SEX DIFFERENCES IN LATERALIZATION OF ATTENTION FUNCTIONS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Meaning
AAA	Attention to Activation Area
ANT	Attention Network Task
BOLD	Blood-Oxygen Level Dependent
CBF	Cerebral Blood Flow
fMRI	Functional Magnetic Resonance Imaging
LANT	Lateralized Attention Network Task
LH	Left Hemisphere
LVF	Left Visual Field
PET	Positron Emission Tomography
RH	Right Hemisphere
ROI	Region of Interest
RT	Reaction Time
RVF	Right Visual Field
VF	Visual Field
VOA	Vocalization Area

ABSTRACT

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Performance on two lateralized attention tasks, a unique, modified version of the Stroop task, and the Lateralized Attention Network Task, was investigated to add evidence to the topic of lateralized hemispheric strengths and weaknesses between the sexes. Sixty total participants at a mid-sized public university completed both tasks to obtain research credit for their classes. Results concluded that there were no significant differences between the sex of the participant and visual field in their efficiency in responding to the three metrics of the Lateralized Attention Network Task. Individual analysis of the six cue types showed some interactions between sex and visual field on response accuracy however, generally the results were not significant. Stroop task data analysis yielded no significant differences between sex and visual field in either Stroop effect or response accuracy. Overall, results were not consistent with our hypotheses. There was, however, a noticeable trend that males were likely to be more efficient at responding to the tasks when the stimuli were presented in the left visual field, as well as that women tended to perform more efficiently when the stimuli was presented in the right visual field. Although not a significant finding, the trend does add further evidence to the current belief that men respond better to items lateralized to the right hemisphere and that women respond better to items lateralized to the left hemisphere.

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INTRODUCTION

A recurring finding in neuropsychology research is that cognitive functions are sometimes lateralized. That is, a particular cortical area in one of the hemispheres of the brain is more active than the same area in the opposite hemisphere when a cognitive function is carried out. For example, Broca's area in the left inferior frontal lobe is known to be the functional cortex for speech planning and production in the large majority of humans (Toga & Thompson, 2003). Another functional lateralization involves the right inferior parietal lobe. Hugdahl (2000) proposes that lesions in this area produce attentional neglect of information presented in the left visual field (i.e. - processed by the right hemisphere), whereas lesions in the homologous area of the left hemisphere rarely lead to neglect, or if neglect is shown, it is typically not as severe.

A number of studies have also presented evidence for functional asymmetries in attentional tasks (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Corbetta, Patel, & Shulman, 2008; Stephan et al., 2003). For example, Corbetta et al. (2008) found that reorienting of attention to a visual stimulus produced more activation in the right hemisphere (RH) ventral frontoparietal network than in the left hemisphere (LH). Stephan et al (2003) showed that there is a clear dissociation of activation between the hemispheres during a letter-decision task and a visuospatial task. Their findings provide evidence that verbal attention is more lateralized to the left hemisphere, while spatial attention is more lateralized to the right hemisphere. These studies are indicative of cerebral lateralization during attentional tasks.

Although sex differences in lateralization of attentional function have been documented (Clements et al., 2006; Kansaka & Kitazawa, 2001; Voyer, 1996), more research is needed to better understand the differences between the male and female brain in performing attention functions. A recurrent finding has been that women perform better on attentional tasks with a language component and men perform better during attention tasks involving spatial properties (Gur et al., 2000; Clements et al., 2006). Sex differences in lateralization of attention functions might therefore also depend on whether the task is more language or spatially based. For example, the Attentional Network Task (Fan, McCandliss, Sommer, Raz, & Posner, 2002) is a more visuospatial attention task and the Stroop more language based. The orienting function of attention (measured by the Orienting metric of the Attention Network Task), has been shown to more strongly activate the right hemisphere than the left (Corbetta et al., 2000), leading to the prediction that men could potentially be more efficient than women at orienting attention because they are generally better than women in visuospatial tasks (Astur, Ortiz, & Sutherland, 1998; Gur et al., 2000). Moreover, due to differences in functional lateralization men may perhaps show stronger performance when orienting attention to the LVF (RH), given that many visuospatial tasks have right hemispheric dominance (Clements et al., 2006; Kolb & Whishaw, 2008; Stephan et al., 2003). On the other hand, females might perform better on the Stroop than males because it is a language-based task. Moreover, females might also show better performance when stimuli are presented to the RVF (LH) because the left hemisphere is dominant in language functions.

The current study hoped to discover more about lateralization of attention functions, and what role sex might play in such lateralization. We used the ANT and

Stroop tasks to examine lateralization of the three attention network functions proposed by Posner and others (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Posner & Peterson, 1990). The ANT and the Stroop task are commonly used measures of attention functions, yet little research has been done using a lateralized version of these tasks. Moreover, sex differences in attentional function have not been adequately examined. Below, we present a review of attention research and hemispheric asymmetries of cognitive function that is relevant to the goals of the present study.

LITERATURE REVIEW

Attention

Alan Allport (1989) describes attention as being necessary for the protection of the limited information-processing capacity of the brain to prevent information overload. Attention has been defined as "a selective awareness of a part or aspect of the sensory environment or a selective responsiveness to one class of stimuli" (Kolb & Whishaw, 2008, pg. 263). Corbetta (1998, pg 831) defined attention as being able to "select stimuli, responses, memories, or thoughts that are behaviorally relevant among the many others that are behaviorally irrelevant." Posner and Peterson (1990) hypothesized that attention is not carried out by any single anatomical area in the brain. They proposed that there were three networks of attention active in the brain, and their three independent functions are: "(a) orienting to sensory events; (b) detecting signals for focal processing, and (c) maintaining a vigilant or alert state" (p. 26). These three networks were thought by Posner and Peterson to act independently of each other, thereby leading to greater efficiency in attentional behavior. More recent research indicates that these networks might not be entirely independent. Callejas, Lupianez, Funes, and Tudela (2005) found that the alerting network inhibits the executive control network; and that being oriented to an area where a conflict resolution stimulus is presented raises the efficiency of responding accurately to that stimulus. Further, being in a state of high alertness was shown to improve orienting efficiency (Callejas, Lupianez, Funes, & Tudela, 2005).

A major function of the *Orienting* network in visual processing is to shift attention from one location to another, thereby improving efficiency of target processing (Callejas, Lupianez, Funes, & Tudela, 2005; Posner & Peterson, 1990). Corbetta, Patel, and Shulman (2008) describe this network as being pivotal to survival, as our ability to reorient our attention to novel, threatening, or rewarding stimuli is fundamental to adaptive behavior.

The second network has been referred to as the *Executive*, or Conflict Resolution network. This network involves the ability to detect and interpret stimuli despite conflicting influences (Fan, McCandliss, Sommer, Raz, & Posner, 2002). Posner and Peterson state that this network is distinctively different than the Alerting network, as the detecting system involves not just the process of detecting the stimulus, but instead the process of interpreting the signal accurately regardless of conflicting information (1990).

