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Right Hemisphere Theory and The Valence Theory: A Closer Look at How Gender Infleunces Emotional Processing

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RIGHT HEMISPHERE THEORY AND THE VALENCE THEORY: A CLOSER LOOK AT HOW GENDER INFLUENCES EMOTIONAL PROCESSING

by

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Right hemisphere theory and the valence theory: A closer look at how gender influences emotional processing

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Abstract

Research suggests that gender can influence the lateralization of emotional processing. Specifically, women exhibit more bilateral activation while men are more strongly lateralized. The current study sought to investigate the influence of gender on emotional processing. The lateralized Emotional Stroop Task (EST) was used to present 50 male and female participants with positive, negative, and neutral words in one of four different colours to the right visual field or the left visual field. Participants had to indicate the colour that each word was printed in. Participants were more accurate at indicating the colour of negative words relative to other words. We did not find any significant main effects for reaction time latencies. The results suggest that there are no laterality differences with respect to how men and women process emotional words. The findings also question the usefulness of the lateralized EST as a measure of automatic emotional processing in normals.

Acknowledgments

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List of Abbreviations

ANEW	Affective Norms for English Words
BOLD	Blood-oxygen-level dependence
EEG	Electroencephalograph
EST	Emotional Stroop Task
fMRI	Functional Magnetic Resonance Imaging
JACFEE	Japanese and Caucasian Facial Expression of Emotion
LEAS	Levels of Emotional Awareness Scale
LH	Left Hemisphere
LVF	Left Visual Field
MRI	Magnetic Resonance Imaging
RH	Right Hemisphere
RT	Reaction Time
RVF	Right Visual Field

The Right Hemisphere Theory and the Valence Theory: A Closer Look at How Gender Influences Emotional Processing

"Let's not forget that the little emotions are the great captains of our lives and we obey them without realizing it" (Vincent Van Gogh, 1889)

In the field of neuropsychology, it is widely believed that the right hemisphere of the brain is more involved in processing emotional related phenomena as compared to the left side (Gainotti, 2000). This theory is referred to as the right hemisphere (RH) model of emotional processing. However, subsequent research has suggested that this perspective may be too simplistic, and that emotional processing may be hemispherically lateralized depending upon on its hedonic tone. The valence theory postulates that the right and left frontal brain regions subserve negative and positive emotional processing, respectively (Davidson, 2000). However, there are inconsistent findings among studies that have tested these two models of emotional processing in the brain.

The importance of the RH for emotional processing has been well documented. For instance, it has been reported that patients with lesions to their right cerebrum can be emotionally indifferent or present with symptoms consistent with mania (Starkstein, Boston, & Robinson, 1988). They can also have difficulty expressing emotional prosody and they have been found to speak in a monotone voice (Borod, 1993; Williamson, Shenal, Harrison, & Demaree, 2003). Furthermore, it has been demonstrated that patients with right-sided lesions in parietal and parietotemporal regions can be significantly impaired at comprehending emotional tone of voice relative to patients with left hemisphere (LH) lesions (Banich, 1997). Patients with RH damage also have difficulty as compared to LH patients when trying to recognize, discriminate, or match facial affect between emotional faces (Adolphs, Damasio, Tranel, & Damasio, 1996; Borod et al., 1998; Cicone, Wapner, & Gardner, 1980). Research involving split brain patients has also supported the RH theory. For example, Benowitz et al. (1983) presented different film segments to a patient with this condition. The segments consisted of facial expression alone, body movement alone, and facial and body movements. They found that the patient could not identify the facial expressions when they were presented to his LH but was able to do so when they were presented to his RH.

Some research focusing on healthy individuals has also lent support to the RH theory. For example, Erhan, Borod, Tenke, and Bruder (1998) found a left-ear advantage for judging emotional tone of voice while others have found a left visual field (LVF) advantage on tasks that require participants to recognize and discriminate emotional facial expressions (Mandal, Mohanty, Pandey, & Mohanty, 1996; Weddell, 1994). Research also suggests that the left side of the face is more active than the right side during emotional expression (Sackeim, Gur, & Saucy, 1978). The ability to remember emotionally expressive faces and to match an emotional face to a spoken word has also been linked to the RH (Banich, 1997). In a unique study, Spence, Shapiro, and Zaidel (1996) found that emotional stimuli presented to the LVF/RH causes a greater autonomic reaction as compared to when it is presented to the RVF/LH.

Findings from electroencephalogram (EEG) and neuroimaging studies have also been consistent with the RH theory. For instance, researchers have reported greater ERP amplitude over the right side of the brain during facial affect processing (Kestenbaum & Nelson, 1992; Laurian, Bader, Lanares, & Oros, 1991). Moreover, Narumoto, Okada, Sadato, Fukui, and Yonekura (2001) used a delayed match to sample procedure to examine how paying attention to emotional expression of faces influences neuronal activity (fMRI). Participants were instructed to match the faces based on contour, identity, expression, (i.e. happy or fearful) and arousal (i.e. fearful or sad). They reported that attention to facial emotion enhanced activity in the right superior temporal sulcus. In contrast, this result was not observed when participants focused on the face without regard to emotion. Recently, Kochiyama, Yoshikawa, Naito, and Matsumura (2004) replicated these findings and expanded on them. They presented subjects with faces that were dynamically morphed from neutral to fearful or happy expressions, faces that remained static or mosaic faces (no facial features). They found increased activation in broad regions of the temporal and occipital lobes on the right side of the brain during presentation of dynamically morphed faces.

