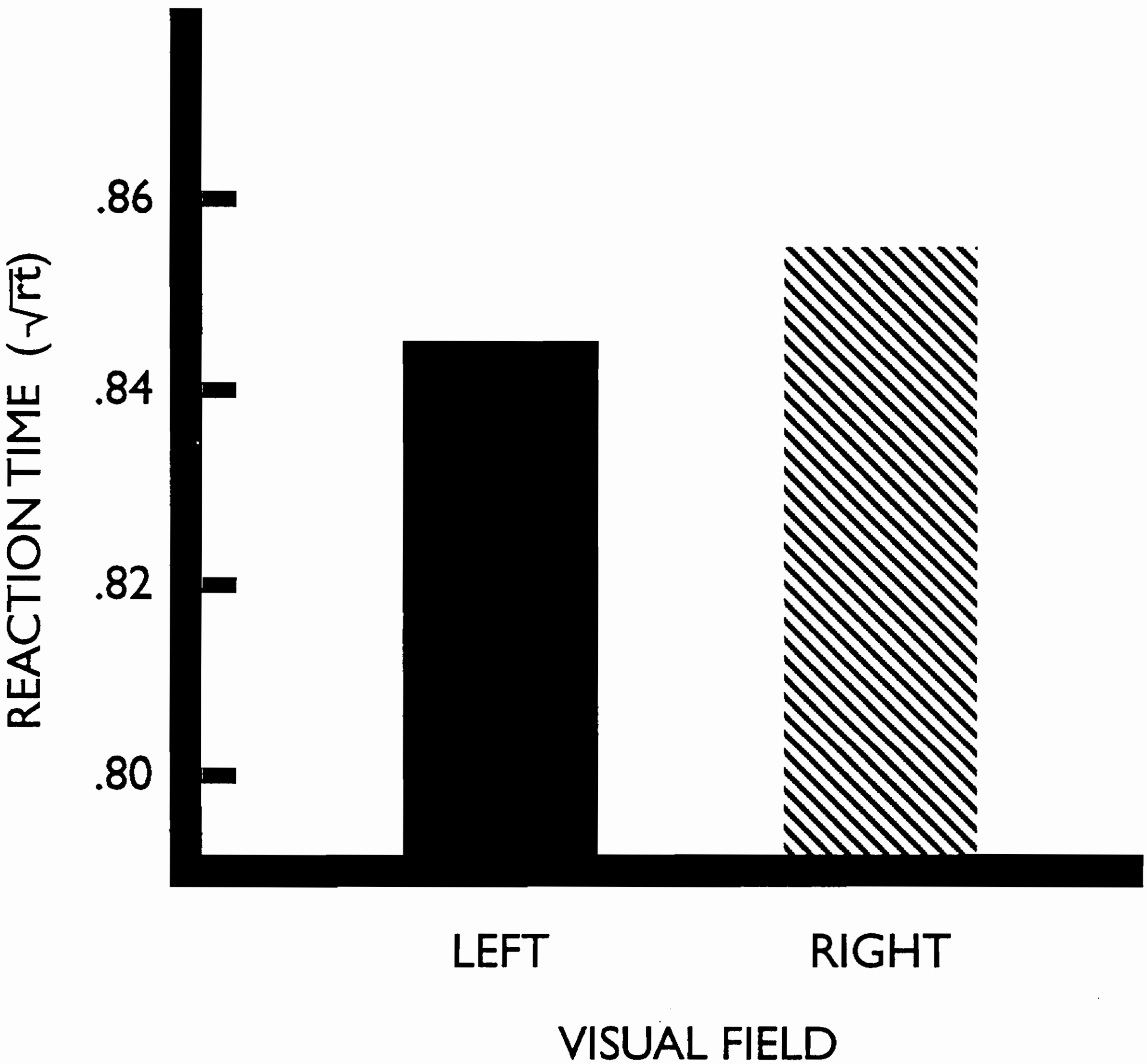

Figure 2. Main Effect of Visual Field for the Reaction Times to Affective Facial Stimuli Presented Tachistoscopically

Figure 3. Main Effect of Slide Affect for the Reaction Times to Affective Facial Stimuli Presented Tachistoscopically

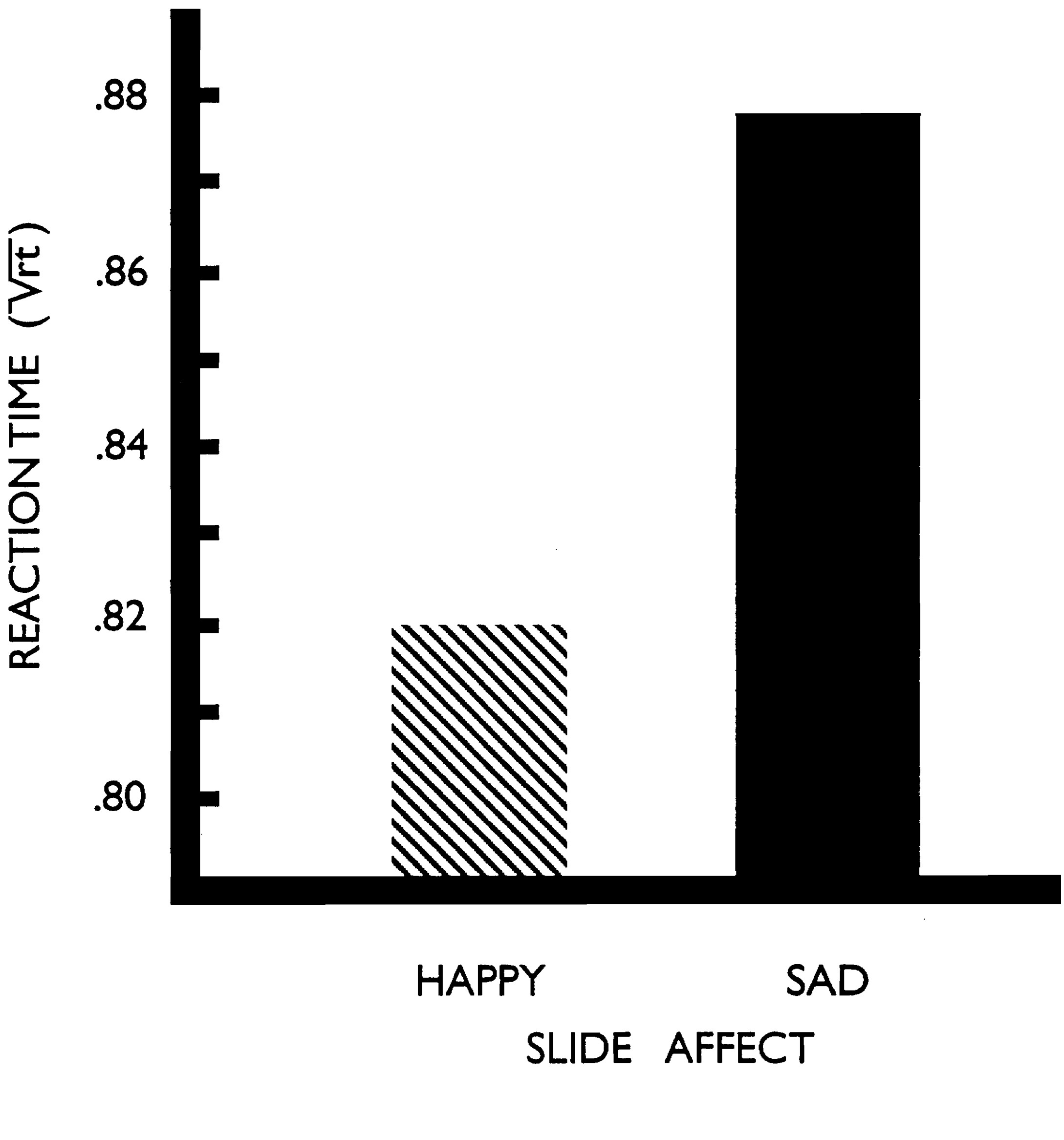

Figure 3. Main Effect of Slide Affect for the Reaction Times to Affective Facial Stimuli Presented Tachistoscopically

identified more rapidly than sad faces irrespective of visual field. Descriptively, the depressed group made a total of 35 errors in the identification of affective valence as compared to 29 total valence identification errors for the nondepressed group. There was no significant between-group difference in error rates.

The reaction time and reported affect data for the neutral facial slides were analyzed in separate ANOVAs using the square root of the reaction time and the reported affect, respectively, as the dependent variables. The reaction time ANOVA revealed a significant main effect of Visual Field, $\underline{F}$ (1,38) = 8.79, $\underline{p}$ < .005 (see Figure 4). Specifically, women displayed significantly faster reaction times to neutral slides presented their RVF as compared to the LVF irrespective of the reported affect. Additionally, the Reported Affect Analysis revealed a reliable main effect of Visual Field, $\underline{F}$ (1,38) = 15.17, $\underline{p}$ < .0004 (see Figure 5). Women tended to identify neutral slides as being sad more often in the RVF as compared to the LVF.

No other reliable interaction or main effects were found in any of the tachistoscopic reaction time or reported affect analyses.