The *Alerting* network is described by Posner and Peterson as the network associated with preparing and sustaining alertness to process signals (1990). Increasing level of alertness has been shown to reduce target detection times (Fan, McCandliss, Sommer, Raz, & Posner, 2002). This has also at times been called “phasic alertness” (Callejas, Lupianez, Funes, & Tudela, 2005). Vigilance tasks also measure the activity of the alerting network. In these tasks, subjects must attend to a target over a measured period of time. Evidence has shown that maintenance of the alert state is dependent upon right-hemispheric activation (Posner & Peterson, 1990).

Positron emission tomography (PET) scans and functional magnetic resonance imaging (fMRI) have been used to measure activation of specific cortical areas during attention tasks (Corbetta, 1998; Corbetta & Shulman, 2002; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Lueng, Skudlarskit, Gatenby, Peterson, & Gore, 2000). PET scans and fMRIs measure changes in cerebral blood flow to specific areas of the brain to study neuro-antaomical activation during attention. The specific neurological areas active in attention function have been studied at great length (Corbetta, 1998; Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002; Posner & Peterson, 1990). Corbetta and Shulman (2002) discuss two systems that are related to the *Orienting* network -- goal- and stimulus-driven orientation. Goal-driven orienting is involved in the voluntary search and selection of sensory information and activates the posterior parietal and frontal cortex. Stimulus-driven attention is active in the detection of behaviorally relevant sensory events, activating the ventral frontoparietal cortex lateralized to the right hemisphere (Corbetta & Shulman, 2002). Covert orienting of attention (i.e., orienting attention without eye movements) appears to activate signals in the parietal and frontal cortexes (Corbetta, 1998). These areas are also linked to voluntarily allocating attention to a visual location or to an object (Corbetta, 1998). Corbetta also established that some of the processes of attention may overlap with oculomotor processes, especially in the parietal cortex where the neurons activated during attentional tasks are in similar areas to those activated during oculomotor tasks. Further, spatial attention has been associated with the fronto-parietal cortical network, as well as the posterior parietal region when subjects switch their attention from one stimulus to another during top-down, or goal-directed, selection of a stimulus (Corbetta & Shulman, 2002). The *Executive* and *Alerting* networks have also been linked to specific anatomical regions, respectively the anterior cingulate and left prefrontal cortex, and the frontal and parietal regions of the right hemisphere (Corbetta et al., 2000; Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; Fan, McCandliss, Sommer, Raz, & Posner, 2002). The above anatomical areas are the areas most commonly associated with the three attentional networks proposed by

Posner and others, although some lesser activation has been noticed in other cerebral regions (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005).

Hemispheric Asymmetries in Anatomy and Function

Many studies have investigated the functional and structural asymmetries of the human brain. Contralateral cortical representation of auditory, motor, and visual functions are now well known. That is the right hemisphere serves the extremities on the left side of the body and the left visual half-field, and vice versa for the left hemisphere (Hugdahl, 2000). Several structural asymmetries have also been found in the brain. The left hemisphere has several structurally larger areas than does the right hemisphere: These include a longer lateral Sylvian fissure, larger insula, and wider occipital lobe. Asymmetries favoring the right hemisphere include the right hemisphere being heavier, having a longer medial geniculate nucleus, a wider frontal lobe, and the right hemisphere extends farther anteriorly than does the left hemisphere (Kolb & Wishaw, 2008). Watkins et al. (2001) found that the left hemisphere has more gray matter relative to the amount of white matter in comparison to the right hemisphere. Kolb and Whishaw (2008) state that one of the most robust anatomical asymmetries between the hemispheres involves the left hemisphere having a longer planum temporale (Wernicke’s area) relative to the right hemisphere, and the right hemisphere having a larger primary auditory cortex (Heschl’s gyrus) relative to the left hemisphere.

The two most common functional asymmetries are language and visuospatial abilities. Language has probably been the most observed functional asymmetry in the brain, and has been shown to be specialized primarily in the left hemisphere (Kolb & Whishaw, 2008; Stephan et al., 2003; Toga & Thompson, 2003; Watkins et al., 2001).

Broca's area, the area most commonly associated with production of speech, is principally organized in the left prefrontal cortex and has no functional equivalent in the corresponding right hemisphere (Hugdahl, 2000). Stephan et al. (2003) reported that in a lateralization study comparing letter and visuospatial decision making that the left hemisphere showed higher blood oxygen-level dependent (BOLD) signals than the right hemisphere in both tasks, and only the left hemisphere was activated during the letter decision task. Toga and Thompson (2003) also report that Wernicke's area, primarily used for language comprehension, is mostly localized to the left posterior temporal-parietal region, further establishing the language dominance of the left hemisphere. Further left hemisphere dominances include processing letters and words presented in the visual fields, language-related sound, and verbal memory tasks (Kolb & Whishaw, p. 298, 2008). Hugdahl (2000) also reports that the left hemisphere is dominant in the processing of local elements, or immediately defined stimulus, and categorical judgments. Overall, the left hemisphere is consistently dominant in the processing of language and verbal information.

The right hemisphere has been shown to be more dominant in visuospatial abilities, including analysis of complex geometric patterns, movements in spatial patterns, nonverbal memory, and mental rotation (Kolb & Whishaw, 2008). In the same study mentioned above by Stephan et al. (2003), increased BOLD signals in the anterior and posterior part of the right inferior parietal lobule during the visuospatial decision tasks were reported, while no overall activation in the left hemisphere was observed.

Attention Network Task – ANT

Following the theory of three proposed attentional networks by Posner and Peterson (1990) listed earlier in this review, the establishment of a task to measure the efficiency of each network became necessary. Fan et al. (2002) designed the Attention Network Task (ANT), which uses a combination of spatial cueing and flanker trial tasks to assess the efficiency of the *Executive*, *Orienting*, and *Alerting* networks of attention. Below is a brief explanation of each network, as well as the technique used in the original ANT to assess the efficiency of each network.

The *Executive* network of attention involves conflict resolution tasks, similar to that of the Stroop task. Activation of the anterior cingulate and the lateral prefrontal cortex has been shown during these types of tasks in fMRI studies (Fan, Flombaum, McCandliss, Thomas, & Posner, 2003). In the executive task, a respondent's reaction time is measured as they determine whether an arrow is pointing left or right, while overcoming conflicting flanker arrows. These arrows appeared either above or below a fixation point in the middle of a computer screen. Depending on the direction of the flanker arrows, RT should be affected by the time it takes for the respondent to resolve the directional conflict of the arrows before responding to the stimulus. Fan et al. (2002) calculated the results for this task by subtracting the mean RT from the congruent flanker trials from the mean RT of the incongruent flanker trials.

Many studies have shown that visual information can be processed more efficiently (faster reaction times) if a spatial cue to the target's location is presented just prior to it. The pre-cue is thought to enable covert orienting of attention to the target location, thereby sensitizing the neurons representing that area of the visual field (Corbetta et al., 2000). In such covert orienting tasks, event-related fMRI studies have shown activation in superior parietal lobe and the temporal parietal junction (Corbetta et al., 2000). The ANT compares target processing times with and without spatial cueing to determine the efficiency of the *Orienting* network.