Overall, the significant role that the RH plays in emotional processing is well supported. Nevertheless, some scientists argue that although the right cerebrum is important, we should not overlook the critical influence that the contralateral hemisphere has on emotional processing. More specifically, the hedonic tone of emotional stimuli may be critical in determining where in the brain it is processed. To this end, the valence model suggests that the LH is superior at processing positive emotion while the RH is superior at processing negative emotion.

The valence theory has been supported by a wide range of evidence. Goldstein (1939) found that patients with lesions to their LH were more likely to present with symptoms associated with depression, while patients with lesions in their RH exhibited signs of mania. Sackeim et al. (1982) investigated pathological laughter and crying in three different populations, those with lateralized lesions, epilepsy patients, and patients who had undergone hemispherectomy. For the first group, they found that pathological laughter was associated with right-sided damage while pathological crying was associated with left-sided damage. The authors interpreted these results by explaining that the damaged hemisphere lost its ability to exert inhibitory control over the contralateral one. For the second group, they reported that patients whose epileptic foci were located on the left side were prone to outbursts of laughing (gelastic epilepsy). Finally, right-sided hemispherectomy was found to be associated with euphoric mood change.

Other methods have also been used to study the valence theory. Sodium amytal is commonly used to deactivate a hemisphere in order to determine the lateralization of various functions. Christianson, Saisa, Garvill, and Silvenius (1993) used this method to study emotional processing and reported that when the LH was deactivated, the patient exhibited negative mood changes, while positive mood changes were observed if the contralateral hemisphere was chemically deactivated.

Some of the strongest support in favour of the valence theory comes from electroencephalogram (EEG) and neuroimaging studies. For example, Davidson and Fox (1982) had 10-month old infants view film clips of an actress making a happy or a sad facial expression while they recorded their brain activity. They reported greater activity over the left frontal area in response to the happy facial expression. In another study, Sutton and Davidson (1997) had 46 undergraduates fill-out the Behaviour Inhibition System (BIS)/Behaviour Approach System (BAS) scale before measuring their anterior resting brain electrical activity. The BAS scale has been found to be related with extraversion and positive affectivity while the BIS scale is related to neuroticism and negative affectivity (Christensen et al., 1998). Sutton and Davidson reported that elevated BAS scores were associated with higher electrical activity in the LH while elevated BIS scores were associated with higher electrical activity in the RH. Other EEG studies have reported similar results (Davidson, 1995; Wheeler, Davidson, & Tomarken, 1993). Sutton, Davidson, Donzella, Irwin, and Dottle (1997) used pictures to induce either positive or negative mood states while using PET to measure regional glucose metabolism. They found that production of negative affect led to right sided increases in metabolic rate in the superior and inferior regions of the prefrontal cortex (PFC). In contrast, the production of positive affect led to similar results in the LH. Overall, neuroimaging and EEG data has been very informative with regards elucidating the relationship between emotional processing and the underlying neural mechanisms.

Researchers have also used behavioural methods to study the lateralization of affective processing. Reuter-Lorenz, Givis, and Moscovitch (1983) used a tachistoscope to present healthy participants with happy or sad faces in one visual field while simultaneously presenting a neutral face in the other visual field. The participants were instructed to identify which visual field the emotional face was presented in. They found that reaction times (RT) were shorter for happy faces when they were presented to the right visual field RVF/LH while the RTs for sad faces were shorter when presented to the left visual field LVF/RH. Jansari, Tranel and Adolphs (2000) used a free-viewing paradigm to simultaneously present subjects with faces depicting a neutral expression and another depicting a very faint emotional expression. Each emotional face was presented twice, once on each side of the neutral face. Subjects were instructed to choose which face (i.e. left or right) was the emotional face (i.e. "Which of these two faces looks more afraid?"). They found that subjects were better at discriminating positive emotional faces when they were presented to the RVF/LH, conversely, they were better at discriminating negative emotional faces when they were presented on the LVF/RH. Bryden and MacRae (1989) used a dichotic listening task and had subjects listen to two-syllable words and detect either the presence of a specific word in one condition or emotion in another. When participants focused on detecting an emotion, a left-ear advantage was found. Interestingly, this advantage was greatest for negative stimuli and weakest for positive stimuli. From the surface, this result seems to corroborate the RH theory but it can also be interpreted to partially support the valence theory. More specifically, under the RH theory all emotional stimuli should have been processed similarly regardless of valence. Overall, many studies that have used a variety of behavioural paradigms have supported the valence model.