Dynamometer

For the hand dynamometer measures, separate analyses of variance were conducted for the perseveration, fatigue, and grip strength data. All post hoc, pairwise comparisons of

Figure 4. Main Effect of Visual Field for the Reaction Times to Neutral Facial Stimuli Presented Tachistoscopically

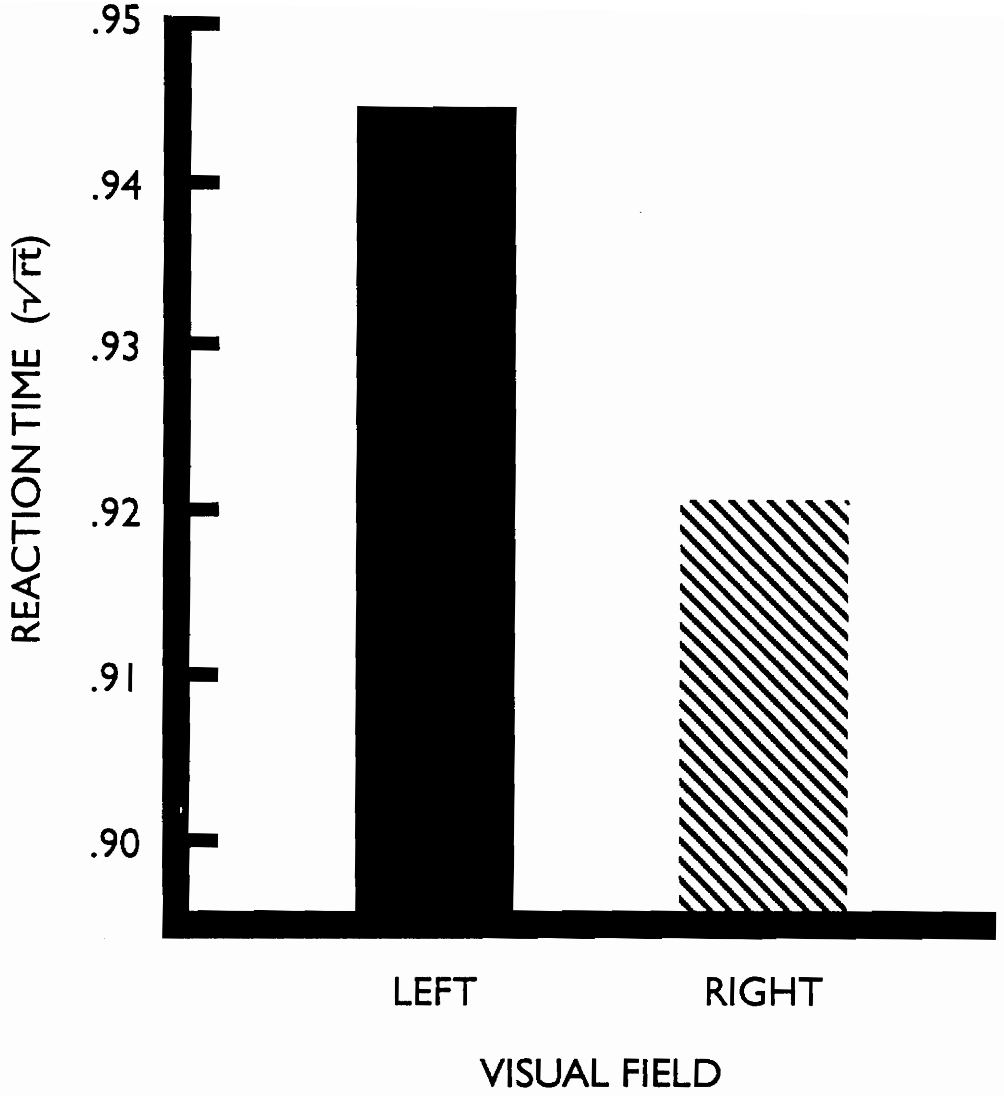

Figure 4. Main Effect of Visual Field for the Reaction Times to Neutral Facial Stimuli Presented Tachistoscopically

Figure 5. Main Effect of Reported Affect for the Neutral Facial Stimuli Presented Tachistoscopically

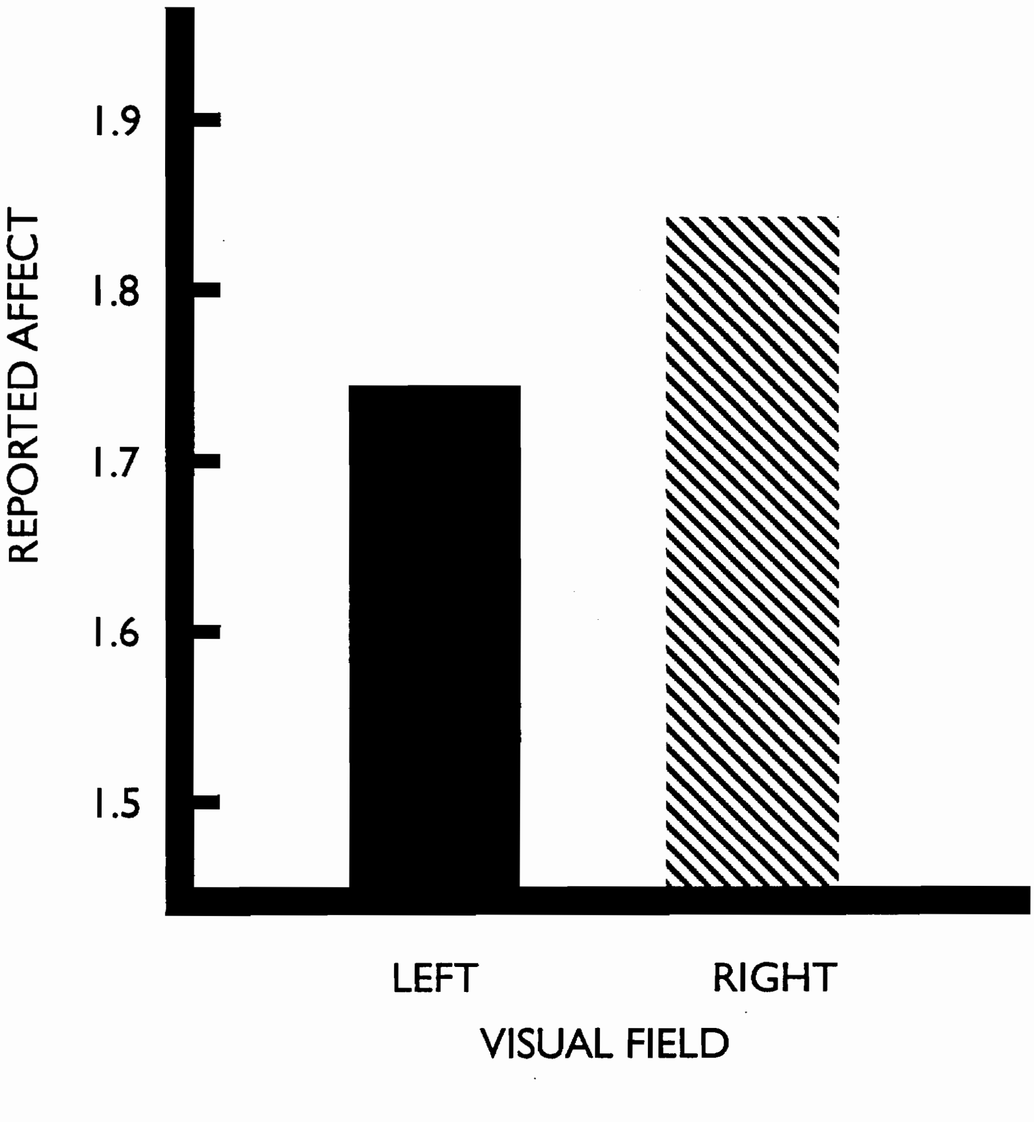

Figure 5. Main Effect of Reported Affect for the Neutral Facial Stimuli Presented Tachistoscopically

the means were made using Tukey's Studentized Range Test. Table 2 provides an overview of all significant dynamometer data results.

The percentage change scores (from Trial 1 to Trial 2) were used as the dependent variable in the Analysis of Perseveration data via a two-factor Analysis of Variance with fixed factors of group (depressed and nondepressed) and hand (left and right). Perseveration was defined as an inaccurate half grip-strength response where there is a tendency to repeat the full grip-strength response (Harrison & Pauly, 1990). The "percent- change" scores for each hand were generated using the following formula:

$$\% \text{ CHANGE} = \frac{\text{HARD} - \text{HALF}}{\text{HARD}} \times 100$$

If the percent-change score equaled 50, the hard to half as hard score was perfect (Huntzinger, 1989). A score less than 50 reflected an inaccurate, perseveration response with greater perseveration denoted by lower scores (Huntzinger, 1989).

The Group x Hand interaction was found to be significant, F (1,76) = 14.92, $p < .001$ (see Figure 6). Specifically, post hoc analyses revealed that depressed women as compared to nondepressed women displayed reliably

Table 2. Summary of Dynamometer Results

TABLE 2

Summary of Dynamometer Results

Source	dF	SS	MS	F	p
Perseveration (% change)					
Group	(1,76)	1197.22	1197.22	6.30	<.025 *
Hand	(1,76)	1564.149	1564.149	8.23	<.01 *
Group x Hand	(1,76)	2834.488	2834.499	14.92	<.001 *
Fatigue (T1-T5)					
Group	(1,38)	129.960	129.960	.93	<.34
Hand	(1,38)	864.360	864.360	64.26	<.0001*
Group x Hand	(1,38)	1.690	1.690	.13	<.73
Trial	(4,304)	278.8850	69.7213	32.63	<.0001*
Hand x Trial	(4,304)	11.8150	2.9538	1.38	<.24
Group x Hand x Trial	(8,304)	9.000	1.1250	.53	<.84
Full Grip Strength					
Group	(1,38)	49.6125	49.6125	1.96	<.17
Hand	(1,38)	127.5125	127.5125	24.85	<.0001*
Group x Hand	(1,38)	12.0125	12.0125	2.34	<.13

* = significant

Figure 6. Group by Hand Interaction on the Perseveration Task with the Dynamometer