The last network, known as the *Alerting* network of attention, is involved in achieving and maintaining an alert state. This network has been associated with the frontal and parietal regions of the right hemisphere (Fan et al., 2002). The alerting task is highly related to vigilance and continuous performance tasks of attention. The alerting metric of the ANT is calculated by subtracting mean RT of the double-cue condition from the mean RT of the no-cue condition.

Results of a number of studies indicate that there might be hemispheric asymmetries in the function of these three attentional networks. Brain imaging studies of sustained (*Alerting*) attention have suggested that this function is right hemispheric dominant, as is the orienting function (Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Posner & Peterson, 1990). Stroop and flanker style executive tasks have been found to activate the left hemisphere (Fan, Flombaum, McCandliss, Thomas, and Posner, 2003). These studies indicate that there might be anatomical asymmetries in the cortical representation of attentional function, but is there evidence for behavioral (i.e., performance) asymmetries in the function of the three networks? Greene et al. (2008) developed a lateralized version of the ANT (LANT) to segregate the stimuli presentation to either left or right visual fields, thereby activating either left or right hemispheres during the task. The experimenters lateralized the ANT by rotating the stimulus display by 90 degrees, putting the target stimuli on the right or left side of the screen, instead of the top and bottom, as was done in the original ANT. They then tested their revised version of the ANT to determine if results were similar to that of Fan et al. (2002). Using both latency and accuracy measures, Greene found that each hemisphere was capable of supporting all the attentional networks. They also found some inconsistencies in their data compared to that of Fan et al. (2002). Greene et al.'s study yielded consistently lower estimates of the independent networks, and their estimate of the *Alerting* network efficiency metric was non-significant (Green et al., 2008). They attributed this finding to their small sample size. Correlations between the attentional networks and the visual field in which the stimuli were presented were found for two networks. This indicates that depending upon which visual field (VF) the stimulus was presented in, the attentional network being used was more efficient (Callejas, Lupianez, Funes, & Tudela, 2005). Better performance was found during the *Executive/Conflict Resolution* component of the LANT when the target was presented in the right visual field (RVF). Better performance in the *Orienting* component of the LANT occurred when the targets were presented in the left visual field (LVF). Poynter, Ingram, and Minor (2008) also used a lateralized ANT to evaluate visual field asymmetries in orienting efficiency, using a sample of subjects who varied in terms of self-reported attentional deficits. The researchers found a left visual field/right hemisphere deficit in orienting attention for those who self-reported high levels of attentional deficits. This finding is consistent with evidence from other research indicating deficiency in spatial attention tasks in individuals with damage to the right parietal region.

Stroop Task

The Stroop effect refers to the observation that when one is asked to identify the color that a color name is printed in (e.g., the color name "GREEN" is printed in red ink), the amount of time it takes to do so is much longer when the ink color and the color name are incongruent with one another, as in the example above (Stroop, 1935). J. R. Stroop developed a task to measure this interfering effect using five colors (red, blue, green, brown, and purple). Differences in total time between congruent and incongruent conditions were analyzed to determine any interference effects. Stroop's original experiment was conducted in three parts: The first experiment compared reading color names where the name and ink were incongruent (the word red in blue ink) with reading color names in black. No significant differences in time of completion were found between these tasks, and no sex differences were found (Stroop, 1935). The second experiment involved the comparison of naming the color of words written in incongruent ink with naming the ink color of a filled solid square (i.e. a "naming color test"). Results of this experiment showed significant interference of the subject's ability to name the color of the word when compared to simply stating the color of a square. The mean interference (i.e., the "Stroop effect") was 74 percent slower to read the color of the word versus the color of the square (Stroop, 1935; Weekes & Zaidel, 1996). The third experiment involved practicing the reading of incongruent color stimuli. Stroop showed that practicing this task lowered the inference effect over time. This added validity to the concept of being able to train one's mind to perform this task more efficiently. The overall results of the three experiments led to the creation of today's Stroop task. The task today is used to measure neurological interference of an automatic process (word naming) against a conscious process (color naming) (Gruber, Rogowska, Holcomb, Soraci, & Yurgelun-Todd, 2000). It has shown to be a reliable measure of the cognitive ability to resolve conflict between competing responses, ignore distracting stimuli, and selective focus attention.

Functional MRI studies have attempted to locate the neuro-antaomical regions most commonly associated with interference in the Stroop Task. Gruber et al. (2000) and Lueng et al. (2000) both used fMRI technology as well as region of interest (ROI) data to attempt to specify regions where cerebral blood flow (CBF) increased during the Stroop task, specifically the interference portion of the task. Gruber et al. (2000) looked at changes in the signal intensity of the left and right anterior cingulate cortex in healthy subjects, including the vocalization area (VOA) and the attention to action area (AAA). ROI measurements were analyzed for the two regions. Results from the color naming and word reading subtests showed non-significant changes within either the VOA or AAA regions between the right and left hemisphere. However, compared to baseline there was a significant change in the AAA region on both sides, and significantly increased signal intensity on right side of the VOA region. Further, the researchers found that the signal intensity in the right VOA region dropped significantly during the interference subtest relative to the word reading subtest. Overall results from this experiment indicated significant changes in the anterior cingulate when comparing the interference subtest results to that of the baseline readings (Gruber et al., 2000).

Lueng et al. (2000) performed a similar study where they measured signal changes in specific areas of the brain during a modified Stroop task. Using fMRI technology, the subject’s brain activity was measured using both conventional (using infrequent, incongruent colored words), and inverse, (using infrequent, congruent colored words) Stroop tasks to determine specific activity levels in several regions of interest. In the first task (the conventional Stroop), results of the MRI measurements reported signal changes to incongruent stimuli in the anterior cingulate, which is a similar finding to that of Gruber et al. (2000). Further changes were found in the insula, inferior frontal, middle frontal, parietal, and mid-temporal regions. Following the incongruent stimuli, decreases in signal were observed in the ventral part of the anterior and posterior cingulate. Middle frontal regions and the posterior cingulate gyrus showed hemispheric asymmetries in the signal intensity following this form of stimulus, where the left hemisphere was more active following incongruent stimuli. Further, the number of activated regions was significantly less in the inverse Stroop condition, though there was some activation in the same ROIs that were activated in the conventional Stroop condition. Results from this study helped to advance the understanding of how the human brain maintains attention during conflict resolution situations. Lueng et al.'s study also showed several other areas of the brain outside of the anterior cingulate that were activated during conventional and inverse Stroop tasks.