In discussing the valence and the RH theories it is important to consider other variables which may influence their validity – one of the most prominent being gender. To this end, many of the studies which have examined these respective theories have overlooked gender affects which is problematic considering that males and females may process emotion differently. Generally, it is believed that women have more complex emotional knowledge –resulting in greater emotional awareness relative to men. For instance, Barrett, Lane, Sechrest & Schwartz (2000) had 50 men and 44 women complete the Levels of Emotional Awareness Scale (LEAS). As described by the authors "The LEAS is an emotion-based performance task in which respondents generate verbal descriptions of their own anticipated feelings and those of another person for each of 20 scenarios" p. 1028. These responses are scored based on complexity (i.e. level of detail). Overall, they found that women significantly outperformed men, even when they controlled for verbal intelligence. Women's superior emotional complexity may also influence self-descriptions of emotional events. Feldman, Barrett, Robin, Pietromonaco, & Eyssell (1998) found that when recalling past emotional events, women tend to endorse feelings such as happiness, sadness and anxiousness more so than men. Interestingly however, this difference was negligible when participants were asked to recall their experience on a real-time basis. One explanation for this is that women's superior emotional knowledge enables them to be more descriptive and detailed when they are recalling emotional experiences (Barrett et al., 2000).

Women have also been found to have superior ability when it comes to judging and decoding nonverbal emotional cues (e.g. Hall, 1978; Carter & Horgan, 2000; Rosip & Hall, 2004). In a unique two part study, Hall & Matsumoto (2004) presented participants with 57 faces from the Japanese and Caucasian Facial Expression of Emotion (JACFEE; Matsumoto & Ekman, 1988) The faces expressed seven different emotions (anger, contempt, disgust, fear happiness, sadness, and surprise) and participants were asked to rate the emotions on a 9-point scale (i.e. low values meant *definitely not a smile* while high values meant *definitely a smile*). The authors believed that more variability (i.e. higher scores for smiles and lower scores for neutral expressions) was reflective of superior ability to discriminate between emotions. In the first part of the study, they presented the faces for 10 seconds while in the second part they presented the faces for .2 seconds – barely enough for conscious awareness. They calculated the standard deviation for men and women in order to examine variability in the scores. They concluded that women (SD = 2.57) were significantly better at judging the emotional expression of the photographs than men (SD = 2.39). Interestingly, this pattern was also observed when minimal emotional information was provided as was the case in part two of the study.

Gender differences have also been found to influence recognition of facial expressions (e.g., Thayer & Johnson, 2000; Campbell et al., 2002). Montange et al. (2005) had male and female subjects view video clips of faces that were morphed into 1 of 6 different emotions (anger, disgust, fear, happiness, sadness, and surprise). The gradual morphing of the faces occurred in 20 steps, going from 0% emotion to 100% emotion. Participants were instructed to label the emotion they perceived as soon as they were able to identify it. Next, the face was morphed back into its neutral expression and participants had to indicate at what point they first perceived the emotion. In doing this, the authors were interested in assessing accuracy and sensitivity. Overall, they reported that men were less accurate and less sensitive in labelling facial expressions.

Hofmann, Suvak, & Litz (2006) also examined sex differences in recognizing facial expressions. They first had participants view photographs of faces depicting neutral expressions on a computer screen. The faces were taken from Ekman and Friesen (1976) and each of them had a first name printed under the photograph. Participants learned to associate the names with the faces. The next phase of the experiment involved cued recall in which the same photographs were presented to the participants, however, this time the faces depicted a neutral, happy, sad, fearful or angry expression. Participants had to identify the name of the person as quickly as possible. Interestingly, the authors found that females were faster than males at naming male faces while males were faster than females at naming female faces. More specifically, participants were quicker at identifying emotional faces if they were of the opposite sex. These results are important because they emphasize the importance of other factors (i.e. sex of the person being perceived) that may influence gender differences with respect to judging and recognizing emotional expressions.

Gender differences have also been reported for non-verbal emotional behaviours. Hall et al. (2001) photographed 96 university employees while they conversed with one another. The participants knew they were being photographed, but they did not know when the pictures were taken. The authors found that females showed an increased tendency to lean forward, display erect posture, touch self, and smile more than men. LaFrance, Hecht, & Paluck (2003) conducted a meta-analysis to investigate sex differences in smiling. Their analysis incorporated 162 studies from which they obtained 448 effect sizes. They reported that women and adolescent girls smiled more than men and adolescent boys. In another study, Helwig-Larson et al. (2004) examined head nodding in a group of college students during classroom interaction. They found that female students nodded more than male students when interacting with peers. Interestingly, this difference was significantly reduced when students were interacting with professors. More specifically, male students nod more when they interact with professor as opposed to fellow peers. This suggests that status can influence nodding behaviour. Other studies have corroborated this interpretation by demonstrating the important role variables such as power, social expectation, and culture can play with respect to emotional behaviours (e.g. Brody, 1997; Hall, 2006). As such, caution should be taken when trying to account for these findings.