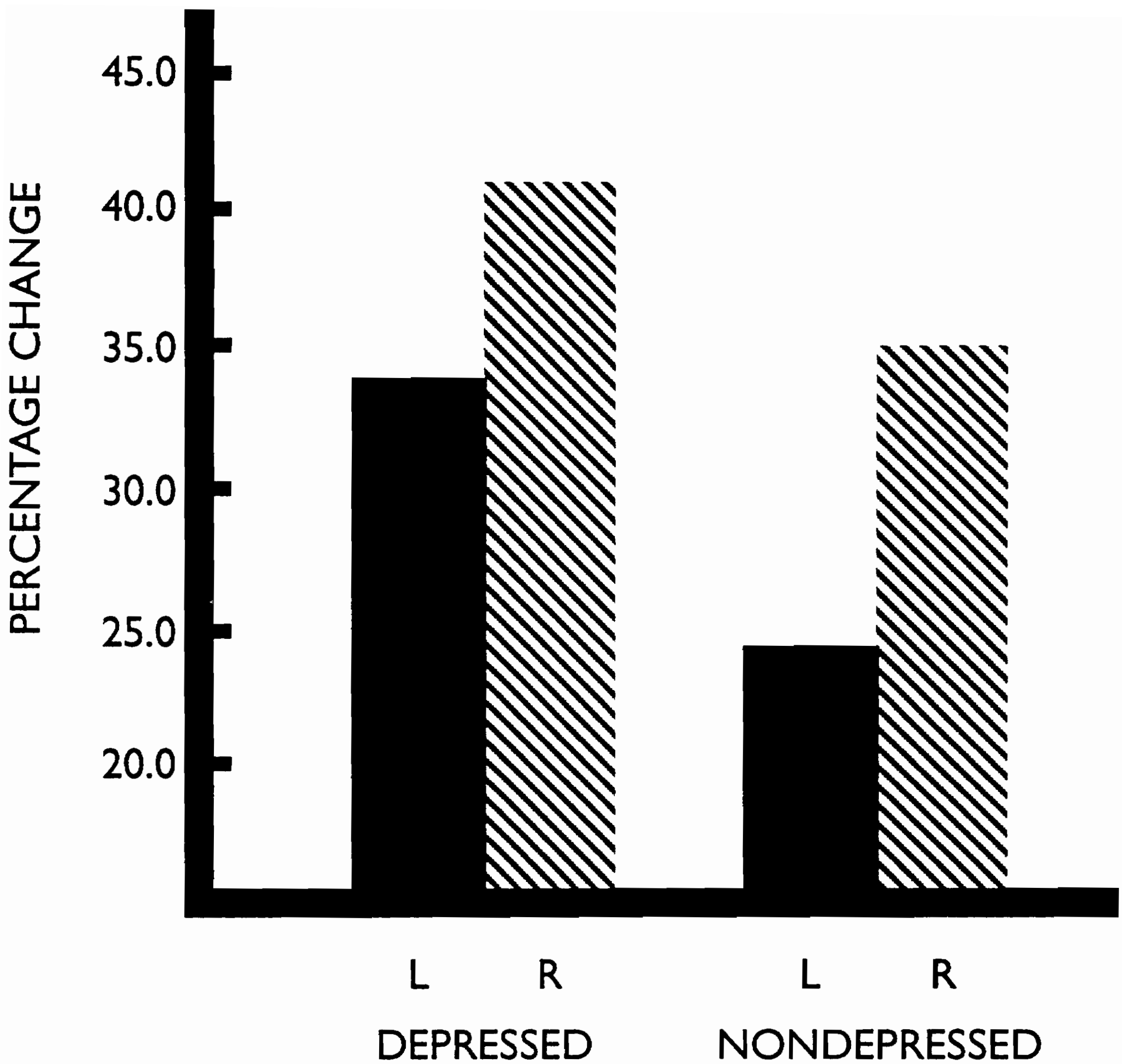

Figure 6. Group by Hand Interaction on the Perseveration Task with the Dynamometer

less perseveration at the left hand. Further, there was a trend, although nonsignificant, for depressed subjects as opposed to nondepressed subjects to show less perseveration at the right hand. Additionally, nondepressed women exhibited significantly less perseveration at the right hand as compared to the left hand. Depressed women, however, displayed less asymmetry as there was no significant perseveration differences between hands.

The main effect of Group was significant, F (1,76) = 6.30, $p < .025$ (see Figure 7). Depressed subjects displayed significantly less perseveration than nondepressed subjects. The main effect of Hand was also significant, F (1,76) = 8.23, $p < .01$ (see Figure 8). Reliably less perseveration was found at the right hand as opposed to the left hand.

For the hand grip fatigue data (in kg.), a three-factor mixed design analysis of variance (ANOVA) with the fixed factor of group (depressed and nondepressed) and with repeated measures of hand (left and right) and trial (1-5) was performed. Fatigue was defined as the amount of decrease in grip-strength seen from trial one to trial five. Thus the score from trial five was subtracted from the score of trial one for each hand to obtain a fatigue score.

The main effect of Hand was significant, F (1,38) = 64.26, $p < .0001$ (see Figure 9). Specifically, grip strength was reliably stronger across trials for the right hand as compared to the left. Additionally, the main effect