The lateralized Stroop was designed to measure the efficiency of the hemispheres during interference tasks. Weekes and Zaidel (1996) used a lateral visual field version of the Stroop in an attempt to explain the hemispheric contributions during completion of the task. The experimenters hypothesized that the Stroop effect would be greater in the right visual field (RVF)/left hemisphere (LH) due to the left hemisphere's dominance in reading tasks. The subjects used both verbal and manual response modalities to react to unilateral stimuli presentations. Weekes and Zaidel found that there was more interference when the subjects responded using the verbal modality. However, latency speed was faster using manual response modality. Some indications of the hemispheric specialization in the task were evident, as faster RTs were noted when stimuli were presented in the left visual field (LVF) during the verbal paradigm, indicating stronger Stroop effects (i.e. slower RT to stimuli) in the left hemisphere. Consistent with this finding, a main effect of visual field was revealed with LVF trials having faster RTs than RVF trials. The experimenters also found that males showed a greater Stroop interference effect than females.

In a meta-analytic study of the lateralized Stroop task, Belanger and Cimino (2002) hypothesized that interference would be greater in the LH than in the right hemisphere (RH), due to the LH's perceived dominance in verbal tasks. The researchers noted discrepancies in the research of the lateralized Stroop in that some studies have shown hemispheric asymmetries and others have not. The purpose of Belanger and Cimino's study was to determine whether or not, when all the studies in their meta-analysis were combined, the LH showed more interference effects than did the RH. Using a combination of techniques from several different experiments, no significant differences in the magnitude of Stroop interference between the cerebral hemispheres was noted. Evidence for hemispheric asymmetries in performance of the Stroop task is therefore inconsistent. Future research is needed, to conclusively state whether or not true hemispheric functional asymmetries exist in the Stroop interferences tasks.

Sex Differences in Laterality

There has been much debate over the topic of lateralization differences between the sexes. Kolb and Whishaw (2008) noted that on average men perform better on spatial tasks, primarily a right hemispheric ability, whereas women have been shown to perform better with language tasks, a left hemisphere dominated trait. Further, evidence has shown that women are less lateralized (i.e. more bilateral) than are men (Toga & Thompson, 2003). Some researchers, however, have claimed that females are more right lateralized on visuospatial tasks, where men tend to be more left lateralized on language tasks (Clements et al., 2006). These results have elicited great debate over the validity of the findings and as to whether true differences in cognitive asymmetries exist.

Men have shown an advantage in performance on spatial tasks such as mental rotation, spatial navigation, and geographical knowledge (Kolb and Whishaw, 2008). Astur, Ortiz, and Sutherland (1998) tested this hypothesis using an adapted version of the Morris water task. In this particular task, the experimenters found that men displayed better spatial navigation, as well as an ability to find the target platform at a faster pace than women. The findings suggested that these differences were not due to motivation, motor, or sensory differences between the genders, when using the computerized Morris water task. A theory behind this finding referenced the societal pressures for men to have more experience with spatial navigation, thus leading to enhanced performance (pg. 189).

Gur et al. (2000) used fMRI technology to study lateralized changes in brain activity during performance on spatial and verbal tasks, using region of interest (ROI) activation to pinpoint areas of the brain that were specifically activated during these tasks. Their findings show more bilateral activation during spatial tasks for men than for women. ROI analysis showed that for both men and women, activation in the inferior parietal and planum temporale regions was strongly left-lateralized during verbal tasks. Clements et al. (2006) found similar results in the parietal lobe, where men showed more bilateral activation while processing visuospatial information. Women conversely showed more bilateral activity during phonological tasks, and were more right lateralized during the visuospatial task.

As mentioned above, women typically show an advantage in performance over men in verbal/phonological tasks. Processing of these tasks typically has shown left hemispheric advantages in both sexes. Women, however, have shown some evidence of more bilateral activity during language tasks (Kansaka & Kitazawa, 2001). The researchers discussed that although previous research has shown that women's verbal skills were superior to those of men, in adulthood women do not exhibit higher verbal intelligence nor tend to have higher vocabularies. Thus, we are unable to combine the fact that women's bilateral activation in these tasks is related to better skills as they relate to language. Further, Frost et al. (1999) found that in fMRI studies, there were no differences between the sexes in lateralization to any ROI, and that both men and women had strongly left lateralized activity during language tasks. These researchers found that there were no significant differences in performance on most language tasks between men and women. However, inconsistencies in the research still remain, and there is still the common belief that on average, women will perform better on verbal tasks than men, and men better than women on visuospatial tasks.

According to Kolb and Whishaw (2008), women's performance is superior to that of men on tests of verbal fluency, and women show superior verbal memory. This may be due to the difference in brain structure between the sexes. In general, women have larger language areas, specifically Broca and Wernicke's areas (Harasty, Double, Halliday, Kril, & McRitchie, 1997). Women have a greater amount of grey matter, as well as more densely packed neurons in the planum temporale (Wernicke's area), an area most commonly related to language comprehension (Kolb and Whishaw, 2008). These structural differences in the female brain may be related to women's superior performance on some verbal tasks.

Meta-analytic studies have shown some evidence that men have greater functional asymmetries than do women. Voyer (1996), for example, found that men generally showed larger laterality effects than did women, but warned about over-generalizing these findings, as not all studies showed a significant lateralization effect. Nagel-Leiby, Buchtel, and Welch (1990) found sex differences in reaction time between the visual fields in a normal patient group. Using the validity effect, a measure of the cost of orienting attention to an incorrect location in the visual field, the researchers found that females responded more slowly to stimuli and showed a greater effect of cue validity to stimuli presented in the LVF, whereas the males showed an opposite effect, with slower RTs and a greater effect of cue validity in the RVF. Another study performed by Merritt et al. (2007) studied the qualitative difference in how males and females respond in selective attention tasks. In two experiments, the researchers found that there were sex differences in cued, visual selective attention tasks. Compared to the no-cue condition, females were found to show increased cost (increased RT) in the condition where invalid cues were presented. Males, on the other hand, showed a benefit (decreased RT) in invalid cue condition (Merritt et al., 2007). These findings show evidence for a distinction between how males and females respond during selective attention tasks.

Limited findings in this area of study indicate that more research is needed to clarify whether performance of attentional function varies between the sexes, and further, whether hemispheric asymmetries in attentional performance vary with sex.

Purpose of the Study

Although there are clearly asymmetries in hemispheric anatomy and function (Kolb & Whishaw, 2008), whether there are asymmetries in behavioral measures of attention (ANT and the Stroop task) is still an open question. Further, little research has been done to determine if there are sex differences in laterality of attention functions. This study will employ two instruments (the ANT and Stroop task) to measure the functional efficiency of the three attentional networks proposed by Posner and Petersen (1990) – the *Executive Control, Orienting*, and *Alerting* networks. The method will use lateralized versions of these instruments to compare the speed and accuracy of attentional processing when stimuli are presented to left and right visual fields. The purpose is to determine whether these measures vary between visual fields (and therefore brain hemispheres), and whether any such visual field asymmetries are affected by sex of the participant.