With this in mind, the literature *does* suggest that there are underlying neurobiological differences with respect to how males and females process emotional phenomena – particularly, as it relates to laterality. For example, Borod, Koff, Yecker, Santschi, and Schmidt (1998) reviewed several studies that examined facial asymmetry during emotional expression. It should be noted that emotional expressions were not specified based on valence (i.e. positive or negative). They reported that 70% of emotional expressions by males were left-sided, 20% were equal, and 10% were right-sided. For females, 38% of their emotional expressions were left-sided, 54% were equal, and 8% were right-sided. It was concluded that males show greater patterns of lateralization during emotional expressions. Cahill, Uncapher, Kilpatrick, Alkire, and Turner (2004) scanned (fMRI) subjects while they viewed a series of slides that depicted scenes that ranged in emotional arousal. They found that males exhibited significant activations in the right anterior hippocampus, right global pallidus, bilateral lateral parietal, and the right frontal cortex. Importantly, 4/6 activations were located on the right side. Conversely, all of the major activations for females were located in the LH. Bourne (2005) presented chimeric faces to 138 male and female undergraduate students. Each face was vertically split – one side had a neutral expression while the other had a positive expression. Subjects were instructed to indicate which side of the face looked happier. She reported that although both sexes were RH dominant for the task, males were significantly more lateralized. Schirmer, Zysset, Kotz, and von Cramon (2003) presented men and women with positive and negative words that were spoken with happy or angry prosody while their blood flow was measured using fMRI. They found that the left inferior frontal gyrus (IFG) was more strongly activated than the right IFG in women but not men. Van Strien and Van Beek (2000) examined the effect of sex and handedness on ratings of emotion in cartoon faces presented to either the RVF or the LVF. Subjects were required to rate the intensity of the emotions expressed on the faces. They found that women rated faces that were presented to their RVF/LH as more positive, meanwhile, they rated faces presented to their LVF/RH as more negative. For men, the visual field did not influence how they rated facial expression. Therefore, they were able to demonstrate valence specific effects only in females. Rodway, Wright, and Hardie

(2003) replicated Jansari et al.'s laterality task with 78 participants. The purpose of their study was to assess the influence of sex as well as other factors such as handedness on emotional processing. They reported that females were more accurate at detecting negative emotions presented to their LVF/RH while they were more accurate at detecting positive emotions presented to their RVF/LH. In contrast, males did not show a significant valence side interaction. Therefore, similar to Van Strien and Van Beek (2000) support for the valence model was only found for female participants.

Relatively fewer studies have used verbal stimuli to study the laterality effects of gender on emotional processing. Graves, Landis, and Goodglass (1981) had twelve male and twelve female participants complete a lexical decision task in which words and non-words were simultaneously presented to each hemisphere. The words that were used included emotional words and non-emotional words. Subjects were instructed to identify which visual field the word was located in by pushing corresponding buttons. They reported all of the participants were quicker to recognize emotional words and that emotional words were recognized faster when they were presented to the RH for both sexes. Interestingly, the authors found that "emotional word advantage" (EWA) was larger in the LVF/RH for males but larger in the RVF/LH for females. (EWA = per cent correct for emotional words minus percent correct for non-emotional words.) These findings suggest that the RH plays a specialized role in emotional processing relative to the LH in males while the opposite pattern is found in females. In a similar study, Ali and Cimino (1997) examined the laterality effects of perception and memory of emotional words in normal individuals. They presented participants with positive, negative, and neutral words as well as non-words to either the RVF or the LVF. They reported that response accuracy was greatest for all words presented to the RVF/LH. They interpreted this result as reflecting the dominant role the LH plays in language processes. In addition, the authors reported that women significantly outperformed men in free recall accuracy as well as recognition memory. With respect to laterality effects, they found that recognition memory was better for positive words presented to the LH while the same pattern was found for negative words presented to the RH. This result was observed regardless of gender and it supports the valence model of emotional processing.

For the most part, the aforementioned studies seem to suggest that men are more lateralized than women for emotional processing, and that although they exhibit some bilateral activation, emotional functioning is an area that is mainly restricted to the right hemisphere. Meanwhile in women, bilateral activation is more commonly observed. In fact, unlike males, the LH seems to play a significant role in emotional processing. The implications of these findings are very important because it can help clarify some of the inconsistencies pertaining to the models of emotional processing which were previously discussed. More specifically, the validity of the valence and the RH theory may depend upon the sex of the individual. Within this vein, the valence model may be more valid for females because they have more LH involvement in emotional processes while the RH model of emotional processing may apply to males because they seem to be more lateralized for many aspects of emotional processing.

Emotional Stroop Task

The Emotional Stroop Task (EST) is a variant of the classic Stroop test. The main purpose of this task is to investigate attentional bias to emotional words. Participants are presented with pleasant and unpleasant words in different colours and are instructed to indicate the ink colour of the stimuli. The theory behind the EST is that words with an emotional valence take longer to process because more attention is devoted to them, leading to an interference affect. To assess this attentional bias, researchers calculate the mean reaction time (RT) to identify the colour of emotional words and subtract this from the mean RT to identify the colour of neutral words (Pratto & John, 1991).

The EST has been administered in a wide range of studies. For instance, it has been used to study populations with emotional disturbances such as those with diagnosed with general anxiety disorder (GAD), panic disorder, specific phobias, obsessive-compulsive disorder (OCD), posttraumatic stress disorder (PTSD), and depression (Williams, Mathews, & Macleod, 1996). The EST has also been used to study emotional processing within the normal population. For instance, Thomas, Johnstone and Gonsalves (2007) administered the EST to college students while measuring their brain activity using EEG. Although no significant differences in RT latencies were observed, they did report greater P2 amplitude in the right hemisphere for emotional words.