Figure 7. Main Effect of Group on the Perseveration Task with the Dynamometer

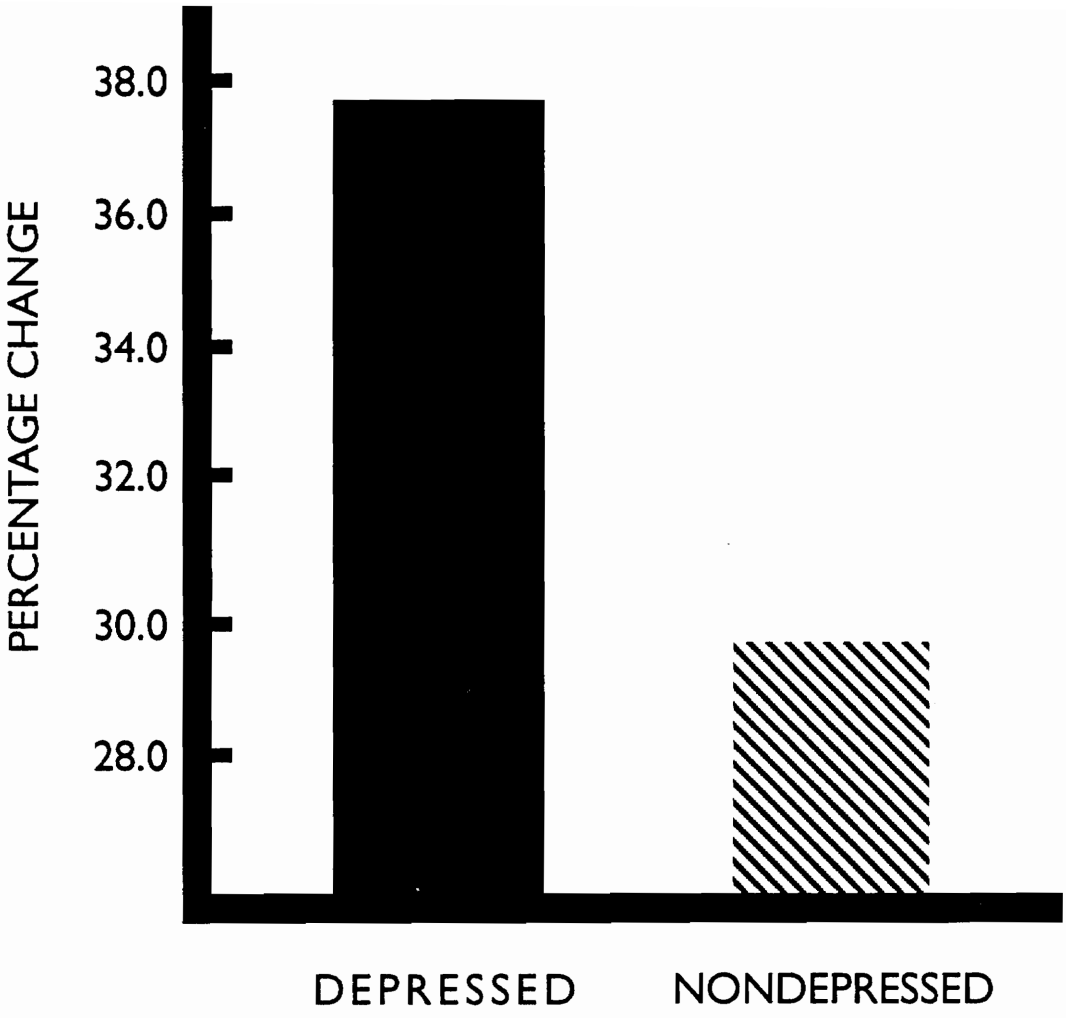

Figure 7. Main Effect of Group on the Perseveration Task with the Dynamometer

Figure 8. Main Effect of Hand on the Perseveration Task with the Dynamometer

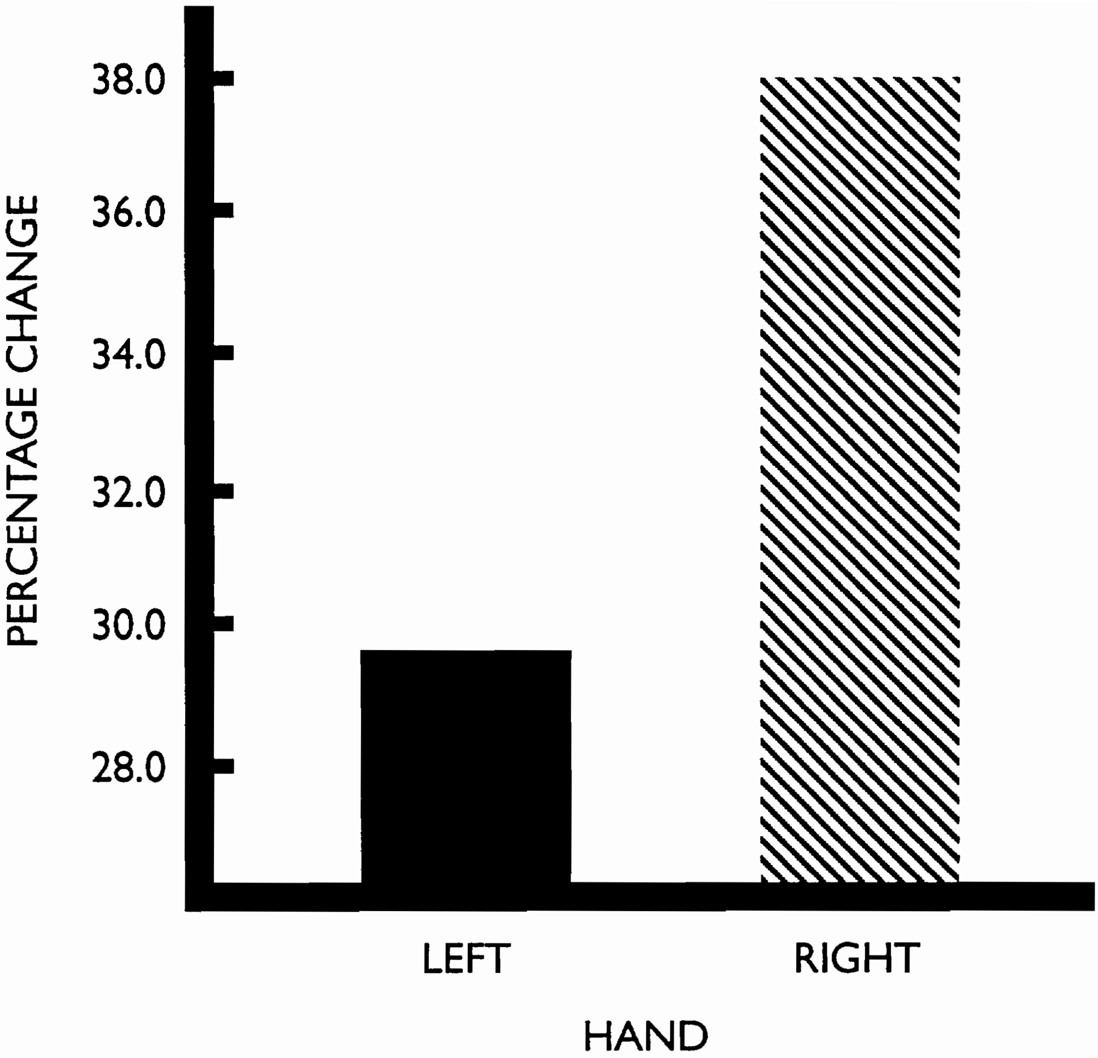

Figure 8. Main Effect of Hand on the Perseveration Task with the Dynamometer

Figure 9. Main Effect of Hand on the Fatigue Task with the Dynamometer

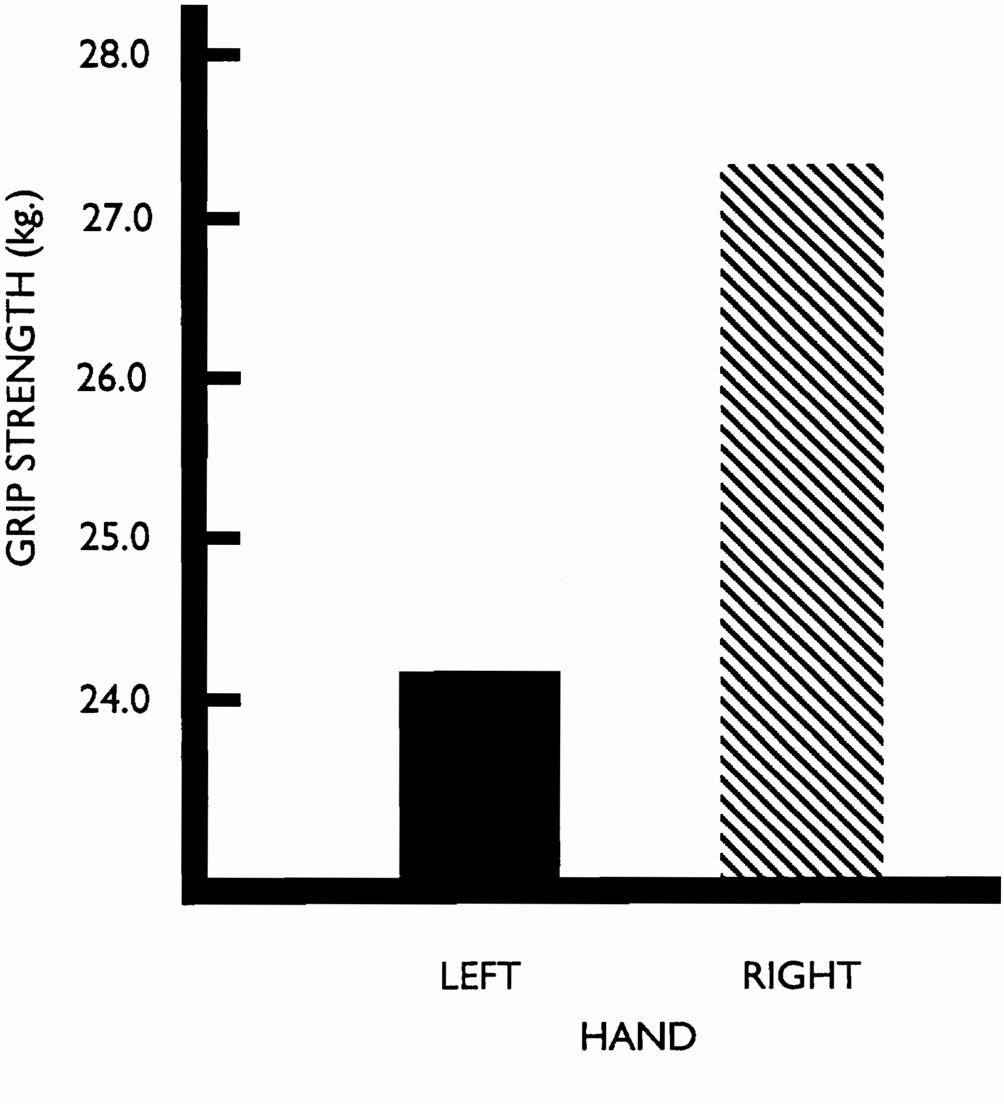

Figure 9. Main Effect of Hand on the Fatigue Task with the Dynamometer

of Trial was significant, F (4,304) = 32.63, p < .0001 (see Figure 10). For Fatigue Trial 1, grip strength was significantly stronger than strength in trials 3, 4, and 5. Likewise, for trial 2, grip strength was reliably stronger than strength in trials 4 and 5. Also, grip strength in trial 3 was significantly stronger than strength found in trial 5.

For the hand grip strength (in kg.) data, a two-factor analysis of variance (ANOVA) with the fixed factors of group (depressed and nondepressed) and hand (left and right) was performed. Only the main effect of Hand was significant, F (1,38) = 24.85, p < .0001 (see Figure 11). Specifically, right hand grip strength was significantly greater than left hand grip strength.

No other interaction or main effects were observed in any of the hand dynamometer analyses.

Additionally, two analyses of variance were performed with the fixed factor of group and the dependent variable of either state or trait anxiety scores. The main effect of Group was significant for the state anxiety scores, F (1,38) = 20.37, p < .0001 (see Figure 12). Specifically, depressed women obtained significantly higher state anxiety scores than did nondepressed women. Similarly, the main effect of Group was significant for the trait anxiety scores, F (1,38) = 30.80, p < .0001 (see Figure 12). Depressed women

Figure 10. Main Effect of Trial on the Fatigue Task with the Dynamometer

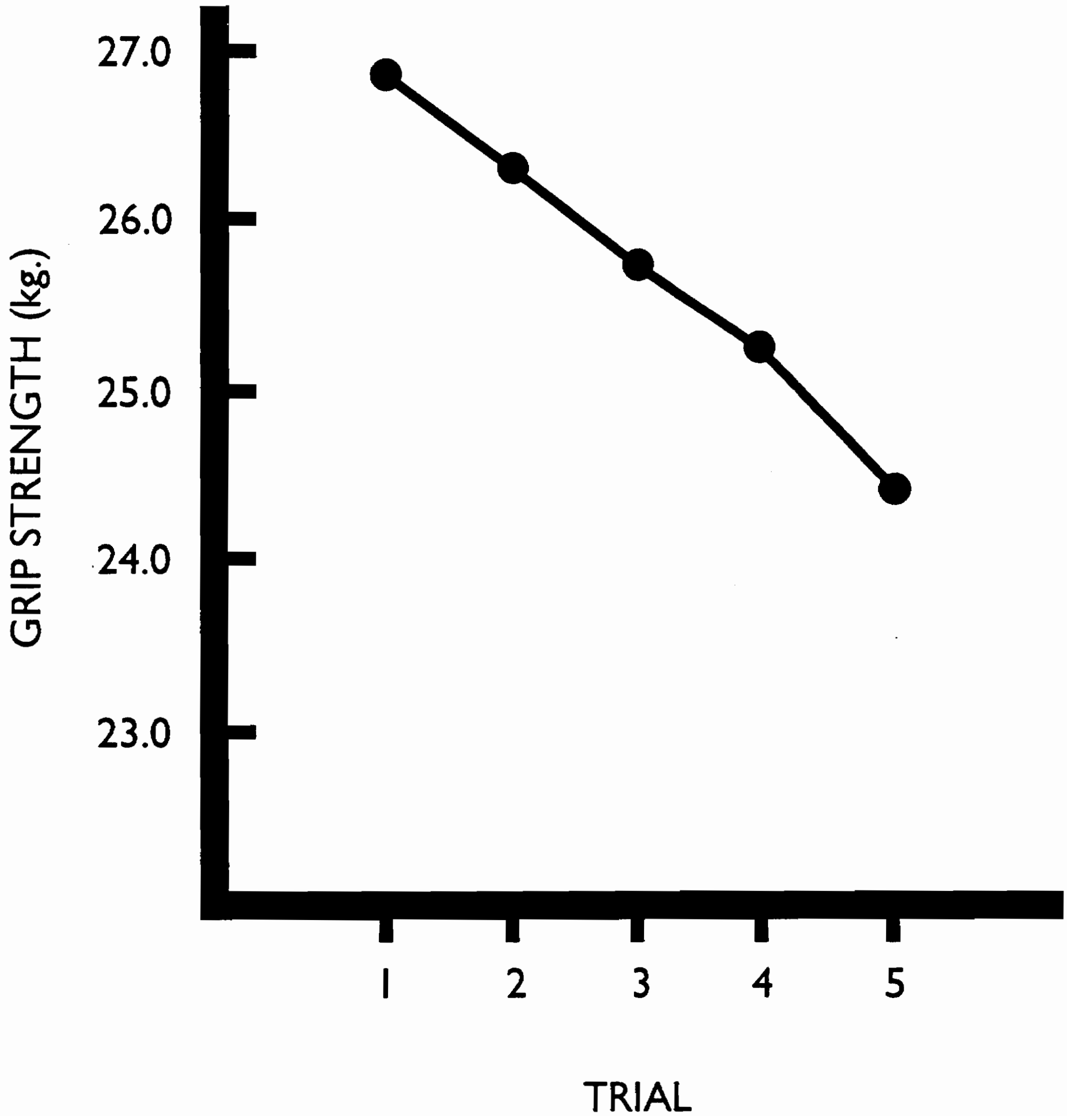

Figure 10. Main Effect of Trial on the Fatigue Task with the Dynamometer

Figure 11. Main Effect of Hand on the Hand Grip Strength Task with the Dynamometer