In accordance with the previous research, we expect to find better performance during the orienting component of the LANT when the stimuli are presented to the LVF, particularly for men, and better performance for the executive component when the stimuli are presented to the RVF. More speculatively, we expect to find a greater asymmetry in performance in men on the orienting task, in that they might show a greater right hemispheric dominance in this visuospatial task. Further, women might show greater left hemisphere dominance in the executive, or conflict resolution task. We expect to find these results for the left hemisphere to be especially strong in the Stroop task, due to both its conflict resolution and language components. Lastly, we may also find better performance in the *Alerting* component when the stimuli are presented to the LVF.

METHOD

Participants

Participants were 60 right-handed undergraduate and graduate students (*M* = 21.6 years of age) from a midsized, public, southeastern university. Each was asked to sign an informed consent form, which had been approved by the university's institutional review board (IRB), as well as a short demographic form with areas for the student's identification number, sex, and age. The informed consent provided information regarding the purpose of the research as well as the participant's right to withdraw from the study without penalty. All participants completed the forms. Of the 60 total participants, 30 were male (*M* = 21.5 years of age) and 30 were female (*M* = 21.6 years of age).

Materials

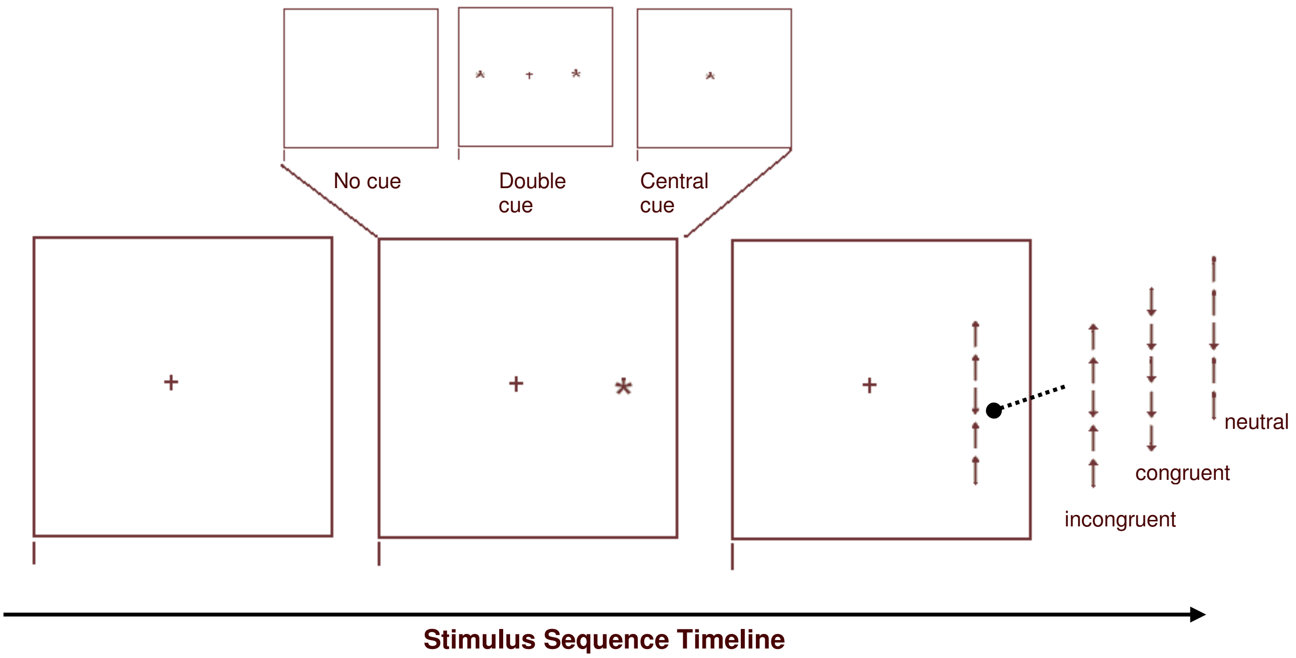
LANT. The modified version of the ANT used for this experiment is the same as that used by Poynter et al. (2008). The original ANT presented a horizontal arrow pointing either to the left or the right and, either above or below a fixation point. Each trial's target stimulus was flanked on the left or right by arrows pointing in either the same or opposite direction as the target stimulus (or a neutral line segment with no directional arrow). The lateralized version of the ANT used in this study presents target and flanker arrows to the left or right of the fixation point, with arrows pointing either up or down. The stimulus array spanned 2.9 degrees, with each of the target stimuli presented 2.2 degrees from fixation, and each arrow segment .5 degrees in length. Targets were preceded by one of 4 cue types: 1) no-cue, 2) valid spatial cue (a presentation of the cue at the location of the upcoming target), 3) central cue, and 4) double cue (presented at the two possible locations of the target). Targets were flanked either by four arrows pointing in the same direction (congruent flankers), opposite direction (incongruent flankers), or line segments with no arrow (neutral flankers). The trial sequence consisted of a fixation point, followed by one of the aforementioned cue types, and then the target stimulus. Duration of the fixation point was between 500 and 1200 msec, the cue duration was 100 msec, and then the target stimulus flashed on the screen either to the right or the left of the fixation point for 100 msec after a delay of 150 msec (See Figure 1). Subjects then used the standard "up" and "down" arrows of the keyboard to respond to which direction the target arrow is pointing. Subjects used their left finger on the "up" arrow key and their right finger on the "down" arrow key to balance the effect of inter-hemispheric transfer times. Subjects first completed 12 practice trials, and then completed the experimental trials lasting approximately 7 minutes.

Lateralized Stroop Task. The lateralized Stroop task used in this study was similar to that used by Weekes and Zaidel (1996). A computer program was developed to present stimuli to subjects on a 19" LCD display. There were four different colors/words used: red, blue, yellow, and green. Color names were presented with either congruent hue (e.g., the word "green" in a green color) or incongruent hue (e.g., the word "green" in yellow color), giving a total of 16 possible stimuli. A green fixation point was placed in the middle of a grey screen, and remained on the screen for between 500 and 1200 msec. The stimulus word was presented either to the left or the right of the fixation point, with its nearest edge 1.2 degrees from fixation. The stimulus appeared for 130 msec in either the RVF or LVF and then disappeared, thereby casting the image of the color name exclusively to one hemisphere or the other (See Figure 2 for Stimulus Sequence). RT was measured from the time the stimulus appeared to the time the participant responded. Total RTs and accuracy for items presented in the LVF and total RTs for items presented in the RVF during the experimental condition were recorded. Participants responded using four keys on a standard keyboard, specifically the “Z”, “X”, “.”, and “/” keys. The left middle and index fingers were used to press the “Z” and “X” keys, which corresponded with the color name/hues of red and green, respectively, and the right index and middle fingers were used to press the “.” and “/” keys, which corresponded with the color name/hues of blue and yellow, respectively. Participants completed 10 practice trials allowing for adequate time to understand which keys corresponded to which color stimulus. Following the practice trials, the participants then began the experimental paradigm of responding according to the color name. Upon completion of this section, the participants then completed a new set of randomized trials responding according to the color hue paradigm. Both sections of the Stroop task had 32 experimental trials each, with VF randomly and evenly assigned.