The EST has been adapted to investigate lateralized emotion processing. In the lateralized EST, words are presented to either the LVF or the RVF while RT is recorded. In a pioneering study, Richards, French, and Dowd (1995) used the lateralized EST to present high and low-trait anxious participants with threat-related, positive, and neutral words vertically in four different colours to either the LVF or the RVF for 180 ms. They found a significant interference effect for emotional words presented to the RH for both groups. In addition, the low-trait group had reduced accuracy for threat related words presented to the LVF/RH. In all, these findings are consistent with the RH model of emotional processing. Compton, Heller, Banich, Palmieri, and Miller (2000) used a different version of the EST in which separate colour patches and words were presented to either the LVF or the RVF. The words were positive, negative, or neutral and they were presented concurrently with the colour patches in either the same or opposite VF. Participants were instructed to name the colour of the patch. They reported increased RT latencies for words presented to the LVF which is consistent with the RH theory of emotional processing. It should be noted that neither of these studies focused on gender effects, perhaps due to small sample sizes and insufficient power to examine possible gender differences.

Van Strien and Valstar (2004) investigated the differential involvement of the hemispheres in emotional processing in women. They used the lateralized EST to present positive, negative or neutral words in one of four colours to the LVF or RVF while they recorded vocal RT's. Overall, they reported longer RT latencies when emotional stimuli were presented to the LVF compared to the RVF. Importantly, latencies were longer for negative words presented to RH relative to positive words presented to the LH. However, there was no advantage for positive words presented to the RVF. These results are equivocal because on the one hand RH interference was greater for negative words as compared to positive words which is consistent with the valence model. On the other hand, they were unable to demonstrate differential LH involvement in processing positive stimuli.

The most recent study to use the lateralized EST (Borkenau & Mauer, 2006) is arguably the most convincing with respect to supporting the valence theory. They presented a relatively equal number of male and female participants with positive, negative, and neutral words in one of four colours while they recorded RT. Although they did not report any main effects for gender, they found that positive words presented to the RVF and negative words presented to the LVF had longer latencies. This finding established a connection between the LH and positive words – a relationship which had eluded previous researchers (Compton et al., 2000; Van Strien & Valstar, 2004). Interestingly, in contrast to other studies, they found that regardless of hemispheric presentation, positive words produced the longest latencies followed by negative words then neutral words. This is an unexpected result, and it may have been influenced by the fact that they did not control for word frequency – which refers to how commonly a word is used in the English language. Word frequency, along with word length and orthographic neighbourhood are critical factors to consider when administering the EST. The latter feature describes how many other words a single word can be converted to by changing one letter while preserving the others (Coltheart, Davelaar, Jonasson, & Besner, 1977). It is generally believed that words with larger orthographic neighbourhoods cause greater semantic priming which in turn results in faster processing speed. In contrast, the emotional words used in many EST studies tend to have smaller orthographic neighbourhoods relative to neutral words which may lead to greater RT latencies (Larsen, Mercer, & Balota, 2006)

In summary, studies that have used the lateralized EST to study emotional processing have reported mixed results. Some have found that negative words lead to longer RT latencies regardless of hemispheric presentation (Compton et al., 2000; Van Strien & Valstar, 2004) while others have found the same result for positive words (Borkenau & Mauer, 2006). Some have been unable to establish a relationship between the LH and the processing of positive stimuli (Van Strien & Valstar, 2004) while others have (Borkenau & Mauer, 2006). Finally, some support the RH theory (Richards et al. 1995; Compton et al., 2000), while others support the valence theory (Borkenau & Mauer, 2006; Van Strien & Valstar, 2004).

Some of these contradictory findings may have been caused by methodological limitations such as small sample sizes or not controlling for factors such word length, word frequency, and orthographic neighbourhood. In addition, most of the lateralized EST literature has overlooked the effects of gender on emotional processing. Having discussed the laterality differences that may exist between males and females it is important to investigate how they manifest on behavioural measures such as the lateralized EST. This will not only further our general knowledge pertaining to emotional processing but it will also contribute valuable information to the debate surrounding the validity of the RH theory versus the valence theory. As such, the current study will use the lateralized EST in order to test the influence of gender on emotional capture of attention. Considering that the bulk of the literature suggests that males are more RH lateralized while females have more bilateral involvement for processing emotional information, our hypotheses are as follows:

1) For males, their performance should be more consistent with the RH model of emotional processing. More specifically, there should be RH interference for all emotional information regardless of valence.
2) For females, their performance should be more consistent with the valence model of emotional processing. More specifically, there should be an interference affect for positive words presented to their LH and an interference affect for negative words presented to their RH.

Method

Participants

Participants included 50 female (mean age = 21) and 50 male (mean age = 24.2) university students. Average level of education for female participants was 14.4 years and 14.5 years for male participants. They were recruited using the psychology participant pool and were given course credit in exchange for their participation. Before they took part in the lateralized EST they were screened for colour blindness as well as language difficulties.

Word Stimuli

Stimulus presentations were programmed using Direct RT and Media Lab software. Forty positive, forty negative, and forty neutral words (nouns and adjectives) were presented in one of four different colours (red, green, blue, or yellow) to the RVF or the LVF. The words were presented in 24-point Times New Roman font and were controlled for word frequency and word length (see Table 1). The words were obtained from the Affective Norms of English Words manual (ANEW; Bradley & Lang, 1999) and were rated on several emotional dimensions by an introductory psychology class.