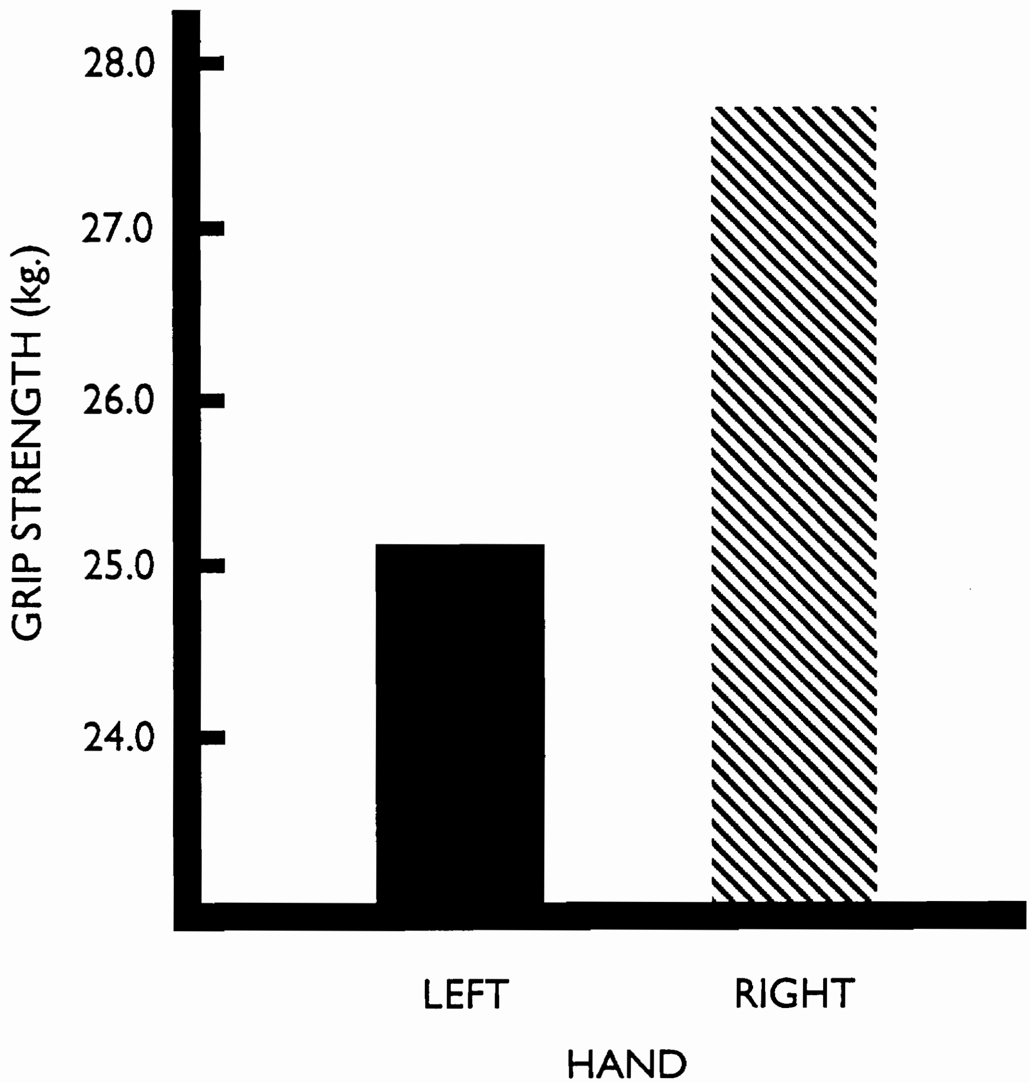

Figure 11. Main Effect of Hand on the Hand Grip Strength Task with the Dynamometer

Figure 12. Main Effect of Group for both the State and Trait Anxiety Scores of the State-Trait Anxiety Inventory

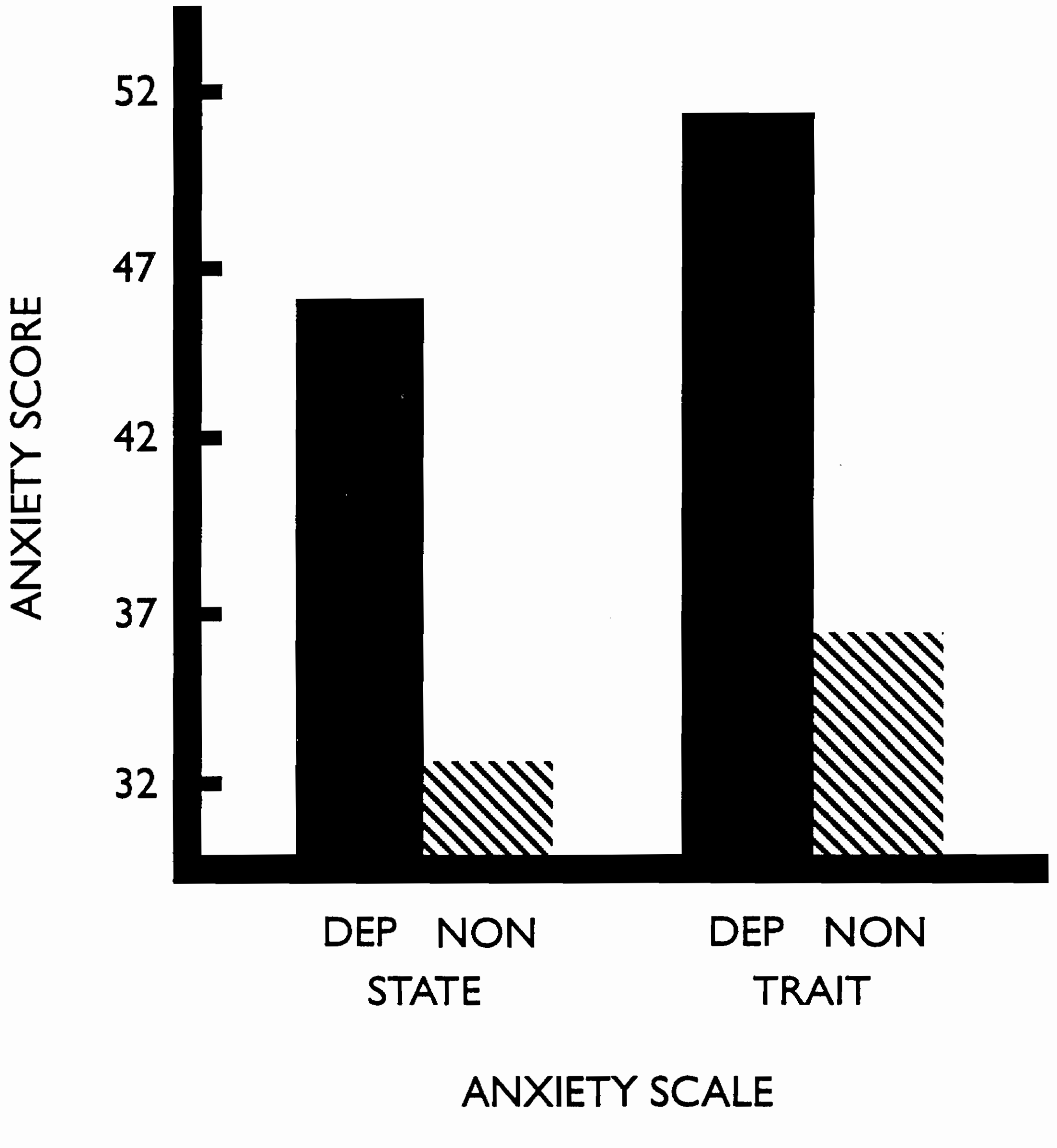

Figure 12. Main Effect of Group for both the State and Trait Anxiety Scores of the State-Trait Anxiety Inventory

received reliably higher trait anxiety scores than did nondepressed women.

Discussion

The primary findings of the present study indicate that the depressed group was characterized by elevated levels of both depression and anxiety as identified by the Beck Depression Inventory and State-Trait Anxiety Inventory. This suggests an anxious, over-aroused depressed group of women which is in contrast to the under-aroused, retarded depression that would be expected in a clinically depressed sample of subjects. This anxious depressed group as opposed to nondepressed women were found to have faster reaction times to affective stimuli and also improved dynamometer performances suggestive of differential arousal of both the left and right hemispheres. Specifically depressed, as compared to nondepressed women, displayed significantly faster reaction times to sad faces presented to their RVF (left cerebral hemisphere). Happy faces were also identified reliably faster when presented to depressed women's LVF (right cerebral hemisphere) as compared to their RVF's and nondepressed women's LVF's. However, for nondepressed women, there was a relative lack of asymmetry for happy faces across their visual fields. Alternatively, nondepressed women exhibited significantly faster reaction times to sad faces presented their LVF's as opposed to their

RVF's. Additionally, depressed women displayed no significant reaction time differences for sad faces across visual fields.

The primary findings for the dynamometer data may also be explained by arousal of the cerebral hemispheres. Specifically, depressed women displayed significantly less perseveration (more accurate half-grip strength) at the left hand as compared to nondepressed women. Further, there was a nonsignificant trend for depressed, as compared to nondepressed women, to show less perseveration at the right hand.

For the tachistoscopic reaction time data, the findings of quicker LVF identification of happy faces and RVF identification of sad faces for depressed women as compared to nondepressed women may indicate differential arousal of both the left and right cerebral hemispheres for depressed women. This hypothesis finds support in arousal theory (Duffy, 1962; Easterbrook, 1959; Hebb, 1955; Harrison & Pavlik, 1983; Lindsley, 1951) where heightened/increased arousal is associated with improved task proficiency up to an optimal level, at which point further increases in arousal may impair performance, especially those which involve complex stimuli and/or require use of a relatively large number of perceptual cues. Alternatively, relatively simple or well-learned tasks/stimuli appear much less susceptible to impairment by high levels of arousal and may actually be facilitated by high arousal as they likely require fewer perceptual cues for task proficiency (Duffy, 1962; Easterbrook, 1959; Hebb, 1955; Lindsley, 1951).

Also, pertinent to this discussion are the findings from previous tachistoscopic studies using Ekman and Friesen's (1976) faces which have indicated that reaction times to happy faces are significantly quicker than reaction times to negatively valenced faces (Harrison, et al, 1990; Harrison & Gorelczenko, 1990; Crews & Harrison, 1992). Hence, as happy face reaction times are already comparably fast, a relatively high level of cerebral arousal may likely be required to further decrease reaction times to happy faces. Additionally, as past studies have indicated that happy faces are more reliably recognized than negatively valenced faces (Ekman & Friesen, 1976), this suggests that happy faces may be easier to identify (less complex) than sad faces. Based on arousal theory, as described above, a significantly increased level of right cerebral arousal may not impair reaction time performances to happy faces but may serve to decrease them. Further, this level of arousal may be too high to result in significant improvement in less recognizable (possibly more complex) stimuli such as sad faces, although it may not be high enough to result in impairment of reaction times for sad faces. Alternatively, reaction times to sad faces may have remained relatively stable as the right hemisphere appears specialized for negative affect (Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz et al., 1983) and may be relatively resilient to the detrimental effects of high arousal on sad (complex) stimuli. Thus, the present study's finding of a significant decrease in reaction time for happy faces presented to depressed women's LVF's may reflect a relatively high level of arousal within the right cerebral hemisphere of depressed as compared to nondepressed women.