Procedure

Participants were recruited using a credit-awarding program from the undergraduate and graduate student pool. Upon arriving to participate in the experiment, the participants were required to read and sign an informed consent form that explains the purpose of the study, the confidentiality of the participant’s identity, the estimated amount of time the experiment will take to complete, and whom to call if there are any questions about the study, including IRB information and the aforementioned demographic form. Participants were tested either individually or in group format, depending upon availability of the computer lab. After completing the forms, the participants completed the two lateralized tasks. The LANT took approximately five minutes to complete, while the combination of the two Stroop Tasks took approximately 10 minutes. Task order was randomized for each participant. Upon completion of each task, the participants were given a two minute break in order to allow them time to completely refocus their attention on the next task. After all the tasks were completed, the participants were thanked for their time, and then told that they will receive appropriate credit.

Figure 1. Visual Stimuli and Timeline of the Lateralized ANT Stimulus Sequence

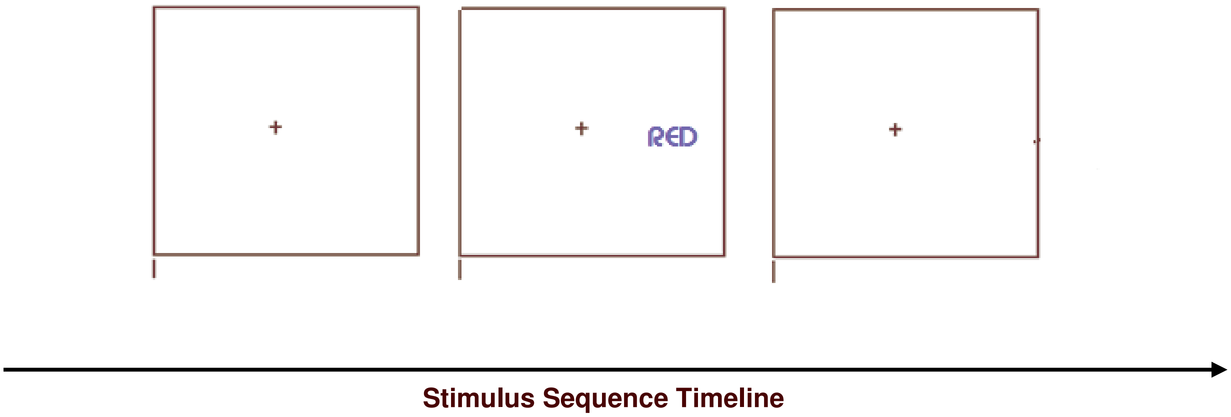


Variable length **fixation interval** (500-1200msec)

Cue is presented (No Cue, Central Cue, Double Cue, Single Cue) -- lasts 100 msec. The single cue condition is shown in timeline above

Target Interval. Central target arrow can point up or down, and flanker arrows can be neutral, incongruent, or congruent with Target arrow (see above right)

Figure 2. Visual Stimuli and Stimulus Sequence of Lateralized Stroop Task



Variable length **fixation interval** (500-1200msec)

The **Stimulus word** is presented on screen for 200 msec.

The **Stimulus word** disappears and the next **trial** begins with the fixation point. This sequence is repeated for **144 trials** with the visual field in which the stimulus is presented randomized.

RESULTS

Prior to analysis, trials with a reaction time greater than 4.87 seconds (*SD* = 1.34 seconds) were removed for the LANT and greater than 5.53 seconds (*SD* = 1.48 seconds) for lateralized Stroop task. This was done to remove all trials where the reaction time exceeded three standard deviations of the mean. We further used geometric means as an additional measure for minimizing the effects of outliers within the data. The geometric mean was found by taking the anti-log of the averaged log reaction time.

The three metrics of the LANT were calculated using the formulas previously used by Fan et al. (2002) and Greene et al. (2008). The *Executive* metric was calculated by subtracting the geometric mean effect of the congruent-flanker trials from the geometric mean of the incongruent-flanker trials. The *Orienting* metric effect was calculated by subtracting the geometric mean effect of valid spatial cue trials from the geometric mean of the center cue trials. The *Alerting* metric effect was calculated by subtracting the geometric mean effect of the double cue trials from the geometric mean effect of the no-cue trials. Repeated-measures ANOVAs were performed on these metrics to determine if there was an interaction effect between the two independent variables (VF and sex). Further analyses were performed to determine whether these variables interacted to affect reaction time and accuracy scores in the six conditions contributing to these metrics (congruent flankers, incongruent flankers, valid spatial cue, center cue, double cue, and no-cue).

For the lateralized Stroop task, we performed repeated measures ANOVAs to determine if VF and sex interacted to affect the size of the Stroop effect metric. The Stroop effect metric was calculated by subtracting the geometric mean of the “color hue” condition from the geometric mean of the "color name" condition for both reaction time and accuracy. For both the LANT and the lateralized Stroop task, sex and visual field were the independent variables.

LANT

To determine if visual field and sex interacted to affect the three metrics of the LANT, we ran 2 x 2 ANOVAs for each of the metrics. Table 1 shows the mean efficiencies for both males and females for left and right visual fields. For the *Executive* network, we found no interaction of visual field and sex, $F(1, 58) = .730$, $p = 396$. There were no main effects found on this metric for either visual field, $F(1, 58) = 2.775$, $p = .101$, or for sex, $F(1, 58) = 1.087$, $p = .302$. The *Orienting* metric yielded no significant interaction between visual field and sex, $F(1, 58) = .777$, $p = .382$. Further, no main effects of visual field, $F(1, 58) = .946$, $p = .335$, or sex, $F(1, 58) = .616$, $p = .436$, were found. There was also no significant interaction found between visual field and sex for the *Alerting* metric, $F(1, 58) = 1.125$, $p = .293$. Main effects of both the visual field, $F(1, 58) = .087$, $p = .770$, and sex, $F(1, 58) = .020$, $p = .889$, were not significant.