Table 1

Average Word length, word frequency, and arousal values for each word group

Word group	Average word length	Average word frequency	Arousal
Positive words	8.02	34.52	5.72
Negative words	7.75	34.62	5.65
Neutral words	7.87	34.77	3.90

Procedure

Participants provided informed consent after having the study described to them by the examiner. They were then asked to complete a simple colour blindness test, a handedness questionnaire and answer a few questions regarding their language background. After this, they were seated in front of a computer and asked to place their head on a chinrest. The chinrest was placed at a distance of 50 cm from the computer monitor. Instructions for the EST appeared on the screen and they took part in 5 practice trials. Upon completion of the practice trials, a screen appeared informing them that the actual task was going to begin after they "pressed the spacebar" key. Each trial began a 1000-ms presentation of the central fixation dot followed by a 150-ms horizontal presentation of one of the 120 words in red, green, blue, or yellow, randomly presented to either the right or the left visual field. Word order was randomized, and each of the participants responded using their right hand by pressing on a button-box that corresponded to the color of ink in which the word was written.

Results

Participants who were colour blind and/or learned English after elementary school were excluded from the analyses – this included 1 male participant and 2 female participants. Responses that were incorrect (i.e. pushed the red button when the word was presented in blue) as well as those that occurred 1500 ms after the initial presentation of the stimulus were also not analyzed. This accounted for less than 1% of the total responses.

Overall, the average accuracy for all the trials regardless of gender was 96%. An analysis of variance on the accuracy data yielded significant main effect for valence $F(1, 94) = 3.103$, $p \leq .05$. Specifically, participants were more accurate at indicating the colour of negative words (M = .97) relative to positive (M = .96) and neutral words (M = .95). No significant main effects were found for visual field $F(1,95) = .353$, $p > .05$. In addition, the valence x visual field x gender interaction was also not significant $F(1,94) = .962$, $p > .05$.

The mean reaction time (RT) latencies for positive, negative, and neutral words are presented for females in Figure 2 and for males in Figure 3. Our RT analysis which included gender as a between-subjects factor and within-subject factors of valence and visual field did not yield significant main effect for valence $F(1, 94) = 1.12$, $p > .05$ or visual field $F(1,95) = .291$, $p >.05$. In addition, the gender x valence x visual field interaction was not significant $F(1,94) = .985$, $p > .05$. Although the results were not significant, the general direction of the means suggests that females may have showed more LH interference for emotional words relative to men.

Figure 1. Mean RTs (ms) for female participants

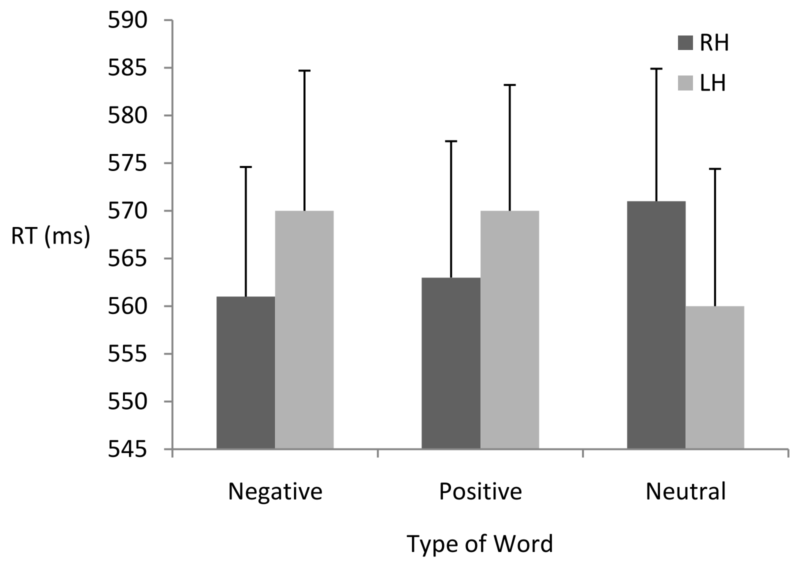
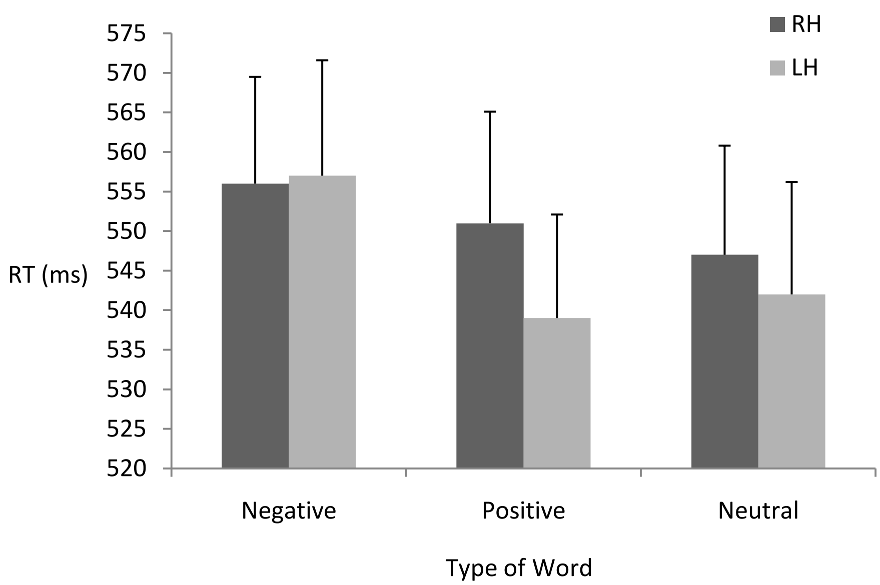