Similarly, the present study's findings regarding depressives' quicker reaction times to sad faces presented to their RVF's may also be explained in terms of arousal theory (Dubby, 1962; Easterbrook, 1959; Hebb, 1955; Lindsley, 1951). As negatively valenced faces appear to be more difficult to recognize (possibly more complex) than happy faces (Ekman & Friesen, 1976), a relatively mild to moderate increase in cerebral hemisphere arousal might result in decreased reaction time to sad faces. Hence, the significant decrease in reaction times to sad faces presented to depressed women's RVF may reflect a relatively mild/moderate elevation in left cerebral hemisphere arousal in these women as compared to nondepressed women. Furthermore, it appears that this arousal level was not of sufficient magnitude to promote decreases in RVF reaction times to happy faces as was found in depressives' LVF.

The dynamometer perseveration results also appear to support those found for the tachistoscopic data. The findings of more accurate half-grip strength responses (less perseveration) in depressed women may indicate differential arousal of both cerebral hemispheres with greater arousal within the right as compared to the left hemisphere. Further, the findings appear to provide partial support for the present study's hypothesis of poorer left versus right hemisphere performance in depressed women. However, improvement was found for both hands in depressed versus nondepressed women which suggested activation of both hemispheres instead of the hypothesized relative deactivation of the LH.

Additionally, although nonsignificant, the trends displayed in the full grip strength Group x Hand interaction (Figure 13) further support the conclusion of differential arousal of both cerebral hemispheres. Depressed as opposed to nondepressed women exhibited increased grip strength at both the left and right hands with a relative greater change in grip strength at the left versus the right hand. Thus, these trends also appear to suggest greater right versus left cerebral hemisphere arousal.

Likewise, depressed women displayed significantly less perseveration (higher percent change scores) than did nondepressed women. Hence, the depressed women displayed more accurate judgments of half as hard grip strength than did nondepressed women. These results may also support the hypothesis of increased arousal across the cerebral

Figure 13. Group by Hand Interaction on the Hand Grip Strength Task with the Dynamometer

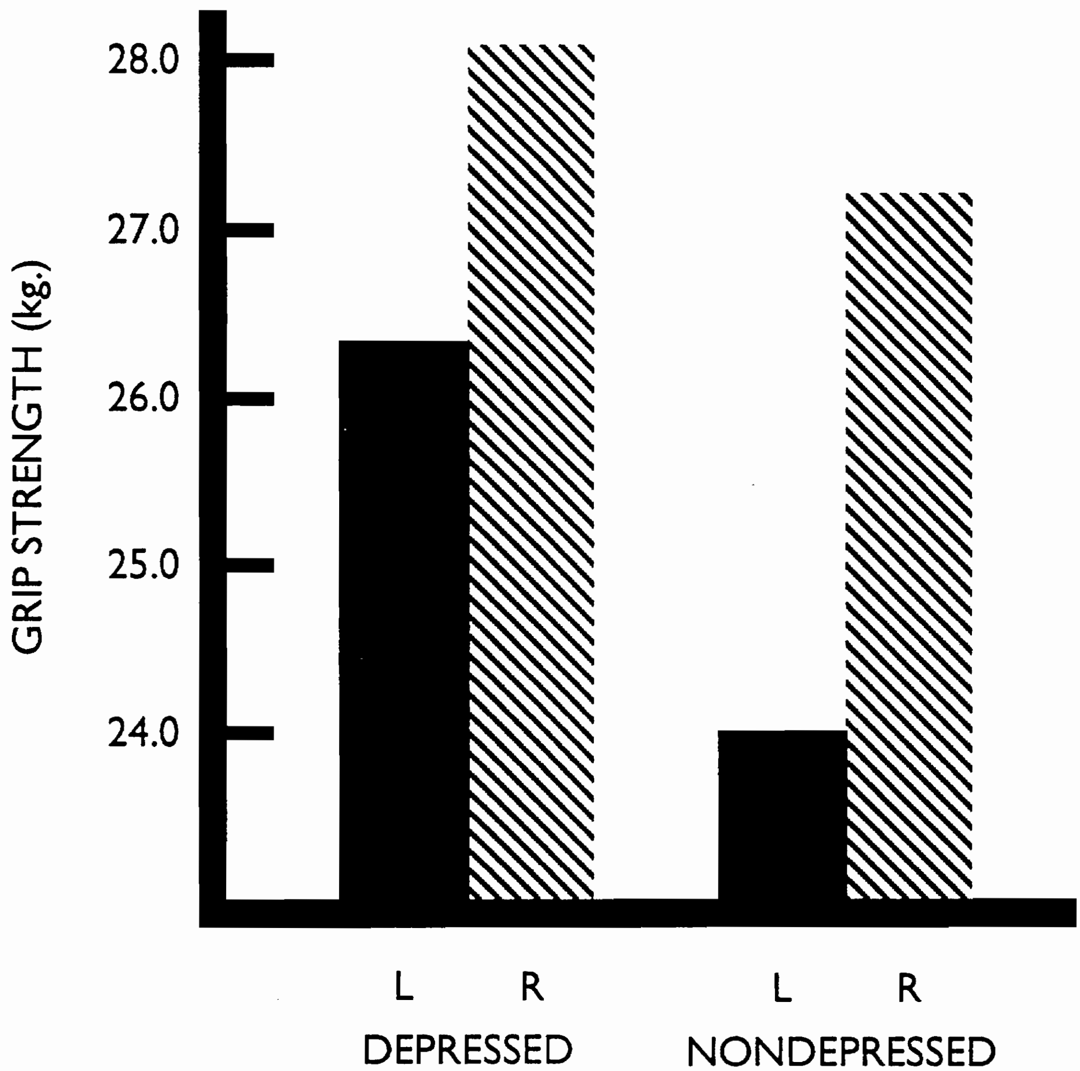

Figure 13. Group by Hand Interaction on the Hand Grip Strength Task with the Dynamometer

hemispheres of depressed as opposed to nondepressed women.

Thus, in summary, these primary findings may reflect that, in depressed women, both left and right cerebral hemispheres are aroused differentially, with higher arousal in the right cerebral hemisphere relative to the left hemisphere. These results appear to support Heilman and colleagues' (Heilman & Van Den Abell, 1979; Heilman et al., 1985) contentions that the right hemisphere plays a dominant role in hemispheric activation/arousal and, also, in mediating emotion. Further, this interpretation appears consistent with a diversity of other neuropsychological research, such as EEG (Tucker et al., 1981; Schaffer et al., 1983), electrodermal, and lateral eye movement (Lenhart & Katkin, 1986) studies which suggest that increased right hemispheric activity, relative to the left hemisphere, is involved in negative affective states and depression (Swartzburg, 1983; Otto et al., 1987).

The present study's findings that nondepressed women identified sad faces reliably faster when presented to their LVF as opposed to their RVF while happy faces were identified more rapidly (and equally) than sad stimuli regardless of visual field support results of previous tachistoscope studies (Crews & Harrison, 1992; Harrison & Gorelczenko, 1990). Further, this finding of bilaterally equal positive, but not negative affect processing supports McKeever's & Dixon's (1981) conclusion that the right hemisphere is specialized for not only visuospatial abilities but for recognition of affective stimuli as well. Likewise, the main effect of faster reaction times to emotional faces in the left versus right visual fields parallels previous studies' findings indicating right hemisphere advantage for the identification of emotional stimuli regardless of valence or group (Buchtel et al., 1976; Harrison & Gorelczenko, 1990). Furthermore, the main effect of slide affect showed that happy faces were identified significantly faster than sad faces irrespective of visual field or group. This supports results of other studies (Crews & Harrison, 1992; Harrison, Gorelczenko, & Cook, 1990; Harrison & Gorelczenko, 1990) where angry faces were used and suggests, as noted above, that happy faces appear to be more easily identified than sad stimuli.

For the neutral slides, significantly faster reaction times were found within the RVF as opposed to the LVF irrespective of the group. Since right-handed women's left hemisphere has been suggested to be dominant for linguistic/verbal abilities, it may be that the faster RVF reaction times represent reliance on left hemisphere verbal strategies to more rapidly identify the ambiguous neutral stimuli. Alternatively, as such verbal strategies are possibly not relied upon within the RH, this may result in the finding of slower identification times for neutral slides presented the LVF. Similarly, as women identified neutral slides as sad more often within the RVF as compared to the LVF, this finding may also indicate reliance on LH verbal strategies. It may be that LH verbal strategies allow women to be more confident that a neutral face presented their RVF is not happy and thus must be sad due to the forced choice paradigm used in this study. Alternatively, if women do not rely on verbal strategies for RH identification of neutral faces, the stimuli presented to the LVF may appear more ambiguous resulting in increased levels of uncertainty and a corresponding decrease in the sad response bias.

Additionally, the main effects for the percentage change scores (perseveration), fatigue, and full grip strength were all significant. Each of these findings indicated significantly better performances (i.e., less perseveration or stronger grip strengths respectively) for women's right hands as compared to their left hands. Since all women in this study had been identified via self-report as right-hand dominant, based on the correlation between such measures and hand proficiency tests (Coran et al., 1979; Bryden, 1982), the results were not unexpected. These findings also replicated results of a previous dynamometer study by Harrison and Pauly (1990). Together the findings may reflect superior left hemisphere motor abilities within these women and the result of daily use/practice with the right hand (Bryden, 1982). Additionally, the main effect of trial was significant for the dynamometer fatigue data. This finding also replicated a result of the Harrison and Pauly (1990) study and suggests that hand grip strength declines over successive trials due to motor fatigue irrespective of the hand (left or right).

As noted above, depressed women, compared to nondepressed, also scored significantly higher on both the state and trait anxiety scales of the State-Trait Anxiety Inventory (Spielberger, 1983). The depressed group's state and trait raw score means placed them at the 75th and 86th percentiles, respectively, while nondepressives obtained state and trait score means at the 39th and 40th percentiles. Thus, depressed women, as opposed to nondepressed women, reported elevated levels of temporary, situational, state anxiety, as well as high levels of relatively stable, long-lasting anxiety-proneness (trait anxiety) (Spielberger, 1983). It should be noted that anxiety is often an associated feature of depression according to DSM-III-R (American Psychiatric Associaton, 1987).

The hypothesized arousal of the cerebral hemispheres in the present study may also be responsible for the findings of elevated anxiety scores in depressed women. Specifically, increased behavioral arousal is closely associated with sympathetic autonomic nervous system (ANS) arousal, which produces such symptoms as increased heart and respiratory rates, tensed muscles, and sweaty palms (Duffy, 1962; Lindsley, 1951). Such ANS symptoms may likely be interpreted as anxiety and result in high self-report levels of anxiety. Hence, the heightened behavioral arousal inferred from the depressed women's tachistoscope and dynamometer performances may be mediated by cerebral mechanisms which, at least indirectly, control ANS arousal and contribute to depressed women's reports of elevated anxiety.