Table 1.
LANT mean efficiencies and standard deviations for sex and visual field for each attention metric

Metric	**Male (mean /** standard deviation)	**Female (mean /** standard deviation)
Executive		
RVF	**.0618** / .0963	**.0622** / .1493
LVF	**.0932** / .1509	**.1598** / .3124
Orienting		
RVF	**.0798** / .0572	**.0914** / .1172
LVF	**.0772** / .0703	**.0394** / .2054
Alerting		
RVF	**.0808** / .2282	**.0491** / .2432
LVF	**.0490** / .1502	**.1054** / .6622

2 x 2 repeated-measures ANOVAs were run for each of the cue and flanker conditions contributing to the attention metrics of the LANT describe above. The purpose of these analyses was to discover any visual field and/or sex effects on response time and response accuracy in the six LANT conditions. Tables 3 and 4 present the mean RT and accuracy data grouped by visual field and sex. Regarding the conditions of the *Executive* metric (congruent and incongruent flanker conditions), there was no significant interaction between visual field and sex for the congruent-flanker condition in reaction time, $F(1, 58) = 1.247$, $p = .269$. There was also no main effect for visual field, $F(1, 58) = .511$, $p = .478$, or for sex, $F(1, 58) = .595$, $p = .444$. Neither was there an interaction effect of visual field and sex on accuracy data, $F(1, 58) = 1.179$, $p = .282$, nor any main effects for visual field, $F(1, 58) = .346$, $p = .559$, or sex, $F(1, 58) = .070$, $p = .792$. Likewise for the incongruent flanker condition, no interaction effect ($F(1, 58) = 1.703$, $p = .197$) or main effects were found (VF: $F(1, 58) = .144$, $p = .706$; sex: $F(1, 58) = .204$, $p = .653$). There was however a significant interaction of visual field and sex for response accuracy, $F(1,58) = 5.820$, $p < .05$. Males responded correctly to the stimuli a higher percentage of the time (83.86%) in the LVF than did females (80.46%), whereas females responded correctly a higher percentage of the time to stimuli in the RVF (84.25%) than did males (78.17%). No main effects for response accuracy were found (VF: $F(1,58) = .236$, $p = .629$; sex: $F(1,58) = .121$, $p = .729$).

For the valid spatial cue condition of the *Orienting* metric, there was no significant interaction between visual field and sex on reaction time, $F(1, 58) = .000$, $p = .995$, and no main effects of visual field, $F(1, 58) = .052$, $p = .820$, or sex, $F(1, 58) = 1.533$, $p = .218$. There was also no interaction between visual field and sex on response accuracy, $F(1, 58) = .613$, $p = .437$, as well as no main effect of sex, $F(1, 58) = 2.742$, $p = .103$. There was however a main effect of visual field in this condition, $F(1, 58) = 5.684$, $p < .05$, indicating a significantly higher percent of correct responses when the item was presented in the LVF ($M = 97.53\%$) than in the RVF ($M = 94.97\%$). Analysis of the center cue condition yielded no significant interaction between the visual field and sex for reaction time, $F(1, 58) = 1.484$, $p = .228$, as well as no main effect of sex, $F(1, 58) = .405$, $p = .527$. There was a significant main effect of visual field, $F(1, 58) = 5.045$, $p < .05$, with reaction time to items presented in the RVF ($M = 612.7$ msec) being responded to more quickly than those items in the LVF ($M = 631.1$ msec). We did not find a significant interaction between visual field and sex for the center cue condition in response accuracy, $F(1, 58) = 1.555$, $p = .217$, or any main effect of visual field, $F(1, 58) = .242$, $p = .625$, or sex, $F(1, 58) = .668$, $p = .417$.

The double cue condition of the *Alerting* metric yielded no significant interaction between visual field and sex for reaction time, $F(1, 58) = 1.376$, $p = .246$, as well as no main effects of visual field, $F(1, 58) = .078$, $p = .782$, or sex, $F(1, 58) = .024$, $p = .878$. There was a significant interaction between visual field and sex for response accuracy, however ($F(1, 58) = 4.690$, $p < .05$). Males responded more accurately ($M = 90.54\%$) in the LVF than did women ($M = 86.87\%$). Females ($M = 92.57\%$) responded more accurately in the RVF than did males ($M = 90.09\%$). Although not significant, we found a main effect approaching significance for visual field, $F(1, 58) = 3.411$, $p = .070$. Results show that a greater percentage of responses were correct when stimuli were presented in the RVF (91.33%) than in the LVF (88.70%). There was no main effect of sex for this condition, $F(1, 58) = .063$, $p = .803$. For the no cue condition, there was no significant interaction between visual field and sex for reaction time, *F*(1, 58) = 1.345, *p* = .251, as well as no main effect for visual field, *F*(1, 58) = .483, *p* = .490, or sex, *F*(1, 58) = .996, *p* = .330. No visual field by sex interaction was observed for response accuracy, *F*(1, 58) = 1.866, *p* = .177, nor were there main effects of visual field, *F*(1, 58) = .044, *p* = .834, or for sex, *F*(1, 58) = .652, *p* = .423.

Table 2.
Reaction time (msec) means and standard deviations for each of the cue conditions separated by sex and visual field

Cue/Flanker Condition *Visual Field*	**Male (mean /** standard deviation)	**Female (mean /** standard deviation)
Congruent Flanker		
RVF	**674.8** / 578.8	**573.4** / 57.4
LVF	**578.7** / 56.8	**594.5** / 89.4
Incongruent Flanker		
RVF	**736.5** / 558.6	**655.5** / 114.1
LVF	**671.9** / 164.9	**691.0** / 134.3
Spatial/Valid Cue		
RVF	**547.4** / 95.3	**575.0** / 111.3
LVF	**550.3** / 60.6	**578.0** / 118.1
Center Cue		
RVF	**611.1** / 77.9	**613.4** / 81.8
LVF	**619.5** / 75.6	**642.6** / 105.3
Double Cue		
RVF	**667.6** / 471.1	**608.0** / 76.7
LVF	**602.7** / 78.2	**648.0** / 124.7
No Cue		
RVF	**748.4** / 692.1	**613.1** / 68.6
LVF	**651.7** / 142.1	**637.4** / 81.4

Table 3.
Accuracy (percent correct) for each of the cue conditions separated by sex and visual field

Cue/Flanker Condition	*Visual Field*	**Male**	**Female**
Congruent Flanker			
	RVF	**96.93**	**98.08**
	LVF	**97.34**	**96.71**
Incongruent Flanker			
	RVF	**78.17**	**80.46**
	LVF	**83.86**	**84.25**
Spatial/Valid Cue			
	RVF	**93.57**	**96.38**
	LVF	**96.97**	**98.10**
Center Cue			
	RVF	**85.96**	**90.01**
	LVF	**89.00**	**88.69**
Double Cue			
	RVF	**90.09**	**92.57**
	LVF	**90.54**	**86.87**
No Cue			
	RVF	**91.69**	**91.74**
	LVF	**93.72**	**90.25**

Lateralized Stroop Task

Separate 2 x 2 ANOVAs were used to determine if there was a significant interaction between visual field and sex on reaction time and accuracy in the Stroop task. Table 4 shows the means for reaction time and accuracy for both sexes grouped by visual field. Visual field and sex did not significantly interact to affect reaction time, $F(1, 58) = 3.496$, $p = .067$. Neither were there main effects of either visual field, $F(1, 58) = .015$, $p = .904$, or sex, $F(1, 58) = .485$, $p = .489$. Likewise, no interaction effect ($F(1, 58) = .061$, $p = .806$) or main effects were found for accuracy data (VF: $F(1, 58) = .633$, $p = .430$; sex: $F(1, 58) = .086$, $p = .770$).