Figure 2. Mean RT(ms) for male participants



Discussion

The purpose of the current study was to investigate two hypotheses; the first one being that the performance of men on the lateralized EST would be more consistent with the RH theory, while the second being that the performance of women would be more consistent with the valence theory. In order to support the first hypothesis, we expected men to exhibit the longest RT latencies for all emotional words presented to their LVF/RH relative to neutral words. In contrast, for women, we expected to find the longest RT latencies for positive words presented to the RVF/LH and negative words presented to the LVF/RH.

However, our analysis for RT did not yield any significant main effects. In addition, we were unable to find a significant 3-way interaction between gender x valence x visual field which fails to support both of our hypotheses. On the other hand, the direction of the means suggests that females may have more LH interference for emotional words relative to men. This pattern partly supports our notion that women exhibit greater LH involvement during emotional processing and is consistent with other studies that have reported similar results (e.g. Cahill et al., 2004). Nevertheless, the group differences did not reach the level required for significance.

Interestingly, our analyses for accuracy revealed a significant main effect for valence in that all of the participants were better at correctly identifying the colour of negative words relative to positive and neutral words. This pattern occurred regardless of which visual field the words were presented in. Other EST studies that have examined accuracy have either reported insignificant findings or have reported the opposite pattern (e.g. Richards et al., 1995; Van Strien & Valstar, 2004). That is, participants were less accurate at identifying the colour of negative words. The reason for these contradictory findings may be attributed to the tendency of early EST studies to overlook important lexical features of the word stimuli they used (i.e. word frequency and word length). Keeping in mind that we controlled for these characteristics, our results seem to suggest that negative words may not capture participant's attention to the extent previously thought. This would help explain why there was no interference effect seen in the RT scores. Nonetheless, our results failed to support our hypotheses. We believe there are several reasons for this which we will discuss below.

To begin with, our study may not have provided sufficient break time between trials. After the participants identified the colour of the word by pressing the corresponding keyboard button, then next word was presented immediately rather than giving them a break. This may not have given them sufficient time to refocus on the central fixation point before the next word was presented. In contrast to our study, Borkenau and Mauer (2006) gave participants a 400 ms break between trials. Moreover, the majority of EST studies present each word stimuli multiple times in different colours (i.e. red, green, blue, and yellow). This improves the likelihood that the participant will process the meaning of the words. In contrast, the current study presented each word only once. The reason for this was that we had a relatively large number of words (40 for each valence group) so we did not think it was necessary to present the words multiple times. Also, using this method can result in practice effects which may influence RT latencies. Consistent with this, presenting each word more than once can also result in expectancy effects. Specifically, participants may try to anticipate the presentation of emotional words which would then make the EST a measure of effortful/directed attention as opposed to a measure of fast automatic processing.

Another factor that could have influenced our RT analysis could be a phenomenon referred to as a slow interference effect. Based on research conducted by McKenna & Sharma (1995; 2004) it has become apparent that interference observed in the EST is not necessarily automatic and that the RT latencies caused by the threat word actually occurs in the subsequent trial rather than the threat trial. They demonstrated the slow interference effect by using a block design which is a common methodology in EST studies. As opposed to our study, which presented words randomly, those that use the block methodology present the words in groups according to their valence (i.e. emotional or neutral). More recently, Phaf & Kan (2007) conducted a meta-analysis to further investigate slow interference as it pertains to the EST. Similar to McKenna & Sharma (2004) they also they also found support for this effect, in particular, this effect was strongest in studies that used a block design. Despite these results, many EST studies continue to prefer using blocked presentations because they have been found to produce greater interference effect for emotional words relative to random presentations (Holle & Neely, 1997). On the other hand, it should be emphasised that several studies have successfully used a random presentation format to demonstrate an interference effect (Foa, Feske, Murdock, Kozak & McCarthy, 1991; Mogg et al., 2000; Owens, Asmundson, Hadjistavropoulos, & Owens, 2004). With this in mind, we decided to use a random design because we felt that it improved our chances of limiting the influence of the slow effect. Nonetheless, it is still possible that the interference caused by the emotional words were “carried over” to the next trial essentially washing out any effects we would have found. To this end, it is important for future researchers to continue examining to what extent slow interference influences RT latencies in EST studies, and in particular focus on how this effect differs depending on the methodology used (i.e. block or random designs). Regardless, if new research continues to unfold in support of this phenomenon it will cast doubt as to the validity of the EST because its usefulness is predicated on its ability to measure fast/automatic processing.