The primary tachistoscope reaction time findings in the present study are in contrast to the present study's prediction of slower reaction times to affective facial stimuli for depressed versus nondepressed women. Further, the hypothesis of a greater sad response bias for depressed as opposed to nondepressed women was also not supported in the current study. It appears that as these hypotheses were based on findings from a study (Crews & Harrison, 1992) of only six depressed and six nondepressed women, the present findings using 20 depressed and 20 nondepressed women may more accurately reflect depressed women's, especially those with agitated, over-aroused features, true responses.

The present study's findings of significant hemispheric asymmetries for emotional processing and motor performances in women appear somewhat surprising in light of the fact that a number of previous studies have had greater difficulty in finding lateralized differences in women versus men (Bryden, 1982; Harrison et al., 1990; Harrison & Gorelczenko, 1990). However, according to Silberman and Weingartner (1986), the evidence of lateralization, especially of emotional processing in women, remains contradictory and inconclusive as some studies have found differential hemispheric processing in women. Thus, this study appears to provide additional support for hemispheric asymmetries in both anxious/depressed and nondepressed women in the processing of affective stimuli and performance of motor tasks.

It should also be noted that there has been a relative lack of studies which have focused exclusively on the neuropsychological functioning of women. Hence direct comparison of the current results with similar studies are difficult at present. Further, it is unknown as how the present data on the anxious/depressed group of women would compare to a retarded depression/clinically depressed group of women. Additionally, it is unknown as to what specific effects (other than slower trial one reaction times) the inclusion of neutral slides may have had on women's performances. For example, the neutral slides may have served as an ambiguous stimuli which may have somehow differentially impacted the processing of happy versus sad faces.

Future research should focus on obtaining answers to these issues. Specifically, anxious, depressed subjects should be compared to a group of clinically depressed women to determine how anxious versus retarded depression may affect cerebral hemispheric processing. Secondly, nondepressed, anxious women should be studied as regards their emotional processing and motor performance cerebral asymmetries. The present study also needs replicating, without the neutral slides, to determine the accuracy of the study's findings without the possible contamination of the neutral slides. Finally, additional, large scale studies need to be conducted with only women to better determine the extent to which they are truly lateralized for motor tasks and the processing of affect.

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Appendix A

Handedness Questionnaire

Subject #:_________

Circle the appropriate number after each item.

	Right	Left	Both
With which hand would you throw a ball to hit a target?	1	-1	0
With which hand do you draw?	1	-1	0
With which hand do you use an eraser on paper?	1	-1	0
With which hand do you remove the top card when dealing?	1	-1	0
With which foot do you kick a ball?	1	-1	0
If you wanted to pick up a pebble with your toes, which foot would you use?	1	-1	0
If you had to step up onto a chair, which foot would you place on the chair first?	1	-1	0
Which eye would you use to peep through a keyhole?	1	-1	0
If you had to look into a dark bottle to see how full it was, which eye would you use?	1	-1	0
Which eye would you use to sight down a rifle?	1	-1	0
If you wanted to listen to a conversation going on behind a closed door, which ear would you place against the door?	1	-1	0
If you wanted to listen to someone's heartbeat, which ear would you place against their chest?	1	-1	0
Into which ear would you place the earphone of a transistor radio?	1	-1	0

# of Right + # of Left = Total Score

_______ + _______ = _______

Is mother left or right hand dominant?_______

Is father left or right hand dominant? _______

NAME ______________________________ DATE ______________

On this questionnaire are groups of statements. Please read each group of statements carefully. Then pick out the one statement in each group which best describes the way you have been feeling the past week, including today! Circle the number beside the statement you picked. If several statements in the group seem to apply equally, circle each one. ***BE SURE TO READ ALL THE STATEMENTS IN EACH GROUP BEFORE MAKING YOU CHOICE. ***

1. 0 I do not feel sad.
   1 I feel sad.
   2 I am sad all the time, and I can't snap out of it.
   3 I am so sad or unhappy that I can't stand it.

2. 0 I am not particularly discouraged about the future.
   1 I feel discouraged about the future.
   2 I feel I have nothing to look forward to.
   3 I feel that the future is hopeless and that things cannot improve.

3. 0 I do not feel like a failure.
   1 I feel I have failed more than the average person.
   2 As I look back on my life, all I can see is a lot of failures.
   3 I feel I am a complete failure as a person.

4. 0 I get as much satisfaction out of things as I used to.
   1 I don't enjoy things the way I used to.
   2 I don't get real satisfaction out of anything anymore.
   3 I am dissatisfied or bored with everything.

5. 0 I don't feel particularly guilty.
   1 I feel guilty a good part of the time.
   2 I feel guilty most of the time.
   3 I feel guilty all of the time.

6. 0 I don't feel I am being punished.
   1 I feel I may be punished.
   2 I expect to be punished.
   3 I feel I am being punished.

7. 0 I don't feel disappointed in myself.
   1 I am disappointed in myself.
   2 I am disgusted with myself.
   3 I hate myself.

over please

8. 0 I don't feel any worse than anybody else.
   1 I am critical of myself for my weaknesses or mistakes.
   2 I blame myself all the time for my faults.
   3 I blame myself for everything bad that happens.

9. 0 I don't have any thoughts of killing myself.
   1 I have thoughts of killing myself, but I would not carry them out.
   2 I would like to kill myself.
   3 I would kill myself if I had the chance.

10. 0 I don't cry any more than usual.
   1 I cry more now than I used to.
   2 I cry all the time now.
   3 I used to be able to cry, but now I can't cry even though I want to.

11. 0 I am no more irritated now than I ever am.
   1 I get annoyed or irritated more easily than I used to.
   2 I feel irritated all the time now.
   3 I don't get irritated at all by the things that used to irritate me.

12. 0 I have not lost interest in other people.
   1 I am less interested in other people than I used to be.
   2 I have lost most of my interest in other people.
   3 I have lost all of my interest in other people.

13. 0 I make decisions about as well as I ever could.
   1 I put off making decisions more than I used to.
   2 I have greater difficulty in making decisions than ever before.
   3 I can't make decisions at all anymore.

14. 0 I don't feel I look any worse than I used to.
   1 I am worried that I am looking old or unattractive.
   2 I feel that there are permanent changes in my appearance that make me look unattractive.
   3 I believe that I look ugly.

15. 0 I can work about as well as before.
   1 It takes an extra effort to get started at doing something.
   2 I have to push myself very hard to do anything.
   3 I can't do any work at all.

over please

16. 0 I can sleep as well as usual.
    1 I don't sleep as well as I used to.
    2 I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
    3 I wake up several hours earlier than I used to and cannot get back to sleep.

17. 0 I don't get more tired than usual.
    1 I get tired more easily than I used to.
    2 I get tired from doing almost anything.
    3 I am too tired to do anything.

18. 0 My appetite is no worse than usual.
    1 My appetite is not as good as it used to be.
    2 My appetite is much worse now.
    3 I have no appetite at all anymore.

19. 0 I haven't lost much weight, if any, lately.
    1 I have lost more than 5 pounds.
    2 I have lost more than 10 pounds.
    3 I have lost more than 15 pounds.
*** > I am purposefully trying to lose weight by eating less YES_____,NO_____.

20. 0 I am no more worried about my health than usual.
    1 I am worried about my physical problems such as aches and pains; or upset stomach; or constipation.
    2 I am very worried about physical problems and it's hard to think of much else.
    3 I am so worried about my physical problems that I cannot think about anything else.

21. 0 I have not noticed any recent change in my interest in sex.
    1 I am less interested in sex than I used to be.
    2 I am much less interested in sex now.
    3 I have lost interest in sex completely.

SELF-EVALUATION QUESTIONNAIRE

Developed by Charles D. Spielberger
in collaboration with
R. L. Gorsuch, R. Lushene, P. R. Vagg, and G. A. Jacobs

STAI Form Y-1

Name ______________________ Date __________ S ____

Age __________ Sex: M ____ F ____ T ____

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	①	②	③	④
2. I feel secure	①	②	③	④
3. I am tense	①	②	③	④
4. I feel strained	①	②	③	④
5. I feel at ease	①	②	③	④
6. I feel upset	①	②	③	④
7. I am presently worrying over possible misfortunes	①	②	③	④
8. I feel satisfied	①	②	③	④
9. I feel frightened	①	②	③	④
10. I feel comfortable	①	②	③	④
11. I feel self-confident	①	②	③	④
12. I feel nervous	①	②	③	④
13. I am jittery	①	②	③	④
14. I feel indecisive	①	②	③	④
15. I am relaxed	①	②	③	④
16. I feel content	①	②	③	④
17. I am worried	①	②	③	④
18. I feel confused	①	②	③	④
19. I feel steady	①	②	③	④
20. I feel pleasant	①	②	③	④

Consulting Psychologists Press
577 College Avenue, Palo Alto, California 94306

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

Name ______________________________ Date ______________

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21. I feel pleasant	①	②	③	④
22. I feel nervous and restless	①	②	③	④
23. I feel satisfied with myself	①	②	③	④
24. I wish I could be as happy as others seem to be	①	②	③	④
25. I feel like a failure	①	②	③	④
26. I feel rested	①	②	③	④
27. I am "calm, cool, and collected"	①	②	③	④
28. I feel that difficulties are piling up so that I cannot overcome them	①	②	③	④
29. I worry too much over something that really doesn't matter	①	②	③	④
30. I am happy	①	②	③	④
31. I have disturbing thoughts	①	②	③	④
32. I lack self-confidence	①	②	③	④
33. I feel secure	①	②	③	④
34. I make decisions easily	①	②	③	④
35. I feel inadequate	①	②	③	④
36. I am content	①	②	③	④
37. Some unimportant thought runs through my mind and bothers me	①	②	③	④
38. I take disappointments so keenly that I can't put them out of my mind	①	②	③	④
39. I am a steady person	①	②	③	④
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	①	②	③	④

Appendix D

HISTORY QUESTIONNAIRE

NAME: ______________________________ AGE: __________

Have you ever experienced or been diagnosed with any of the following, or are you experiencing any of the following at present?

Please circle the appropriate response and explain "Yes" answers below.