Table 4.
Stroop task effect and accuracy means and standard deviations for both sexes in the separate visual fields

	Male (**mean** / standard deviation)	**Female** (**mean** / standard deviation)
Stroop Effect (***msec***)		
RVF	**-16.2** / 309.8	**-143.6** / 425.7
LVF	**-81.7** / 352.1	**-86.1** / 448.7
Accuracy		
RVF	**-.0250** / 124.6	**-.0139** / 180.2
LVF	**.0014** / 132.9	**-.0278** / 172.2

Further analysis of the "color name" condition revealed no significant interaction between visual field and sex¸ *F*(1, 58) = 1.273, *p* = .264. There were no significant main effects for this task for either visual field, *F*(1, 58) = .010, *p* = .920, or sex, *F*(1, 58) = .572, *p* = .453. Similarly, the "color hue" condition yielded no significant interaction between visual field and sex, *F*(1, 58) = 1.202, *p* = .277. There were no main effects for visual field, *F*(1, 58) = .082, *p* = .776, or sex, *F*(1, 58) = .005, *p* = .944, in this condition.

DISCUSSION

There has been a long history of research examining the functional differences between the hemispheres as well as how each sex performs on tasks lateralized to one hemisphere only (Kolb & Whishaw, 2008; Toga & Thompson, 2003). Functional asymmetries, particularly those related to tasks of orienting to spatial stimuli, have been found to show higher activation in areas of the RH (Corbetta, Patel, & Shulman, 2008). Stephen et al (2003) noted that there was a difference in activation in the hemispheres regarding letter-decision and spatial tasks. Letter-decision tasks activated cortical areas in the left hemisphere more-so than did the spatial task, and the opposite effect for the spatial task was found, with the right hemisphere showing more cortical activation than the left hemisphere. Further, it has been noted that women tend to perform better on tasks involving a verbal element, while men tend to perform better on tasks that have a spatial component to them (Gur et al., 2000). On the basis of these results, one might speculate that men would perform better on spatial tasks, particularly those lateralized to the LVF, and women on tasks that are lateralized to the RVF, especially if the task contains a verbal element. In this study, we looked for such differences in performance between the sexes using two lateralized attention tasks, the LANT (Greene et al., 2008), and a lateralized Stroop task similar to that used by Weekes and Zaidel (1996). For the LANT, we hypothesized that *Orienting* performance would be better for LVF stimuli presentations, and this lateralization of function might be greater for men, given the spatial nature of the task. Similarly, we expected to find a RVF advantage for the *Executive* component, which we extrapolated would also be found in the Stroop task, specifically for women due to the both the language and conflict resolution elements of the task (Stephen et al., 2003). Lastly, we hypothesized that for the *Alerting* component there would be indications of better performance when the stimuli was presented in the LVF as proposed by Posner and Peterson's (1990) description of neuro-anatomical activation associated with this metric.

Our results were generally not consistent with our hypotheses, with the following few exceptions. The significant finding of higher response accuracy in the LVF for the valid spatial cue of the *Orienting* component of the LANT adds additional evidence to the previous research indicating a RH advantage for orienting tasks (Corbetta et al., 2000). Further, we found that in the double-cue condition of the *Alerting* attention metric, men showed a LVF advantage and women a RVF advantage in response accuracy, which to some degree supports the hypothesis of a RH advantage for men and a LH advantage for women.

Despite the general lack of significant findings in the study, there were a few statistical trends found in the data that are supportive of our hypotheses. For both the *Orienting* and *Alerting* metrics of the LANT, we found that men were more efficient when the stimuli were lateralized to the LVF, although not significantly so. We found similar results for women in that they were more efficient during the *Executive* and *Alerting* components when the items were lateralized to the RVF. This is consistent with research that indicates that men are better suited for tasks processed by the right hemisphere and women for tasks processed by the left hemisphere (Kolb & Whishaw, 2008). Further, consistent with the results from Greene et al. (2008), there was a LVF advantage for both men and women in the *Orienting* and *Alerting* components of the LANT, and a RVF advantage for the *Executive* component for both sexes.

We found a slightly greater Stroop interference effect in the LVF, where men and women were found to perform similarly. There was a greater difference between the sexes in the RVF, where men did not appear to incur the interference of the "color hue" paradigm as much as did the women. Inconsistent with Weekes and Zaidel (1996), we did not observe a greater interference effect for men versus women (using accuracy scores as the dependent variable). However, we did find a trend toward higher accuracy in the RVF. These data are inconsistent with our original hypothesis. Our results from this task only appear to add further evidence to the results of Belanger and Cimino (2002), who reported inconsistent findings in a meta-analytic study of sex differences in hemispheric asymmetries in Stroop performance.

Hemispheric asymmetries in cognitive function and anatomical structure have been reported, but the body of literature on this topic has proved inconclusive (Frost et al., 1999; Kolb & Whishaw, 2008; Voyer, 1996). It has been noted that women tend to have some dominance in language tasks, a result possibly related to women having larger language areas in the left hemisphere (Harasty, Double, Halliday, Kril, & McRitchie, 1997), while men tend to perform better regarding spatial ability tests, what is believed to be more heavily weighted in the right hemisphere (Astur, Ortiz, and Sutherland, 1998). Our results were inconsistent with the previous research in many regards, though not entirely. It is often thought that men are more right brained while women more left brained (Kolb & Whishaw, 2008), but this continues to be a controversial topic in neuropsychology. Researchers have found different results regarding the amount of lateralization between the sexes, particularly in the amount of task dependent lateralization (Frost et al., 1999; Clements et al., 2006; Toga & Thompson, 2003). The question of whether or not men or women are more lateralized in spatial or verbal tasks has dominated previous research, and has not at this point yielded concrete findings. It appears that this topic will continue to be heavily debated as long as inconsistencies in the data are as persistent as they have been.

It is important that we note several key limitations in our research. The use of two different experimental settings, (i.e. – one person administration and group administration) may have skewed the results due to there being a potential for distraction in the group administration setting. Further, the additional use of students as participants may have been problematic as motivation to complete the attention tasks given the demanding nature of the tasks. This could be due to a failure to provide adequate compensation for their participation or the time of the day of administration, as most students completed the experiment in the evening. Further, we neglected to use any screening measures for disorders related to attentional deficits, which may have added to a lack of significant findings. The small sample size created low power for our data analysis, which may have contributed to our insignificant findings. Further, our instructions prior to administration of the lateralized Stroop task, as well as the methodology of using a standard keyboard as a response instrument instead of a more task specific input device, such as a four button controller, may have lead to complications in completing the tasks for the subjects. Lastly, the amount of trials during the Stroop task, 32, may not have been enough to illicit a strong enough effect to help substantiate our hypotheses. Corrections to these limitations, specifically the use of a larger sample size and a longer instructional period, may be enough of an alteration to find significance sex differences and hemispheric asymmetries in the data from a future replication of this study. Modifications of the lateralized ANT and Stroop methods we employed may help researchers gain a better understanding of hemispheric specialization in males and females. The differences between the sexes in attentional function should continue to be studied to build a comprehensive knowledge in how the sexes differ.

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