Despite some of these potentially confounding factors, the current study also controlled for others that have been previously overlooked by many EST studies. To begin with, we had a relatively large sample size consisting of males and females. We screened for language ability as well as colour blindness. Further, our stimuli set consisted of 120 words in total (40 for each valence), which to our knowledge, is the largest number of stimuli used in any lateralized EST study. In addition, all of the words used in our study were selected from the ANEW (Bradley & Lang, 1999). This comprehensive normative database was developed in order to provide emotional ratings for a large number of words commonly used in the English language. We categorized our words as either positive, negative, or neutral based on the valence ratings in the ANEW. We felt confident in using this method since the words in the ANEW were normed using an introductory psychology class. Conversely, most of the other EST studies use a limited number of expert judges to determine the desirability of their word stimuli. Most importantly, our study also controlled for word frequency and word length. These two factors, particularly word frequency have commonly been overlooked in other EST studies. Larsen, Mercer, & Balota (2006) examined the lexical characteristics of the 1033 words used in 32 published EST studies. They reported that the negative words used in these studies had lower frequency of use, were longer in length and had smaller orthographic neighbourhoods, thereby biasing the negative to be responded to slower and less accurately. More importantly, when they controlled for these lexical features they found that the RT latencies for negative words and neutral words were not significantly different. They concluded that with the exception of disorder specific stimuli, the lexical features of words have a significant influence on RT latencies. A couple of years later, Estes & Adelman (2008) published an article in the same journal refuting Larsen et al. (2006) findings. Their main concern was that Larsen et al., categorized the words in their analysis based on how the original 32 EST studies designated them. They argue that this fails to control for the variability in methodology, measures, and criteria used in each study. To address this, they conducted a study in which they controlled for these differences and sampled all their words from the ANEW in order to examine whether negative words lead to longer RT latencies relative to positive and neutral words. They reported that even when they covaried factors such as word frequency and word length, participants exhibited significantly slower RT latencies for negative words relative to other words. In response, Larsen, Mercer, Balota & Strube (2008) analyzed the same data set but include arousal ratings for each word. They reported that not all negative words produce the same RT latencies. That is, even within a specific valence group (i.e. positive, negative, and neutral) there is a considerable amount of variability with respect to how much interference a certain word can cause. With these inconsistencies in mind, it is important for researchers to investigate what particular components of words are most predictive of the interference effect.

Moreover, many studies that employ the EST paradigm are seeking to investigate how humans process emotional information. To add to this, the two main theories at the forefront of emotional research; the right hemisphere theory and the valence theory, were constructed with the purpose of explaining emotional processing. However, neither of these models clearly defines what is meant by the term emotional processing. Years of research focusing on this domain have emphasized that emotion is an extremely broad and complicated area. It is comprised of many different components, each one being unique from the other. For example, two important aspects of emotion are emotional expression and emotional perception. However, it is widely accepted that both of these areas are distinct, and that different regions of the brain are specialized to deal with each of them respectively (Phan et al., 2002). Perhaps we are overzealous in trying to find one model that describes how we process *all* emotional related information. It is possible that the valence theory is more suitable for describing a particular aspect of emotional processing while the RH theory is more suitable for describing another. Keeping this in mind, it would be useful for future researchers to examine the literature in this area in order to determine if these theories can be distinguished based on the specific aspect of emotion in question and the methodology used to investigate it.

Furthermore, it is possible that these two theories are not mutually exclusive and that they can coexist. Killgore & Yurgelun-Todd (2007) demonstrated this by using a backward stimulus masking design to present participants with chimeric faces to either their RVF or LVF. One side of the face displayed an emotional expression (i.e. happy or sad) while the other side of the face was neutral. The chimeric faces were presented quickly as to render them imperceptible to conscious awareness and were followed by the presentation of the same face with a neutral expression. The purpose of the study was to investigate the activation caused by these emotional expressions using BOLD functional magnetic resonance imaging. They found that the posterior right hemisphere was activated regardless of valence, which supports the RH theory. However, greater activation was observed for sad expressions relative to happy expressions – which partially supports the valence model. Interestingly, they found that chimeric faces presented to the RVF/LH caused bilateral activation of the anterior regions of the brain. Specifically, sad faces activated regions in the LH while happy faces activated regions in the RH (this pattern is opposite to that described by traditional valence theory). Overall, their study found partial support in favour of both theories. The authors interpreted this by proposing that these two rival theories may work together as part of an elaborate emotional processing system. Specifically, they suggest that the posterior right hemisphere is specialized for the perception of emotion in general but is specialized at processing negative affect. In contrast, regions of the LH can also process emotional information, albeit not as efficiently as the RH.

In summary, the results of this study point to several areas that future research should focus on. To begin with, it is important that we investigate which specific characteristics of words influence the interference effect besides the emotional valence. Secondly, serious consideration should be directed towards elucidating whether the EST causes a slow effect. If advocates of the EST are correct in believing that this paradigm measure fast automatic attention, then why is it that block designs are more successful at teasing out an effect relative to mixed designs? On the other hand, studies that use a random presentation format also have limitations. More specifically, the majority of these studies present their word stimuli multiple times in order to find an emotional Stroop effect, which also contradicts the notion of the EST as a measure of fast/automatic processing. Thirdly, instead of trying to find a “blanket” theory to cover all aspects of emotional processing, perhaps each theory applies to a particular area of this domain. Lastly, the RH theory and the valence theory may not be mutually distinct. That is, they may both contribute insights to a theory about a comprehensive emotional system.

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