1. Vision difficulties, blurred vision or eye disorders	Yes	No
2. Blindness in either eye	Yes	No
3. If Yes to either of the above, have problems been corrected	Yes	No
4. Severe head trauma/injury	Yes	No
5. Stroke	Yes	No
6. Learning disabilities (problems of reading, writing, or comprehension)	Yes	No
7. Epilepsy or seizures	Yes	No
8. Paralysis	Yes	No
9. Neurological surgery	Yes	No

Please explain any "Yes" responses:

____

____

____

Appendix E

INFORMED CONSENT STATEMENT

This form is to certify that I volunteer to participate in a scientific investigation into how quickly and accurately I respond to stimuli of happy and sad faces presented to my left and right visual fields and also measures of my hand grip strength with the left and right hands. This form will provide you with information about the study and answer questions you may have.

In this experiment you will be asked to fill out a series of questionnaires. These questionnaires will assess your handedness, depressive symptomatology, anxiety level, and history of neuropsychological and eyesight disorders. You will then be asked to identify the valence of emotional faces presented to your left and right visual fields. Finally your hand grip strength will be assessed via a hand-held dynamometer. The research will be conducted by W. David Crews, Jr. and David W. Harrison, Ph.D. The whole process should be about one hour.

Factors Affecting Informed Consent

1. I have had the study described to me, knowing that I will be asked to push buttons to indicate that I have perceived happy or sad faces and also asked to squeeze a hand dynamometer to measure grip strength. I have had all my questions answered, realizing that this experiment is an evaluation of cognitive functioning and neuropsychological correlates.

2. To the best of my knowledge I have not had any brain damage or concussions that might interfere with the experiment.

3. The tests are purely evaluative, so there are no risks involved. However, in case of any discomfort, you may stop at any point without prejudice or penalty.

4. By testing your reactions to affective stimuli and voluntary motor responses, new insights into the differences between the right and left hemisphere processing will be better understood. Also, if you would like your results, the information will be made available to you upon your request.

5. Since response procedures should pose no problems to anyone in the study, no alternative treatments are foreseen.

6. Your responses in this experiment will remain anonymous and confidential. Your name or any identity-related information will not be used in any way. The exception to this confidentiality is if you indicate (verbally or via questionnaire) that you are planning to hurt or kill yourself. If this occurs, we are bound by law to refer/obtain help for you to prevent such acts.

7. If you are currently enrolled in Introductory Psychology, you will receive one point extra credit toward your final grade for your participation in the session.

8. All subjects must be 18 years of age or older or obtain written parental permission to participate in this study.

This research project has been approved by the Human Subjects Research Committee and the Institutional Review Board and any questions you may have about this experiment should be directed to W. David Crews, Jr. at 953-5516 or David W. Harrison, Ph.D. at 231-4422.

I hereby certify that I have read this informed consent statement and that I understand the procedures, risks, and potential benefits involved in this study. I voluntarily agree to participate in the research project described above and under the conditions listed above. A copy of this form has been given to me.

Signature ____ Date ______

I.D.# ____

Appendix F

T-SCOPE PRACTICE SLIDES DATA SHEET

Subject ______________ Handedness ______________

BDI (Group) ______________ BDI (Test Session) __________

Present Order	Slide	Affect Response	Reaction Time	Present Order	Slide	Affect Response	Reaction Time
1	17, SR	_____	_____	11	9, SL	_____	_____
2	15, HR	_____	_____	12	12, HR	_____	_____
3	8, SL	_____	_____	13	7, SL	_____	_____
4	5, HL	_____	_____	14	3, HL	_____	_____
5	13, HR	_____	_____	15	11, HR	_____	_____
6	2, HL	_____	_____	16	19, SR	_____	_____
7	20, SR	_____	_____	17	6, SL	_____	_____
8	1, HL	_____	_____	18	18, SR	_____	_____
9	16, SR	_____	_____	19	14, HR	_____	_____
10	10, SL	_____	_____	20	4, HL	_____	_____

Appendix G

T-SCOPE SLIDES DATA SHEET

ORDER 1

Subject ____________________ Date ________________________

Age ________________________ Handedness __________________

BDI (Group) ________________ BDI (Test Session) __________

STAI-S _____________________ STAI-T ______________________

Present Order	Slide	Affect Response	Reaction Time	Present Order	Slide	Affect Response	Reaction Time
1	3, HL	______	______	31	51, NR	______	______
2	32, HR	______	______	32	7, HL	______	______
3	59, NR	______	______	33	49, SR	______	______
4	47, SR	______	______	34	43, SR	______	______
5	5, HL	______	______	35	23, NL	______	______
6	34, HR	______	______	36	50, SR	______	______
7	13, SL	______	______	37	22, NL	______	______
8	54, NR	______	______	38	16, SL	______	______
9	14, SL	______	______	39	40, HR	______	______
10	26, NL	______	______	40	46, SR	______	______
11	33, HR	______	______	41	21, NL	______	______
12	41, SR	______	______	42	39, HR	______	______
13	18, SL	______	______	43	6, NL	______	______
14	53, NR	______	______	44	60, NR	______	______
15	17, SL	______	______	45	8, HL	______	______
16	25, NL	______	______	46	36, HR	______	______
17	37, HR	______	______	47	12, SL	______	______
18	20, SL	______	______	48	9, HL	______	______
19	44, SR	______	______	49	30, NL	______	______
20	24, NL	______	______	50	38, HR	______	______
21	52, NR	______	______	51	56, NR	______	______
22	19, SL	______	______	52	10, HL	______	______
23	57, NR	______	______	53	55, NR	______	______
24	27, NL	______	______	54	1, HL	______	______
25	45, SR	______	______	55	48, SR	______	______
26	4, HL	______	______	56	11, SL	______	______
27	29, NL	______	______	57	35, HR	______	______
28	42, SR	______	______	58	15, SL	______	______
29	58, NR	______	______	59	2, HL	______	______
30	28, NL	______	______	60	31, HR	______	______

Response Key Order: H/S or S/H

T-SCOPE SLIDES DATA SHEET

ORDER 2

Subject ____________ Date ____________

Age ____________ Handedness ____________

BDI (Group) ____________ BDI (Test Session) ____________

STAI-S ____________ STAI-T ____________

Present Order	Slide	Affect Response	Reaction Time	Present Order	Slide	Affect Response	Reaction Time
1	10, HL	____	____	31	59, NR	____	____
2	40, HR	____	____	32	19, SL	____	____
3	26, NL	____	____	33	56, NR	____	____
4	45, SR	____	____	34	48, SR	____	____
5	36, HR	____	____	35	11, SL	____	____
6	24, NL	____	____	36	37, HR	____	____
7	39, HR	____	____	37	27, NL	____	____
8	53, NR	____	____	38	43, SR	____	____
9	28, NL	____	____	39	57, NR	____	____
10	47, SR	____	____	40	9, HL	____	____
11	4, HL	____	____	41	42, SR	____	____
12	41, SR	____	____	42	21, NL	____	____
13	2, HL	____	____	43	38, HR	____	____
14	54, NR	____	____	44	20, SL	____	____
15	17, SL	____	____	45	55, NR	____	____
16	51, NR	____	____	46	30, NL	____	____
17	1, HL	____	____	47	12, SL	____	____
18	46, SR	____	____	48	58, NR	____	____
19	6, HL	____	____	49	31, HR	____	____
20	52, NR	____	____	50	5, HL	____	____
21	3, HL	____	____	51	33, HR	____	____
22	49, SR	____	____	52	15, SL	____	____
23	29, NL	____	____	53	32, HR	____	____
24	34, HR	____	____	54	25, NL	____	____
25	60, NR	____	____	55	18, SL	____	____
26	16, SL	____	____	56	8, HL	____	____
27	7, HL	____	____	57	35, HR	____	____
28	44, SR	____	____	58	13, SL	____	____
29	23, NL	____	____	59	22, NL	____	____
30	14, SL	____	____	60	50, SR	____	____

Response Key Order: H/S or S/H

Appendix H

Dynamometer Task

Administration--Perseveration

INSTRUCT: I WANT YOU TO SQUEEZE THIS AS HARD AS YOU CAN WITH YOUR RIGHT HAND, AND THEN I AM GOING TO ASK YOU TO SQUEEZE IT JUST HALF AS HARD.

DO: Test right hand with scale turned away from the subject.

INSTRUCT: NOW I WANT YOU TO DO THE SAME THING WITH YOUR LEFT HAND.

DO: Test left hand with scale turned away from the subject.

Administration--Strength and Fatigue

INSTRUCT: NOW I WANT YOU TO SQUEEZE IT AS HARD AS YOU CAN WITH YOUR RIGHT HAND FIVE TIMES. I WILL TAKE A READING AFTER EACH TRIAL.

DO: Keep scale turned away from the subject, score, and reset your scale for the five trials.

INSTRUCT: NOW I WANT YOU TO SQUEEZE IT AS HARD AS YOU CAN WITH YOUR LEFT HAND FIVE TIMES.

DO: Keep scale turned away from the subject, score, and reset scale for the five trials.

DYNAMOMETER DATA RECORD

SUBJECT:____________________________________

RIGHT __________; RIGHT (1/2) __________.

LEFT __________; LEFT (1/2) __________.

TRIAL	RIGHT HAND	TRIAL	LEFT HAND
1	__________	1	__________
2	__________	2	__________
3	__________	3	__________
4	__________	4	__________
5	__________	5	__________

Appendix I

Tachistoscopic Reaction Time Data Trial

Means and Standard Deviations

Happy/Sad Affects

Trial	Raw Reaction Times Mean	Raw Reaction Times S.D.	Transformed Reaction Times ($\sqrt{rt}$) Mean	Transformed Reaction Times ($\sqrt{rt}$) S.D.
1	.79892	.2598	.88412	.1318
2	.75069	.2164	.85909	.1120
3	.74983	.2510	.85569	.1335
4	.71546	.2045	.83845	.1117
5	.74342	.2649	.85113	.1387
6	.73434	.2499	.84676	.1321
7	.76773	.3021	.86324	.1499
8	.75746	.2786	.85824	.1453
9	.72248	.2555	.83947	.1333
10	.72084	.2567	.83832	.1340

Neutral Affects

Trial	Raw Reaction Times Mean	Raw Reaction Times S.D.	Transformed Reaction Times ($\sqrt{rt}$) Mean	Transformed Reaction Times ($\sqrt{rt}$) S.D.
1	.89110	.4016	.92507	.1834
2	.88624	.4228	.91865	.1949
3	.94964	.4465	.95512	.1943
4	.96630	.4414	.96090	.2058
5	.90069	.3529	.93263	.1716
6	1.00410	.4111	.98295	.1893
7	.84399	.2708	.90816	.1395
8	.84175	.3266	.90235	.1673
9	.85041	.2853	.90992	.1499
10	.88185	.3152	.92538	.1604

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BOOK CHAPTERS

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